The Ecology of the Woodlands of Central Park, New York City

By

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A dissertation submitted to the Graduate Faculty in Biology in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York.

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This manuscript has been read and accepted for the Graduate Faculty in Biology in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

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THE CITY UNIVERSITY OF NEW YORK

Abstract

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Regina V. Alvarez

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A quantitative ecological inventory was conducted in the 54.6-hectare (ha) urban woodlands of Central Park, New York City. Fifteen sites were selected and woody stems greater than or equal to one centimeter (cm) diameter were surveyed using the point-centered quarter transect method. Total area surveyed was 1.091 hectares. The survey tallied 1,271 stems from 82 species in 31 families and 50 genera. Stem diameters ranged from 1 cm to 218 cm. In terms of ecological dominance, *Prunus serotina* Ehrh. was the dominant taxon followed by *Quercus rubra* L. The largest trees were *Quercus rubra*, *Prunus serotina*, *Morus alba* L., *Phellodendron amurense* Rupr., *Platanus occidentalis* L., *Liriodendron tulipifera* L., *Quercus palustris* Münchh., *Ulmus americana* L., and *Styphnolobium japonicum* (L.) Schott, ranging in diameter from 100 cm to 218 cm. Lower diameter at breast height (DBH) quartile stem sizes were dominated by *Acer platanoides* L.*, Prunus serotina, Celtis occidentalis* L. and *Q. palustris.*

As a fully human-made park under continual management, these woodlands contain a high percentage of non-native and horticultural species. A survey of the biodiversity of the park, however, shows the significant role even a highly managed park can play in wildlife habitat.

Invasive plants are a serious threat to native plants and wildlife habitat everywhere. Numerous invasive species are present in Central Park. This study evaluates management practices to control these species and makes further recommendations. It analyzes the potential of other non-native species, as well as native species, to become invasive. This study can help park managers decide which plants to highlight and preserve and which to manage and control.

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"If you are scientifically literate, the world looks very different to you."-Neil deGrasse Tyson

Dedication

This work is dedicated to my late father, Antonio Valentin Alvarez, from whom I inherited my passion for learning, and to the late Dr. Carlos Rene Ramirez-Sosa, who started me on this journey and who always generously shared his knowledge and friendship.

Este trabajo está dedicado a mi difunto padre Antonio Valentín Álvarez, de quien heredé mi passion pore el aprendizaje, y el fallecido Dr. Carlos Rene Ramírez-Sosa, quien me inicío en este camino y que siempre compartió generosamente sus conocimientos y su amistad.

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Chapter 1: Introduction

1.1 Introduction

New York City is not the first place that comes to mind when one thinks of woodlands, native plants or wildlife habitat. In the last century or so the New York Metropolitan region has lost much of its original landscape and any natural areas that are left are highly fragmented. Despite this, New York City still contains as many as 3,000 species of vascular plants (Glaeser 2006, Weston et al. 2005). Of the plant species ever recorded in New York State, 56.8% can be found in New York City, and New York City harbors 60.3% of the native species recorded in the state (DeCandido et al. 2004). Many of these plants survive in fragments of wooded parkland which are similar to forested islands (Glaeser 2006).

Invasive plants are those that reproduce in great quantities, have the ability to spread over great distances and usually displace native plants. Of the plants found in New York City, many are non-native and some are invasive. It is estimated that non-native plants now exist in New York City as 42% to 48% of the total vascular plant species present in some local forests (Glaeser and Kincaid 2005). Non-native plant species comprise 36% of the total species in New York State (Yost et al. 1991). A 2006 survey of naturally occurring flowering plant species shows 58% as non-native species in Central Park, substantially higher than the city or state percentage (DeCandido et al. 2007).

The study of the flora of urban environments has become increasingly important because more than half of the worldwide population lives in cities. As natural areas are lost, wildlife depends on plants in urban areas for survival. One of these urban environments that merits close study is

Central Park. It is one of the largest natural areas in any densely urban environment of the United States and is under the Atlantic Flyway, one of four major migration routes for birds between North, Central and South America. It has been listed as one of the top 14 places in the United States to go bird watching, on the same level as Everglades National Park in Florida, Hawk Mountain Sanctuary in Pennsylvania and Cape May Point in New Jersey (Pasquier 1994). It is critical for park managers to have proper information with which to base ecology-oriented management decisions. Another important factor in preserving plant species diversity is to develop public support for natural areas in parks. Because Central Park receives over 35 million visits per year (Central Park Conservancy 2011) it is an ideal place in which to teach the public about the loss of species diversity due to urban sprawl and the negative impact of invasive species. This study can help park managers decide which plants to highlight and preserve and which to manage and control.

1.2 Description of Central Park

Central Park is a public park encompassing 341.2 hectares (ha), located in the middle of Manhattan (40° 46' 12" N, 73° 58' 1" W). The current park boundaries are from 59th Street to 110th Street, between Central Park West and Fifth Avenue. The landscape is highly varied and includes woodlands, meadows, water bodies, lawns, ball fields and playgrounds (Figure 1.1). Manhattan was at one time a highly varied landscape, with more ecological communities per acre than Yellowstone, more native plant species per acre than Yosemite and more bird species than the Great Smoky Mountain National Park (Sanderson 2009). However, Central Park is an entirely human-designed and landscaped park; it is not a remnant of any previously forested area. Many areas of the park were once wetlands. The Saw Kill flowed through the swamp that later

became the Reservoir; Montayne's Rivulet running though Harlem to its mouth at Hell's Gate Bay became the Loch, the stream flowing through the south end of the North Woods (Barlow 1971). In the southern section of the park, about a half dozen streams of varying volume were originally there; their flow turned some of the site into bogs. The southernmost principal water course, DeVoor's Mill Stream, was used to form the five-acre pond that borders the Hallett Nature Sanctuary (Kinkead 1990). The area where the park stands today was reconfigured using horse-drawn carts, gun powder and many laborers, who moved over four million cubic yards of earth and rock and imported about 700,000 cubic yards of topsoil (Rogers et al. 1987). Boulders were blasted out of the ground and, house movers who knew how to load two-story brick houses onto stone flatbeds, were hired to move these massive boulders (Rosenzweig and Blackmar 1992). The park was built over a rocky land with many hills, some of which still exist today. Areas in the Park that underwent the greatest topographic reduction are today areas with the least topographic variation (Sanderson 2009). Despite these changes, the park serves as an important forest fragment. As urbanization proceeds, urban parks and forest fragments become more important than ever as habitat, especially for avian wildlife that needs large tracts of land or contiguous habitat for migration routes. Central Park is an important green space under the Atlantic flyway. It has harbored over 275 species of birds either residing in or migrating through the park. Other wildlife includes mammals, amphibians, reptiles and fish. In addition, there are myriad insects, including moths, butterflies, dragonflies and cicadas. For example, in a 24-hour survey conducted in the Park by the 2003 BioBlitz 173 invertebrate species were tallied, including two species of tardigrades. Eventually, urban tracts such as Central Park may become refugia for many species of biota.

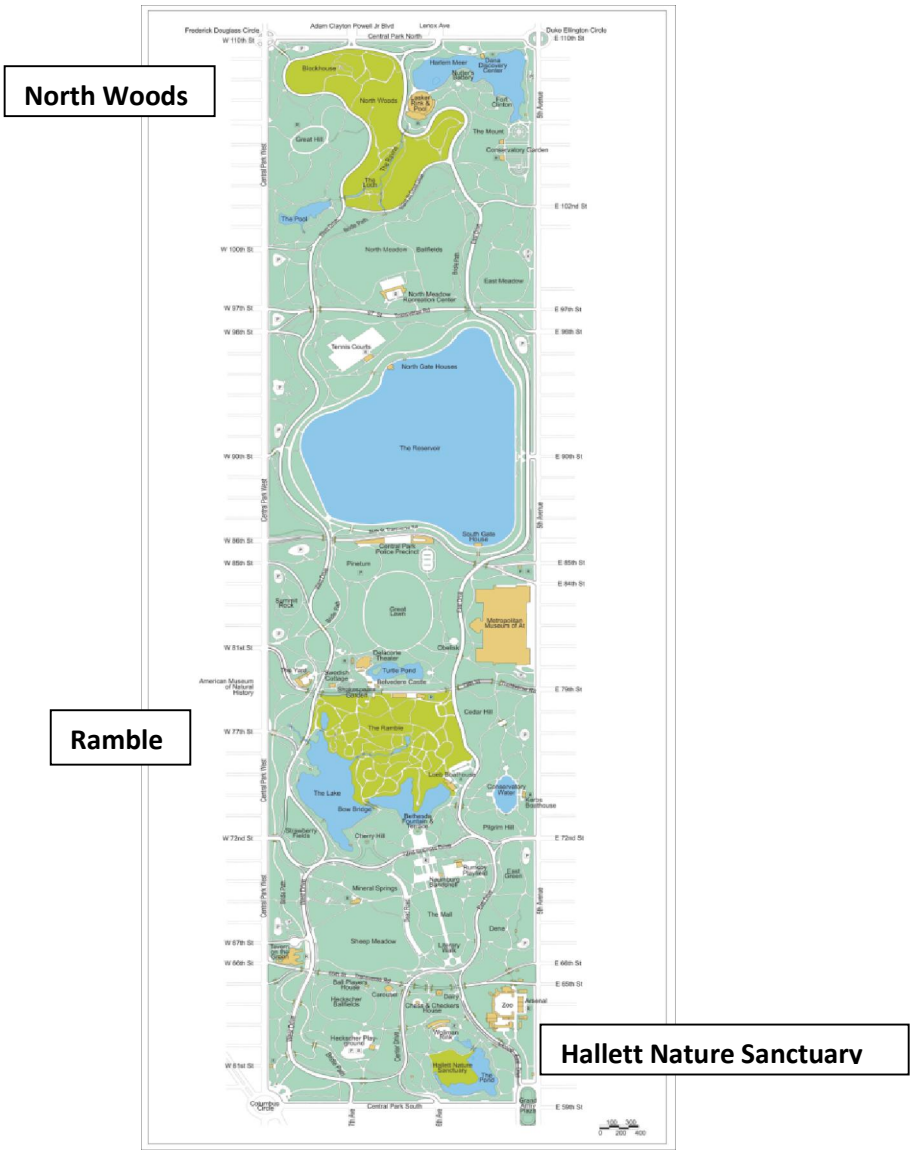

Figure 1.1 Map of Central Park highlighting the three woodland regions of this study (Central Park Conservancy)

Recreational use of parks by people can impact their floristic composition (DeCandido et al. 2004). The impact of urbanization on the structure and function of natural areas needs to be incorporated into the ecological understanding of these increasingly fragmented areas (Cadenasso et al. 2007). Urban habitats have climates, soils and hydrology different from non-urban habitats and these factors correlate with a high percentage of non-native plant species (Clements and Moore 2003). Central Park has the added factor that over the course of its early history (the mid-to-late 1800s), more non-native species were planted than native species (Loeb 1993), although in the past 30 years, the trend has been to plant mostly native species and remove invasives (personal experience).

1.3 History of Central Park

At the time of the creation of Central Park (1850), the City of New York was expanding at a rapid pace. The original intent of the park was to provide a place where the people of the city would always be able to enjoy a natural setting away from the noise and stress of city life. It still serves that purpose today. However, it now serves the additional purpose of being a resting place for migrating birds traveling over large tracts of urban areas and as a refuge for other non-migrating wildlife.

Central Park's woodlands have not undergone changes in the same way as other forests and woodlands. The original landscape was almost entirely altered to create a horticulturally-oriented space. Areas were cleared, swamps were drained, bedrock was dynamited, tons of soil were imported and many species of plants - native and non-native alike - were planted. Although the design of what are now the woodlands was meant to be reminiscent of the Adirondack Mountains (Cramer 1993), the plantings were not limited strictly to native plants.

Olmsted's design was meant to be a naturalistic landscape, but not natural in species composition (Cramer 1993). Since that time (1850s), the Park has gone through several cycles in which the landscape was allowed to deteriorate and was then followed by restoration.

Each restoration of the park saw the installation of different species of plants. Following the history of the plantings is not always possible, but there are records available that give us an idea of what species were present at different times. At the time the park was created, there were approximately 5000 people living within the original park boundaries (57th Street to 106th Street), the land use included farms, pasturage, piggeries, and dwellings with subsistence gardens. Non-native species were planted around the dwellings, species such as *Ailanthus altissima* (Cramer 1993).

During the City's budgetary shortfall in the 1960s and 1970s, the Park declined and the woodlands were the first areas to be abandoned by the Park's management (Cramer 1993). Therefore, the woodlands spread into what were once open areas.

The Central Park Conservancy (Conservancy), a not-for-profit organization under a contract with the Department of Parks and Recreation and the City of New York is currently the official manager of the Park. The Conservancy was founded in 1980 by Elizabeth Barlow Rogers, its first president, who was subsequently appointed Central Park Administrator by the then-Commissioner of Parks, Gordon Davis. The park is currently under the direction of Douglas Blonsky, President of the Conservancy and Administrator of Central Park. At present, the park is in the longest period of renovation in its history.

1.4 Research Intent

The objective of this study was to quantify the community ecology of the Central Park woodlands, focusing most closely on the woody plant species. Which species are present? Which taxa are dominant? Are there significant positive and negative associations among taxa? This study also pulls together several other inventories to document the general biodiversity of Central Park and the change in that biodiversity over time. As a fully human-made park under constant management, the woodlands contain a large number of non-native and horticultural species. This work examines several invasive species as well as two non-native species that have the potential to become invasive. However, this study shows that despite the presence of invasive plant species, Central Park still plays an important role in the ecology of wildlife habitat. The results of this study will help the Central Park management to make ecologically oriented decisions on how to increase the diversity of native species. This study will also provide a baseline for comparison of future quantitative ecological inventories.

There have been several early works on the floristic composition of Central Park, mainly in-house publications by the Park's designers and builders. Although most of these are not scientific inventories and do not offer enough information to make accurate statistical comparisons to any new inventories that may be done, they are still helpful in documenting the change in plant diversity over time, e.g., ordination of presence or absence of data by multivariate methods (Rachlin et al. 2008). Examining such change can provide information as to which species survive when exposed to urban development and intense human activity. It can also help park managers in their decision-making process regarding which species to plant and how best to manage invasives.

1.5 Methods

In 1982, an exhaustive survey was done of trees with a diameter at breast height (DBH) of 6" (15.24 cm) or more. The survey tallied 24,000 trees (Rogers 1987). The Conservancy grouped the trees within specific "lawn areas," that is, discrete areas bounded by pathways, water bodies or other permanent markers. These lawn areas were used to identify the areas surveyed for this study (Figure 1.2).

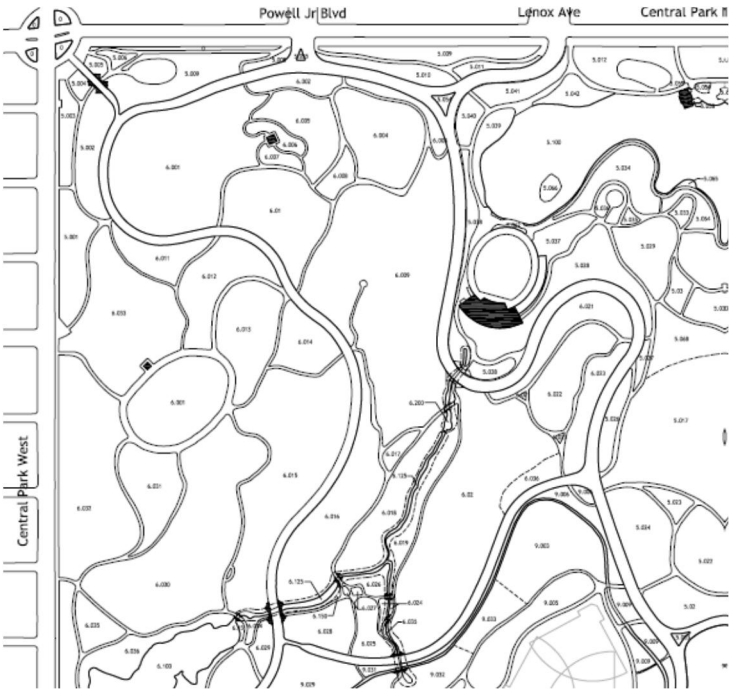

Figure 1.2 Section of map indicating "lawn area" designations (Central Park Conservancy)

The point-centered quarter transect method (PCQ) is a plot-less transect method for sampling a plant community (Cottam and Curtis 1956, Mueller-Dombois and Ellenberg 2002). In this method, one takes random points in the study site. The area at each point is divided into 90º quarters (Figure 1.3). It is generally thought that a minimum of 20 random points in each area is necessary for proper statistical analysis. From each of these points, measurements are made. The stem in each quarter that is closest to the point is measured (Barbour et al. 1999, Mueller-Dombois and Ellenberg 2002). For each stem, distance to the sampling point, DBH, species and family are recorded (Figure 1.4). For this study, sites were chosen to survey the different habitats within each woodland. Using the point-centered quarter transect method I tallied woody species in the three woodlands of the Park. I walked along a transect from a chosen starting point and the distance between each subsequent point was the number of steps on a list of randomly generated numbers. Diameter at breast height was measured at 1.3 m from the ground. For individuals that had multiple stems, I measured the DBH of each stem and the recorded DBH was that diameter which would account for the total basal area of the summed stems. Note that I used a cutoff point of 1cm. Many surveys only use 2.5 cm or larger and park managers usually do surveys with a cutoff of 6" (15 cm). As this study will show, it is important to use a smaller cutoff when possible to analyze species regeneration. I chose this method of data collection not only because of the efficiency of this method, i.e., each point gives data on four stems instead of one, but also because in a park as highly used as Central Park, it is not possible to set up permanent plots. The PCQ method makes it possible for one to gather information about absolute density, relative density, size and frequency (spatial) of different tree species without setting up permanent plots. Analysis was done using R showing dominance and importance values for the woodlands as a whole and for the individual sites.

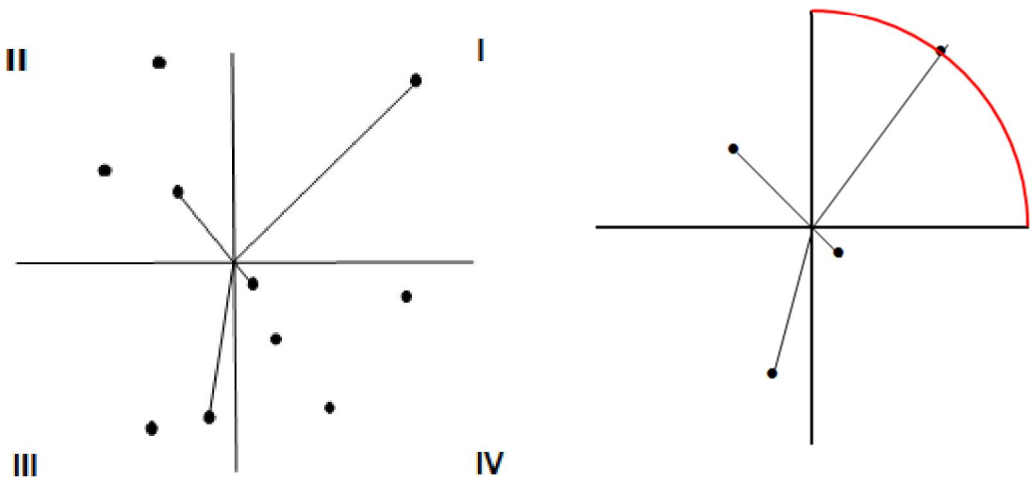

Figure 1.3 One sampling point in the point-centered quarter method. The "point" defines a Cartesian Coordinate System. The tree closest to the center in each of the four quadrants is measured for DBH and distance to the origin. Species is also recorded. The area inventoried is Area = (pi x r^2)/4 for each sampling point (right).

From this I determined the ecological dominance of each species within each community or habitat. Separate ecological analyses proceeded for the entire woody flora, and for the small trees (e.g., the first quartile DBH). This method gives the same information as the quadrat method and it is more efficient than other transect methods. Whereas other transect methods provide one individual stem per point, this method gives four. It saves time as there are no plot boundaries to lay out and no errors from judging whether boundary individuals are in or out of the plot (Mueller-Dombois and Ellenberg 2002). PCQ does assume a random distribution of trees.

Limitations to this method are that a tree must be present in each quadrant and individuals must not be counted twice; therefore, stands with very wide spacing of individuals may present a problem unless "empty space" is coded as a taxon (Mueller-Dombois and Ellenberg 2002).

Figure 1.4 Measuring distance and diameter in point-center-quarter method

Plants were identified using Gleason and Cronquist (1991) and Bailey (1949). Nomenclature was updated using USDA Plant Database (http://plants.usda.gov/java/). If one follows the most recent taxonomic changes on such sites as Tropicos (out of the Missouri Botanical Garden) or The Plant List (out of Kew, The Royal Botanic Gardens and Missouri Botanical Garden), there are several major changes. Table 1.1 shows these changes. However, throughout the text I use the nomeclature that follows the USDA Plant Database. The reason is that some of these changes are still in flux (Robert Naczi, New York Botanical Garden, personal communication) and the older names are most familiar to ecologists at this time. One species that I did not find in USDA Plant Database, The Plant List, or Tropicos was *Crataegus lavallei* Henrincq. Bailey lists it as a hybrid between *C. crus-galli* and *C. pubescens.* For this species, therefore, I used the name from Bailey. It is a hybrid found in many horticultural webpages, including those of some university extensions (University of Florida, IFAS Extention, University of Illinois, University of British Columbia Botanical Garden) and interestingly enough, a document describing the hybrid can be found at the USDA Forest Service website. The same is true for *Evodia daniellii*.

Old names for species and family	New names for species and family
Acer species Aceraceae	*Acer* species Sapindaceae
Aesculus hippocastanum Hippocatanaceae	*Aesculus hippocastanum* Sapindaceae
Amelanchier canadensis	*Pyrus canadensis*
Celtis occidentalis Ulmaceae	*Celtis occidentalis* Cannabaceae
Evodia daniellii	*Tetradium daniellii*
Frangula alnus	*Frangula dodonei*
Liquidambar styraciflua Hamamelidaceae	*Liquidambar styraciflua* Altingiaceae
Malus sylvestris	*Malus pumila*
Prunus virginiana	*Padus virginiana*
Quercus prinus	*Quercus michauxii*
Tilia americana Tiliaceae	*Tilia americana* Malvaceae
Viburnum species Caprifoliaceae	*Viburnum* species Adoxaceae

Table 1.1 Nomenclature updates using Tropicos and The Plant List

A full list for species tallied by PCQ can be found in Appendix 1. Authorities for species are not used throughout the text unless that species is not included on the full species list.

This survey utilizes a random selection of stems to be analyzed. As such, it did not capture every species present in the woodlands, nor was it intended to do so. Examples of species my survey did not capture are *Maclura pomifera* (Raf.) C.K. Schneid., *Nyssa sylvatica* Marsh., and *Juglans nigra* L.

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Chapter 2

The Woodlands

2.1 Introduction

There are three distinct woodlands in Central Park: the Ramble, 14.6 hectares located mid-Park; the North Woods, 36.4 hectares, located in the northern region of the Park; and the Hallett Nature Sanctuary (Hallett), 1.6 hectares located in the southeastern part of the Park. Each had a different original design intent. The Ramble was an open landscape with sweeping vistas (Figure 2.2). The North Woods was the only one of the three sites that was a wooded environment in the original design (Figure 2.3). Hallett is a landscaped area on a high bluff and was intended solely as a visual backdrop to the Pond, a small water body that borders the woodland (Figure 2.1).

Surveyors at the time of the Park's design found the vegetation below 72nd Street sparser than on the rugged northern ground (Rosenzweig and Blackmar 1992). Elm, beech, sugar maple, sweet gum and black walnut trees were scattered through the valleys of the upper and lower Park. Found on rocky hillsides were sassafras, witch hazel and choke cherry. In the 1850s, when construction of the Park began, there were as many as 5,000 people were living on the land that was to become the Park (Cramer 1993). Land use varied from farms, pastures, piggeries, and dwellings with subsistence gardens to churches and cemeteries. Inhabitants had already planted non-native species such as *Ailanthus altissima* (Cramer 1993). Near farmhouses, former residents had planted poplars, mulberries and ornamental flowering honey locusts and catalpas (Rosenzweig and Blackmar 1992). Before construction began, inhabitants had cut down many mature trees for firewood, but more than 150,000 saplings and shrubs, heavily laced with poison ivy, still covered the land. A survey conducted by Charles Rawolle and Ignaz Pilat in 1857

records more than 280 species, many of them native. They estimated that there were 12,000 *Carpinus americana;* 9,000 *Acer rubrum;* 8,000 *Quercus* encompassing nine species; 6,000 *Liquidambar styraciflua,* and many other native trees and shrubs (Cramer 1993). Between 1861 and 1863, during the design of the Park, Ignaz Pilat, the Viennese landscape gardener in charge of the plantings, installed 240,000 trees and shrubs (Rosenzweig and Blackmar 1992). Over the years when the park was minimally managed, these areas were left undisturbed and many trees grew to fill them in as truer woodland areas. By the mid-1970s, the severely reduced maintenance staff could not keep up even with lawn care and garbage collection. Areas that were once open glades were filled in by opportunistic species (Cramer 1993). As was noted in my introduction, those areas have become important habitat for wildlife as well as areas enjoyed by naturalists and others who desire to visit natural areas in the middle of a large city.

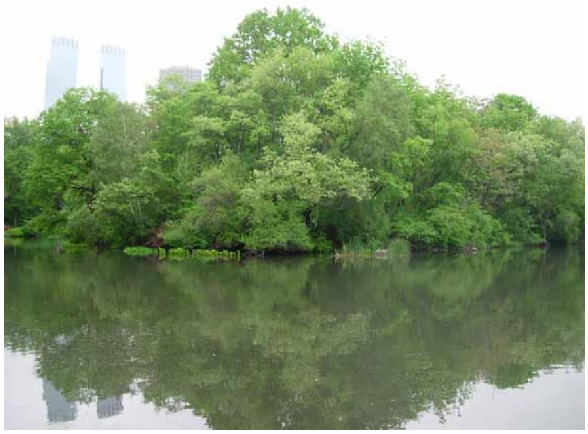

Figure 2.1 The Hallett Nature Sanctuary and The Pond

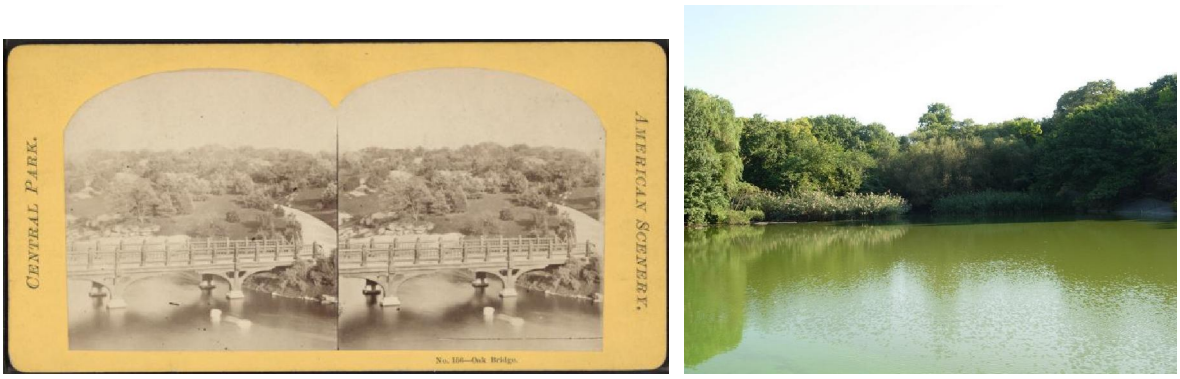

Figure 2.2 The Ramble late 1800s (left). The Ramble today (right). Historic photo from the New York Public Library digital gallery.

Figure 2.3 The North Woods

The woodlands of Central Park have many problems caused by human disturbance and overuse. These include soil compaction and erosion, lack of understory vegetation, large stands of invasive species and large numbers of native pioneer species such as *Prunus serotina.* The woodlands' artificial origins, relatively small size, and high degree of human disturbance are factors that produce a community dominated by invasives and pioneer species rather than by climax species. Periods of drought and severe winters have taken their toll on species. For instance, the severe winter of 1917-1918 killed off large numbers of trees as well as most of the 30,000 Rhododendrons, and in the 1920s periodic drought killed most of the elms that lined the Mall (Rosenzweig and Blackmar 1992). However, there is a lack of quantitative understanding of plant community structure of this environment, hence the need for this study.

In this chapter, I examine the three woodlands as a whole. Although they are separated spatially, they are managed in the same manner, a manner that is distinctly different from the way the rest of the Park is managed. Therefore it is useful to look at them as one unit. Although safety and

cleanliness are top priorities, as in the rest of the Park, the woodlands are treated as special wildlife habitat areas.

Using the point-centered quarter method described in the introduction, I tallied 1,272 stems for all three woodlands as a whole. The total area inventoried was 1.091 hectares. This included 82 species of trees and shrubs in 50 genera and 31 families. These were tallied from a total of 318 points, at 15 different sites. Unlike all other surveys done in the Park, I tallied stems as small as 1 centimeter diameter. This is useful, as will be seen, for looking at regeneration of species and for facilitating management decisions regarding invasive species and other taxa.

2.2 Importance Value

Importance Value (IV), a common tool for ecologists, can be described as the relative contribution of a species to the entire community (Barbour et al. 1999) and is a reasonable measure of ecological dominance. IVs are calculated by combining relative density, relative frequency and relative dominance, each of which add up to 100 with IV totaling 300. For example, a species with an IV of 300 would occur in a monodominant stand, that is, a stand comprised of only one species (Mueller-Dombois and Ellenberg 1974). Density is the number of stems counted in the study area. Relative density is the density of one species as a percent of total plant density. Frequency is the percentage of total quadrats or, in this study, points that contain at least one stem of a given species. Relative frequency is the frequency of one species as a percent of total points of occurrence. Dominance within an IV table is defined by total basal area. Relative dominance is the basal area of one species as a percent of total basal area.

IVs in this study were analyzed using a program created by Dwight Kincaid using the open-source computer language R (Appendix 2). Table 2.1 shows IVs for all 82 taxa. *Prunus serotina* stands out with an IV of 67.45. This species is a native taxon with high wildlife value. It is an excellent source of food for both vertebrate and invertebrate wildlife. It supports a high number of Lepidoptera species and it produces copious fruits on which birds depend during the late summer (Tallamy 2007). It is a pioneer species that does extremely well in disturbed environments. In an intact forest, disturbance usually adds to diversity, but in an area that is all disturbed, diversity is lowered. Since Central Park is essentially all "disturbed," *Prunus serotina* has always been the number one species in frequency in this and other surveys. Therefore, it is not surprising that it falls into first place in ecological dominance in this study. Interestingly enough, if one looks at historic records, one will find that this species has never been deliberately planted in the Park by the park creators or by any of the subsequent managers. Furthermore, even though today the Central Park Conservancy (Conservancy) manages this species by carefully removing it where it may be hindering other desirable species, it still remains in high ecological dominance.

Ranked second in dominance is species is *Quercus rubra* with an IV of 29.99. Although *Q. rubra* has a basal area almost equal to *P. serotina* (21.49, 22.63 respectively), *P. serotina* has a much higher relative density and relative frequency: 24.84 and 19.98 vs. 3.93 and 4.57, respectively. Oaks are very important for supporting vertebrate and invertebrate wildlife. With the demise of the American chestnut, oaks are one group that provides nuts to many vertebrates, including raccoons, mice, squirrels and wood ducks. Cavities that develop in oaks are used by many cavity-nesting birds such as woodpeckers, flickers, owls, chickadees and wrens. But most

important, oaks are an essential genus for herbivorous insects, a vital source of food for birds. Oaks are also host to approximately 100 Lepidoptera species (Tallamy 2007, Martin, et al. 1951).

Acer platanoides, although an aggressive invasive (Martin 1999), was third in IV with 25.17. This rank is likely due to management practices, which remove young saplings and occasionally larger specimens of this species on a continual basis. Several larger *A. platanoides* were removed because of an Asian longhorned beetle infestation (see Chapter 7). *Acer pseudoplatanus,* ninth on the IV list, is another invasive (Cronk and Fuller 2001) which the Conservancy manages using similar methods.

Ulmus americana is fifth in IV, perhaps surprising, since this species has had great losses all over the country because of the Dutch elm disease fungus (see Chapter 7). However, the Conservancy has aggressively controlled this fungus since the organization was established in 1980. Trees are inspected on a regular basis-generally early spring to early summer-) when the fungus is active. Any infected limbs are immediately pruned to at least six feet of clean wood. If the tree is terminally infected, it is removed completely, including grinding the stump and trenching around the area if other elms are nearby that could potentially be infected. In this way, although there is a loss of elms every year due to the fungus, many more are preserved and protected from infection.

Two interesting natives that fall in the top 10 in IV are *Celtis occidentalis* and *Viburnum dentatum* var. *lucidum.* Both are native plants with high wildlife value. The Hackberry is host plants to butterflies such as the Hackberry Emperor, Mourning Cloak and the Eastern Comma. (A host plant is a species on which an adult butterfly lays its eggs. The caterpillar of that species is dependent on that particular plant species for food and often cannot live on another plant

species.) It also provides forage for birds. Cedar waxwings, yellow-bellied sapsuckers, mockingbirds and robins are fond of the drupes this tree produces in great quantity. Arrowwood viburnums are host plant for the Spring Azure butterfly and provide forage for birds such as brown thrashers and cedar waxwings. More importantly, these shrubs attract myriad insects that are crucial for birds to feed on during reproductive periods (Tallamy 2007, Martin, et al. 1951).

Phellodendron amurense and *Styphnolobium japonicum* are 11th and 12th in IV. Both of these are potentially destructive invasive plants. *Phellodendron amurense* has been shown to be invasive in forests in Queens (Glaeser and Kincaid 2005) and elsewhere in the New York region (Morgan and Borysiewicz 2012). *Styphnolobium japonicum* is a species that has not been cited often as invasive but has the potential to become invasive (see Chapter 7).

Liriodendron tulipifera, Lindera benzoin, Sassafrass albidum, and *Carya cordiformis* are all ecologically desirable natives that are in the top 20 in IV. Tuliptree is a host plant for the Tiger Swallowtail butterfly. Both *C. cordiformis and S. albidum* are host plants to the Luna moth. Sweetgum and Tuliptree are also hosts to the Tiger Swallowtail (Tallamy 2007, Martin, et al. 1951). Very often when people think about habitat for butterflies, they plant species that give nectar, but fail to think about host species for butterflies and moths to use for reproduction.

2.3 Descriptive Statistics

Table 2.2 lists descriptive statistics for the total data set. Abundance, frequency and mean diameter at breast height (DBH) were generated from the same analysis program as the IVs. Abundance is the number of stems counted for each species. Percent sampling units is determined by dividing frequency by the total number of points in the study (318). Frequency is

the number of points in which each species can be found. DBH is measured in centimeters. From the mean DBH I determined the standard deviation and the minimum and maximum mean for each species. Absolute density is the estimate of the number of stems of one species per hectare (10,000 m^2) (Barbour 1999). Absolute density was determined using a program created by Dwight Kincaid using the open-source computer language R (Appendix 2). Absolute density for the total data is shown in Figure 2.5.

Here again, *Prunus serotina* comes out on top. In abundance, it is represented by 316 individuals and is found in 59.12% of sampling units. Estimated absolute density is 314 stems per hectare.

Although *Quercus rubra* is second in importance value, *Acer platanoides* has a higher abundance with 121 stems vs. 50. The difference in IV values comes from the dramatic difference in stem size. *Quercus rubra* had the largest stem size, 218 cm, and the mean DBH was 41.27 compared with 11.57 for *A. platanoides*.

2.4 Stem Diameters

Stem diameters ranged from 1 cm to 218 cm. The largest trees were *Quercus rubra*, *Prunus serotina*, *Morus alba*, *Phellodendron amurense*, *Platanus occidentalis*, *Liriodendron tulipifera*, *Quercus palustris*, *Ulmus americana*, and *Styphnolobium japonicum*, ranging in diameters from 100 cm to 218 cm.

Analysis of the lower quartile DBH values of total data (Table 2.3) can be used to estimate the future trajectory of the composition of the woodlands. The table shows that *Acer platanoides*, an aggressive invasive, comes in at the number one position with an IV of 53.30, despite years of

continual removal of saplings and small stems by the Park managers. The number of stems in this lower quartile total 322 with *A. platanoides* having 61 of those stems. *Acer pseudoplatanus,* another aggressive invasive, is lower on the list, most likely because, despite being invasive, it is more sensitive to drought. Over the years, during seasons of severe drought, this species, along with *Fraxinus americana,* suffered the most losses. Despite these losses and despite years of removal by management, *A. pseudoplatanus* still ranks in the top ten (seventh) on this list.

In this lower quartile DBH category is the first time we see *Prunus serotina* drop from first to second with an IV of 35.4, presumably due to the very aggressive nature of *A. platanoides*. Surprisingly *Celtis occidentalis*, an ecologically desirable wildlife native, but one that is never deliberately planted in the Park, is third with an IV of 25.48. *Lindera benzoin,* another desirable native, is also among the top 10. Only in recent years has the Conservancy begun planting small specimens of this species. *Ulmus americana* regenerates well despite the presence of Dutch elm disease and is within the top 10 of this lower quartile group. *Acer saccharum*, a native maple is substantially higher in the IV table of the lower quartile (12^{th}) than in the total data (26^{th}). This may be due partially to planting efforts by the Conservancy, although I have seen this species regenerating in areas where planting was not done.

Quercus rubra, on the other hand, falls from second place in IV of total stems to 22 in IV of lower quartile stems. Only four stems of this species are represented in this category, indicating a lack of regeneration. The reason that this species, and other oaks, do not regenerate well is the compacted soil (personal observation). Regionally, the decline of oaks in mature forests is of concern.

One invasive that shows a high ranking in this small-stem category is *Aralia elata.* In the full IV table (Table 2), it ranks 36, with an IV of 1.4. However, in the lower quartile table, it comes in at 11, with an IV of 7.21. This indicates that this species is one to be aware of as a potentially destructive invasive species, especially in areas of storm damage where large amounts of light reach the woodland floor.

2.5 Families and Genera

The most represented families were Rosaceae with 13 species, Fagaceae with nine species, Caprifoliaceae with six species, and Ulmaceae and Caesalpinaceae each with four species. Eleven families were represented by only one species.

Importance Values are shown for families for total data set in Table 2.4. The total number of families is 31. First in IV is Rosaceae with a value of 81.19. This family is largely represented by *Prunus serotina,* but also includes two other *Prunus* species as well as *Malus sylvestris, Rhodotypos scandens*, *Amelanchier canadensis*, *Crataegus* spp., *Photinia* spp. and *Rosa multiflora*. Second in IV is Fagaceae with a value of 52.18. *Quercus rubra* and *Q. palustris* largely represent this family but also present are *Q. alba, Q. laevis, Q. macrocarpa,* and *Q. phellos*. Although Aceraceae contains two very significant invasive species (*A. platanoides* and *A. pseudoplatanus*), the family is third in IV with a value of 38.91. Other maple species include *A. saccharum, A. rubrum* and *A. negundo*.

Twenty-one species were represented by single individuals. *Rhus glabra, Castanea dentata* and *Hamamelis vernalis* are likely planted specimens. I have observed *Sambucus nigra* ssp. *canadensis* regenerating from either old seed bank or old stumps in areas that have undergone

restoration and are now protected from trampling. *Euonymus alatus, Cornus kousa, Cornus mas, Quercus laevis, Ginkgo biloba*, and *Aesculus hippocastanum* are not generally found in the woodlands but are common throughout the rest of the Park as ornamentals. *Evodia daniellii* is easily confused with *Phellodendron amurense* when young and both species are found in the Ramble (both are members of the Rutaceae). Other singletons include *Viburnum opulus, V. setigerum, Vaccinium corymbosum, Pinus nigra, Platanus occidentalis, Crataegus phaenopyrum, Crataegus viridis, Photinia glabra,* and *Tilia cordata.*

Only one species of vine, with one individual, was found in this study*, Parthenocissus tricuspidata*. The related native vine, *Parthenocissus quinquefolia* (L.) Planch. (Vitaceae) is present throughout the woodlands but is generally more a ground creeper and does not reach diameters measurable for this study. *Toxicodendron radicans* (L.) Kuntze (Anacardiaceae) is found throughout the Park and, because of its toxicity to humans, is systematically removed everywhere except the woodlands. Since it is a native plant that is used by wildlife (Tallamy 2007, Martin, et al. 1951), it is left in the woodlands to grow, provided it is not along paths where people may come into contact with it.

Several invasive vines occur in the woodlands. A large stand of *Ampelopsis brevipedunculata* (Maxim.) Trautv. (Vitaceae) on the grounds of the Central Park Zoo, which is not under Conservancy management, has not been eradicated. As a result, being a bird-dispersed species, it shows up throughout the Park and is removed as a matter of course. *Celastrus orbiculatus* Thunb. (Celastraceae) is another invasive vine that is regularly removed. In all three woodlands, especially Hallett and the Ramble, there has been a preponderance of *Wisteria sinensis* (Sims) DC. (Fabaceae), which is perhaps the most problematic of the invasive vines for Central Park. However, aggressive management practices that remove this invasive have substantially

decreased the biomass of this species. This may be why no stems showed up in this study. Two other species of vine, *Polygonum perfoliatum* L. (Polygonaceae) and *Humulus japonicus* Sieb. & Zucc. (Cannabaceae), were introduced via horticultural plant material brought into the park. These vines are discussed further in Chapter 7.

2.6 Diversity Indices

Diversity indices are mathematical measures of species diversity in a community. They provide information on species richness (number of species present) and take into account evenness (the relative abundances of the different species), that is, they give us information on the rarity or commonness of species in a community. Evenness can also be described as how similar are the population sizes of each of the species present in the community. Many equally abundant species would indicate high species diversity. Higher species diversity is thought to indicate a more complex community, which in turn is probably healthier due to more species interactions and greater system stability.

There are many different diversity indices used in ecology, each having its own merits and disadvantages. As such, whichever indices are used, they should be seen as another method of describing the community, along with the list of species, IV, descriptive statistics, etc. (Barbour 1999, Molles 2010). Species diversity is defined based on the number of species in a community (species richness) and the relative abundance of species (species evenness). For example, a community may have a high number of species but be dominated by one or a few of those many species. In that case, the diversity index will be low (Molles 2010).

One of these indices is the Shannon-Weiner diversity index (also called the Shannon diversity index), represented by H. This index accounts for both abundance and evenness of the species present. A community with an H=0 is dominated by one species. As species richness and evenness increases, so does H increase (Barbour 1999, Molles 2010). Values increase to 5 and generally anything above 3 is considered highly diverse. The Shannon index is reasonably independent of sample size (Odum and Barrett 2005).

Simpson D index reflects dominance because it is more sensitive to the most abundant species than to the rare species. Therefore, this index may not vary much from sample to sample, since it is the rare species that would vary from place to place rather than the common species (Barbour 1999). This index ranges from 0 to 1, where higher values indicate stronger dominance and low diversity (Odum and Barrett 2005). For Simpson 1-D index, the reverse is true. The range is still between 0 and 1, but in this case, the higher value means higher diversity. For Simpson 1/D, the range is between 1 and the number of species in the sample and this means the higher the value, the greater the diversity. Table 2.6 shows diversity indices for the total data set.

The measure of species richness is strongly dependent on sample size and effort. The Margalef index tries to account for this problem. This index is similar to the Shannon-Weiner index and is calculated from the total number of species present and the abundance of individuals. For this index, the higher the index, the greater the diversity. Although no diversity index accounts for all problems, they can still be intuitively useful and should be used in conjunction with other analysis methods.

	Total data	**Ramble**	**North woods**	**Hallett**
Species richness	82	50	57	27
Total N	1272	444	660	168
Shannon diversity	2.51 (2.22,2.62)	3.08 (2.90, 3.14)	3.09157	2.506472
Shannon evenness	0.76 (0.71, 0.82)	0.79 (0.77, 0.82)	0.7646626	0.7604963
Margalef diversity	5.07 (3.71, 4.88)	8.04 (6.40, 7.71)	8.625683	5.074196
Simpson D	0.17 (0.13, 0.22)	0.08 (0.07, 0.10)	0.08707989	0.1657455
Simpson 1-D	0.83 (0.78, 0.87)	0.92 (0.90, 0.93)	0.9129201	0.8342545
Simpson 1/D	6.03 (4.46, 7.94)	11.89 (9.84, 13.77)	11.48371	6.033348

Table 2.6 Comparison of species diversity by woodland. Bootstrap 95% upper and lower confidence intervals in parentheses.

2.7 Collector's Curves

A collector's curve (Figure 2.4) is used to determine if enough data has been collected, with regard to species, to do an adequate statistical analysis and to compare visually the dominance hierarchy by the shape of the curve. This curve plots the cumulative number of species observed against the cumulative number of individuals tallied. The slope continues to increase until fewer and fewer species are collected and the slope levels off to zero. If the slope of the collected data stops as it is increasing, before it levels off, too little data has been collected. If the slope has leveled off, there is enough data to perform adequate statistical analyses. It is useful to determine this point not only to ensure that there are enough species for analysis, but to avoid collecting too much data since data collection and analysis are very time-consuming (Ugland et al. 2003).

The collector's curves for this study were created using the program written by Dwight Kincaid using the open-source computer language R (Appendix 2). This program takes the data and randomizes the order of the sequence of data and samples with replacement, and plots them on a graph of species "observed" (y-axis) vs. number of individuals per species (x-axis) for 10,000 randomizations.

Figure 2.4 shows the collector's curves for the total data and the individual woodlands. The curves for Hallett and the Ramble show those curves beginning to level off. The North Woods curve and, even more so, the full data curve has not yet leveled off. This is not surprising since this was not an exhaustive floristic but a transect sample study.

2.8 Parsimony and Correspondence Analyses

Using a parsimony algorithm is a good way to graphically represent the distribution of species across sampling sites. It also groups sites into allied zones based on species associations (Rachlin et al. 2008). This method is newly applied to ecology by Rachlin and others; in general it is used in phylogenetics. The method uses sampling sites as "taxa" and species as "characters states," adding a root site, that is, a site with zero species. Although I sampled from 15 different sites (lawn area numbers, Figure 1.2), I combined several that were small, close to each other, and similar in characteristics. I used Winclada to analyze the data. Three trees, data matrix and species identification numbers are found in Appendix 3.

The analysis gave me two trees. The difference between the two trees lies in the position of the East of Azalea Pond Ramble site. In choosing a strict consensus tree, the program collapses on a node based on the "character" of *Malus sylvestris* (Species identification number 41).

By noting all of the species from the start of a clade to the terminal site of that clade, it is possible to see easily which species are present at each site, that is, see the community structure (Rachlin et al. 2008). This tree tabulates floristic presence and absence in each site. The data resulted in one tree with a length of 134, Ci = 61 and Ri = 40 (Consistency and Retention).

This placed six species at the base of the tree: *Acer platanoides, Fraxinus americana*, *Lindera benzoin, Prunus serotina, Quercus palustris* and *Vibunum dentatum.* These six species define the woodlands of Central Park. However, only four of them occur in all nine sites. *Fraxinus americana* and *L. benzoin* occur in seven of the nine sites. Furthermore, the "character" on which the node collapsed, *Malus sylvestris,* is found in eight of the nine sites. It is missing from

the East of Azalea Pond Ramble, which is the site the program had trouble placing. The data matrix and comparison of trees can be found in Appendix 3.

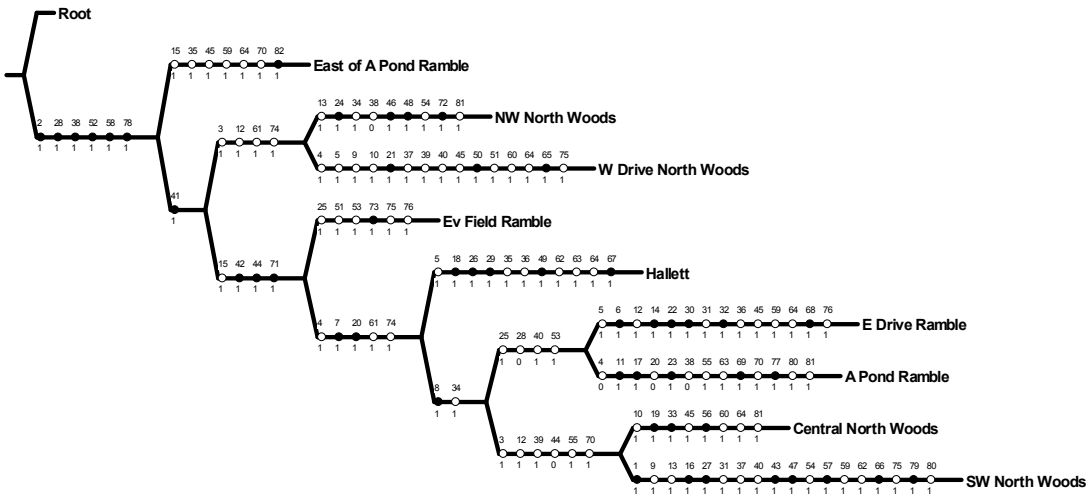

Figure 2.7 Single most parsimonious tree based on nine sampling sites plus root and 82 species. Numbers above circles represent species from the data matrix (Appendix 3). Closed circles represent species either unique to a site or uniquely supporting a clade of sites. Open circles represent species not unique to a station or clade.

Correspondence analaysis is another method for visiualizing the distribution of species in the different sites. It is a multivariate statistical technique that provides a means of summarizing data into a two dimensional graphical format. The same 8 sites were used as in the parsimony analysis above. Figure 2.8 shows the correspondence analysis of the species across these sites.

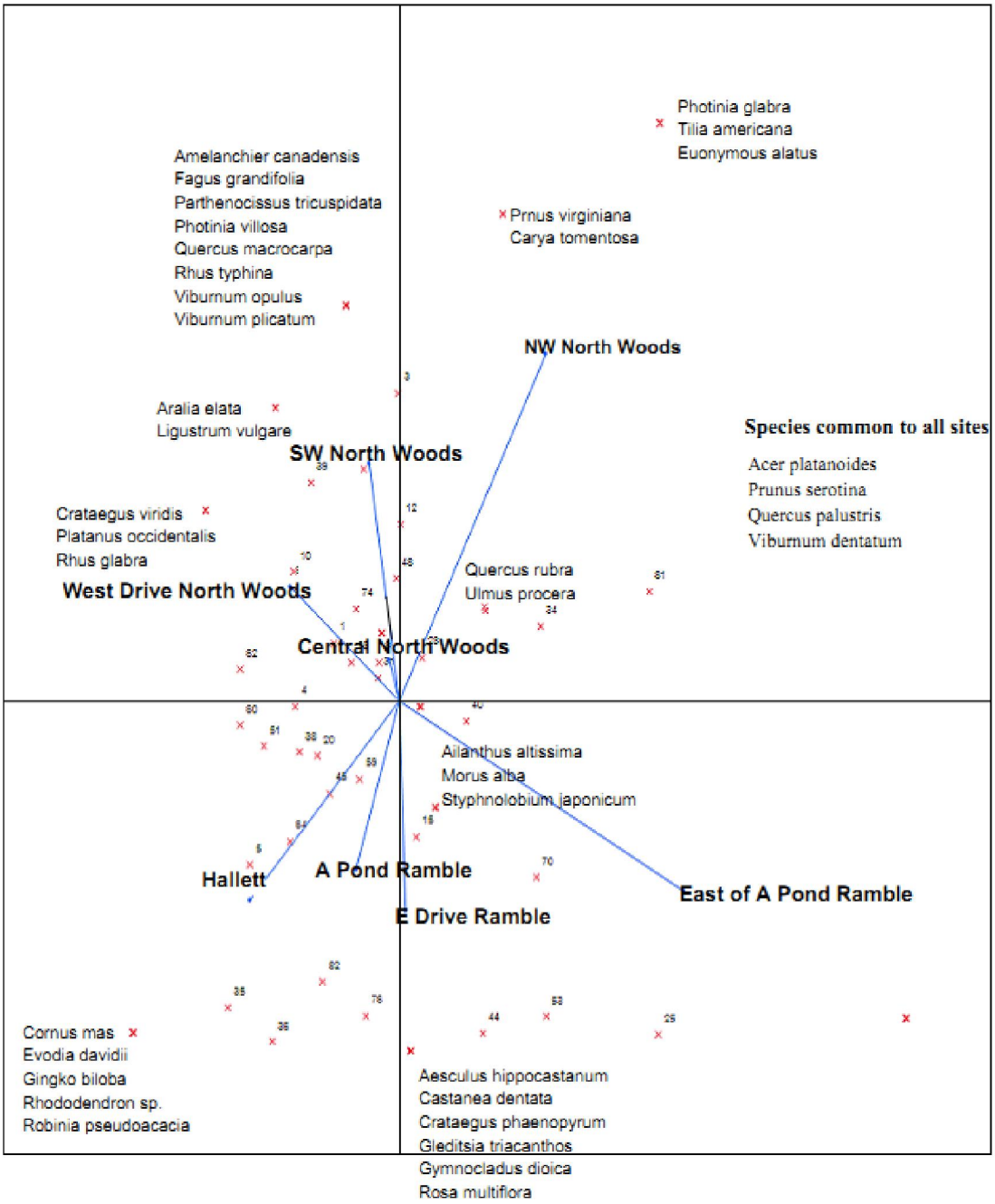

Figure 2.8. Correspondence analysis of sites. Jmp 9 (SAS)

2.9 Conclusions

Of the dominant species, the most dominant, *Prunus serotina,* is a native pioneer species. It produces large quantities of seeds easily dispersed by birds. Two other dominant species, *Acer platanoides* and *A. pseudoplatanus,* are classified as non-native invasive plants and rank in the top ten, despite continuous removal of these species by the Park's managers. *Acer platanoides* is the more problematic of the two, because of its drought tolerance and the fact that it appears in all sites. Future studies of this type will determine the effect of management of these species. *Quercus rubra* is high in Importance Value but shows little regeneration. My own observation of sites where soil was restored shows regeneration of oaks. Future surveys will determine if this species is surviving in these restored areas. Future studies will also help to determine if species such as *Phellodendron amurense, Aralia elata* and *Styphnolobium japonicum* are to be managed as invasives.

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Table 2.1 Ecological dominance assessed by Importance Value analysis for total data set. Cumulative values in parentheses.

	Species	Relative density	Relative frequency	Relative dominance	Importance value
1.	*Prunus serotina* Ehrh.	24.84 (24.84)	19.98 (19.98)	22.63 (22.63)	67.45 (67.45)
2.	*Quercus rubra* L.	3.93 (28.77)	4.57 (24.55)	21.49 (44.12)	29.99 (97.44)
3.	*Acer platanoides* L.	9.51 (38.29)	9.56 (34.11)	6.09 (50.21)	25.17 (122.61)
4.	*Quercus palustris* Muenchh.	3.22 (41.51)	3.83 (37.94)	9.07 (59.27)	16.12 (138.72)
5.	*Ulmus americana* L.	3.62 (45.13)	3.61 (41.55)	2.01 (61.28)	9.24 (147.96)
6.	*Morus alba* L.	2.28 (47.41)	2.55 (44.10)	4.34 (65.62)	9.17 (157.13)
7.	*Fraxinus americana* L.	2.52 (49.92)	3.08 (47.18)	3.49 (69.12)	9.09 (166.22)
8.	*Celtis occidentalis* L.	4.40 (54.32)	3.93 (51.12)	0.60 (69.71)	8.93 (175.15)
9.	*Acer pseudoplatanus* L.	2.99 (57.31)	3.40 (54.52)	2.28 (71.99)	8.67 (183.82)
10.	*Viburnum dentatum* var *lucidum* Ait.	3.93 (61.24)	4.04 (58.55)	0.68 (72.67)	8.65 (192.47)
11.	*Phellodendron amurense* Rupr.	1.73 (62.97)	2.02 (60.57)	3.41 (76.08)	7.16 (199.63)
12.	*Styphnolobium japonicum* (L.) Schott	1.73 (64.70)	1.81 (62.38)	2.67 (78.75)	6.21 (205.83)
13.	*Liriodendron tulipifera* L.	0.86 (65.57)	1.17 (63.55)	3.48 (82.23)	5.51 (211.35)
14.	*Lindera benzoin* (L.) Blume.	2.52 (68.08)	2.76 (66.31)	0.17 (82.40)	5.45 (216.80)
15.	*Sassafras albidum* (Nutt.) Nees.	2.91 (70.99)	2.13 (68.44)	0.36 (82.76)	5.39 (222.19)
16.	*Ailanthus altissima* (Miller) Swingle.	1.42 (72.41)	1.70 (70.14)	1.38 (84.14)	4.50 (226.69)
17.	*Ulmus procera* Salisb.	2.28 (74.69)	1.91 (72.05)	0.23 (84.37)	4.42 (231.11)
18.	*Malus sylvestris* (L.) Mill.	1.81 (76.49)	2.34 (74.39)	0.09 (84.46)	4.24 (235.34)
19.	*Carya cordiformis* (Wangenh) K. Koch.	1.02 (77.52)	1.38 (75.77)	1.08 (85.54)	3.49 (238.83)
20.	*Rhodotypos scandens* Makino.	1.49 (79.01)	1.49 (77.26)	0.12 (85.67)	3.10 (241.93)
21.	*Liquidambar styraciflua* L.	0.71 (79.72)	0.85 (78.11)	1.21 (86.88)	2.77 (244.71)
22.	*Quercus phellos* L.	0.55 (80.27)	0.64 (78.75)	1.48 (88.36)	2.67 (247.37)
23.	*Acer rubrum* L.	1.10 (81.37)	1.17 (79.91)	0.31 (88.67)	2.58 (249.95)
24.	*Robinia pseudoacacia* L.	0.55 (81.92)	0.64 (80.55)	1.31 (89.98)	2.50 (252.45)
25.	*Philadelphus coronarius* L.	0.94 (82.86)	1.28 (81.83)	0.27 (90.25)	2.49 (254.94)
26.	*Acer saccharum* Marshall.	1.10 (83.96)	1.28 (83.10)	0.03 (90.28)	2.41 (257.35)
27.	*Gymnocladus dioicus* (L.) K. Koch.	0.79 (84.75)	0.64 (83.74)	0.98 (91.26)	2.40 (259.75)
28.	*Photinia villosa* (Thunb.) DC.	1.26 (86.01)	0.96 (84.70)	0.11 (91.37)	2.33 (262.08)
29.	*Amelanchier canadensis* (L.) Medikus.	1.18 (87.19)	0.96 (85.65)	0.10 (91.47)	2.23 (264.31)
30.	*Frangula alnus* Mill.	1.10 (88.29)	1.06 (86.72)	0.02 (91.49)	2.18 (266.49)
31.	*Quercus alba* L.	0.24 (88.52)	0.32 (87.04)	1.31 (92.80)	1.86 (268.35)
32.	*Ulmus* sp. L.	0.79 (89.31)	0.74 (87.78)	0.25 (93.04)	1.78 (270.13)

33.	*Platanus occidentalis* L.	0.08 (89.39)	0.11 (87.89)	1.52 (94.56)	1.70 (271.83)
34.	*Viburnum prunifolium* L.	0.79 (90.17)	0.74 (88.63)	0.10 (94.66)	1.63 (273.46)
35.	*Euonymus europaeus* L.	0.47 (90.64)	0.64 (89.27)	0.30 (94.96)	1.41 (274.87)
36.	*Aralia elata* (Miq.) Seem	0.86 (91.51)	0.53 (89.80)	0.01 (94.97)	1.40 (276.27)
37.	*Rhododendron* sp. L.	0.63 (92.14)	0.64 (90.44)	0.07 (95.03)	1.33 (277.61)
38.	*Platanus hybrida* Brot.	0.16 (92.30)	0.21 (90.65)	0.94 (95.97)	1.31 (278.92)
39.	*Acer negundo* L.	0.55 (92.85)	0.64 (91.29)	0.02 (96.00)	1.21 (280.13)
40.	*Crataegus* sp. L.	0.47 (93.32)	0.64 (91.92)	0.07 (96.07)	1.18 (281.31)
41.	*Gleditsia triacanthos* var. *inermis* Willd.	0.24 (93.55)	0.32 (92.24)	0.43 (96.50)	0.98 (282.29)
42.	*Hamamelis virginiana* L.	0.39 (93.95)	0.53 (92.77)	0.02 (96.52)	0.95 (283.24)
43.	*Prunus* sp. L.	0.39 (94.34)	0.53 (93.30)	0.01 (96.53)	0.94 (284.18)
44.	*Koelreuteria paniculata* Laxm.	0.31 (94.65)	0.43 (93.73)	0.18 (96.71)	0.92 (285.10)
45.	*Cornus racemosa* Lam.	0.47 (95.13)	0.43 (94.16)	0.02 (96.73)	0.92 (286.01)
46.	*Tilia americana* L.	0.16 (95.28)	0.21 (94.37)	0.50 (97.24)	0.87 (286.89)
47.	*Ilex opaca* Aiton.	0.31 (95.60)	0.43 (94.79)	0.10 (97.34)	0.84 (287.73)
48.	*Gleditsia triacanthos* L.	0.16 (95.75)	0.21 (95.01)	0.41 (97.75)	0.78 (288.51)
49.	*Rosa multiflora* Thunb.	0.31 (96.07)	0.43 (95.43)	0.01 (97.76)	0.75 (289.26)
50.	*Viburnum plicatum* Thunb.	0.31 (96.38)	0.32 (95.75)	0.02 (97.78)	0.66 (289.91)
51.	*Pinus strobus* L.	0.16 (96.54)	0.21 (95.96)	0.28 (98.06)	0.65 (290.56)
52.	*Aesculus hippocastanum* L.	0.08 (96.62)	0.11 (96.07)	0.46 (98.52)	0.65 (291.21)
53.	*Cercis canadensis* L.	0.31 (96.93)	0.21 (96.28)	0.04 (98.56)	0.56 (291.77)
54.	*Ginkgo biloba* L.	0.08 (97.01)	0.11 (96.39)	0.30 (98.86)	0.48 (292.26)
55.	*Carya alba* (L.) Nutt.	0.16 (97.17)	0.21 (96.60)	0.09 (98.95)	0.46 (292.72)
56.	*Tilia cordata* Miller.	0.08 (97.25)	0.11 (96.71)	0.27 (99.21)	0.45 (293.17)
57.	*Fagus grandifolia* Ehrh.	0.24 (97.48)	0.21 (96.92)	0.00 (99.22)	0.45 (293.62)
58.	*Quercus laevis* Walter.	0.08 (97.56)	0.11 (97.02)	0.25 (99.47)	0.43 (294.05)
59.	*Prunus virginiana* L.	0.16 (97.72)	0.21 (97.24)	0.02 (99.49)	0.39 (294.44)
60.	*Quercus prinus* L.	0.16 (97.88)	0.21 (97.45)	0.01 (99.49)	0.38 (294.82)
61.	*Betula lenta* L.	0.16 (98.03)	0.21 (97.66)	0.00 (99.50)	0.37 (295.19)
62.	*Ligustrum vulgare* L.	0.16 (98.19)	0.21 (97.87)	0.00 (99.50)	0.37 (295.57)
63.	*Carpinus caroliniana* Walter.	0.16 (98.35)	0.11 (97.98)	0.09 (99.59)	0.36 (295.92)
64.	*Pinus nigra* Arnold.	0.08 (98.43)	0.11 (98.09)	0.14 (99.74)	0.33 (296.25)
65.	*Rhus typhina* L.	0.16 (98.58)	0.11 (98.19)	0.01 (99.74)	0.27 (296.52)
66.	*Crataegus phaenopyrum* (L.f.) Medikus.	0.08 (98.66)	0.11 (98.30)	0.09 (99.83)	0.27 (296.79)
67.	*Crataegus x lavallei grignonensis* (Henrincq.)	0.16 (98.82)	0.11 (98.41)	0.00 (99.83)	0.27 (297.06)
68.	*Viburnum setigerum* Hance.	0.08 (98.90)	0.11 (98.51)	0.06 (99.89)	0.24 (297.30)
69.	*Cornus mas* L.	0.08 (98.98)	0.11 (98.62)	0.04 (99.93)	0.22 (297.52)
70.	*Cornus kousa* Hance.	0.08 (99.06)	0.11 (98.72)	0.03 (99.95)	0.21 (297.73)

71.	*Quercus macrocarpa* Michx.	0.08 (99.14)	0.11 (98.83)	0.02 (99.97)	0.20 (297.93)
72.	*Hamamelis vernalis* Sarg.	0.08 (99.21)	0.11 (98.94)	0.01 (99.98)	0.20 (298.13)
73.	*Photinia glabra* Maxim.	0.08 (99.29)	0.11 (99.04)	0.01 (99.99)	0.19 (298.32)
74.	*Catanea dentata* (Marshall) Borkh.	0.08 (99.37)	0.11 (99.15)	0.00 (99.99)	0.19 (298.51)
75.	*Viburnum opulus* var. *opulus* L.	0.08 (99.45)	0.11 (99.26)	0.00 (99.99)	0.19 (298.70)
76.	*Sambucus nigra* L. ssp. *canadensis*(L.) Bolli	0.08 (99.53)	0.11 (99.36)	0.00 (100.00)	0.19 (298.89)
77.	*Euonymus alatus* (Thunb.) Siebold.	0.08 (99.61)	0.11 (99.47)	0.00 (100.00)	0.19 (299.07)
78.	*Evodia daniellii* (Benn.) Hemsl.	0.08 (99.69)	0.11 (99.57)	0.00 (100.00)	0.19 (299.26)
79.	*Rhus glabra* L.	0.08 (99.76)	0.11 (99.68)	0.00 (100.00)	0.19 (299.44)
80.	*Crataegus viridis* L.	0.08 (99.84)	0.11 (99.79)	0.00 (100.00)	0.19 (299.63)
81.	*Vaccinium corymbosum* L.	0.08 (99.92)	0.11 (99.89)	0.00 (100.00)	0.19 (299.81)
82.	*Parthenocissus tricuspidata* (Siebold & Zucc.) Planchon.	0.08 (100.00)	0.11 (100.00)	0.00 (100.00)	0.19 (300.00)

Table 2.2 Descriptive statistics for the total inventory data. Species listed in order of Importance Value. Diameter in centimeters. Absolute density (trees per hectare) from point centered quarter data in meters, with bootstrap 95% confidence intervals (NS=10,000 bootstrap samples), upper and lower bound in parentheses.

	Species	Abundance	% sampling units	Mean DBH	Standard deviation	Min, max	Absolute density (Upper bound, lower bound)
1.	*Prunus serotina* Ehrh.	316	59.12	16.25	17.12	1.0, 189.0	314.15 (293.57, 336.26)
2.	*Quercus rubra* L.	50	13.52	41.27	40.84	1.5, 218.0	49.71 (46.45, 53.21)
3.	*Acer platanoides* L.	121	28.30	11.16	16.39	1.0, 63.5	120.29 (112.41, 128.76)
4.	*Quercus palustris* Münchh.	41	11.32	26.33	32.40	1.0, 106.5	40.76 (38.09, 43.63)
5.	*Ulmus americana* L.	46	10.69	8.09	16.73	1.0, 104.0	45.73 (42.73, 48.95)
6.	*Morus alba* L.	29	7.55	21.55	26.87	1.0, 111.0	31.81 (29.73, 34.05)
7.	*Fraxinus americana* L.	32	9.12	19.09	22.34	1.0, 68.0	55.67 (52.02, 59.59)
8.	*Celtis occidentalis* L.	56	11.64	5.11	7.61	1.0, 42.0	37.78 (35.30, 40.44)
9.	*Acer pseudoplatanus* L.	38	10.06	14.46	16.22	1.0, 49.5	49.71 (46.45, 53.21)
10.	*Viburnum dentatum* var *lucidum* Aiton	50	11.95	6.90	7.69	1.5, 45.5	28.83 (26.94, 30.86)
11.	*Phellodendron amurense* Rupr.	22	5.97	21.82	27.63	1.0, 109.5	21.87 (20.44, 23.41)
12.	*Styphnolobium japonicum* (L.) Schott	22	5.35	15.39	27.19	1.0, 100.0	21.87 (20.44, 23.41)
13.	*Liriodendron tulipifera* L.	11	3.46	32.68	39.08	3.5, 108.0	10.94 (10.22, 11.71)
14.	*Lindera benzoin* (L.) Blume.	32	8.18	5.11	3.92	1.0, 21.0	31.81 (29.73, 34.05)
15.	*Sassafras albidum* (Nutt.) Nees.	37	6.29	6.49	5.86	1.0, 22.0	36.78 (34.37, 39.37)
16.	*Ailanthus altissima* (Mill.) Swingle	18	5.03	19.33	15.34	2.5, 67.5	17.89 (16.72, 19.15)
17.	*Ulmus procera* Salisb.	29	5.66	4.65	6.40	1.0, 34.0	28.83 (26.94, 30.86)
18.	*Malus sylvestris* (L.) Mill.	23	6.92	4.29	3.55	1.0, 18.0	22.87 (21.37, 24.47)
19.	*Carya cordiformis* (Wangenh) K. Koch.	13	4.09	18.04	18.67	1.0, 48.0	12.92 (12.08, 13.83)
20.	*Rhodotypos scandens* (Thunb.) Makino	19	4.40	5.35	4.68	2.0, 17.0	18.89 (17.65, 20.22)
21.	*Liquidambar styraciflua* L.	9	2.52	25.39	21.29	2.0, 71.0	8.95 (8.36, 9.58)
22.	*Quercus phellos* L.	7	1.89	27.81	31.81	2.0, 83.0	6.96 (6.50, 7.45)
23.	*Acer rubrum* L.	14	3.46	8.94	9.98	1.0, 38.5	13.92 (13.01, 14.90)
24.	*Robinia pseudoacacia* L.	7	1.89	35.93	13.82	13.0, 56.5	6.96 (6.50, 7.45)
25.	*Philadelphus coronarius* L.	12	3.77	8.41	10.64	2.0, 33.5	11.93 (11.15, 12.77)
26.	*Acer saccharum Marshall.*	14	3.77	3.18	2.64	1.0, 9.0	13.92 (13.01, 14.90)
27.	*Gymnocladus dioicus* (L.) K. Koch	10	1.89	15.95	23.71	1.0, 61.0	9.94 (9.29, 10.64)
28.	*Photinia villosa* (Thunb.) DC.	16	2.83	4.41	6.14	1.0, 24.5	15.91 (14.86, 17.03)
29.	*Amelanchier canadensis* (L.) Medik.	15	2.83	6.27	3.40	2.0, 12.0	14.91 (13.94, 15.96)
30.	*Frangula alnus* Mill.	14	3.14	3.11	1.32	1.0, 5.0	13.92 (13.01, 14.90)

31.	*Quercus alba* L.	3	0.94	46.17	43.29	4.0, 90.5	2.98 (2.79, 3.19)
32.	*Ulmus sp.* L.	10	2.20	7.90	12.01	1.0, 41.0	9.94 (9.29, 10.64)
33.	*Platanus occidentalis* L.	1	0.31	108.50	-	108.5, 108.5	0.99 (0.93, 1.06)
34.	*Viburnum prunifolium* L.	10	2.20	6.75	5.83	2.0, 19.5	9.94 (9.29, 10.64)
35.	*Euonymus europaeus* L.	6	1.89	13.75	15.65	1.5, 40.0	5.96 (5.57, 6.38)
36.	*Aralia elata* (Miq,) Seem	11	1.57	1.91	0.83	1.0, 4.0	10.94 (10.22, 11.71)
37.	*Rhododendron* sp. L.	8	1.89	6.31	5.34	2.0, 18.5	7.95 (7.43, 8.51)
38.	*Platanus hybrida* Brot.	2	0.63	55.00	35.36	30.0, 80.0	6.96 (6.50, 7.45)
39.	*Acer negundo* L.	7	1.89	4.64	2.17	1.5, 7.5	4.97 (4.65, 5.32)
40.	*Crataegus* sp. L.	6	1.89	6.67	7.80	1.0, 20.5	1.99 (1.86, 2.13)
41.	*Gleditsia triacanthos L. var. inermis* (L.) C.K. Schneid.	3	0.94	27.67	22.43	2.0, 43.5	5.96 (5.57, 6.38)
42.	*Hamamelis virginiana* L.	5	1.57	5.40	3.47	1.5, 11.0	2.98 (2.79, 3.19)
43.	*Prunus* sp. L.	5	1.57	3.70	3.03	1.5, 9.0	4.97 (4.65, 5.32)
44.	*Koelreuteria paniculata* Laxm.	4	1.26	13.63	14.77	1.0, 31.5	3.98 (3.72, 4.26)
45.	*Cornus racemosa* Lam.	6	1.26	3.50	3.74	1.0, 11.0	5.96 (5.57, 6.38)
46.	*Tilia americana* L.	2	0.63	32.00	43.13	1.5, 62.5	1.99 (1.86, 2.13)
47.	*Ilex opaca* Aiton	4	1.26	9.38	12.09	3.0, 27.5	3.98 (3.72, 4.26)
48.	*Gleditsia triacanthos* L.	2	0.63	38.00	16.97	26.0, 50.0	1.99 (1.86, 2.13)
49.	*Rosa multiflora* Thunb.	4	1.26	4.00	2.71	2.0, 8.0	3.98 (3.72, 4.26)
50.	*Viburnum plicatum* Thunb.	4	0.94	5.25	4.63	1.5, 11.5	3.98 (3.72, 4.26)
51.	*Pinus strobus* L.	2	0.63	29.75	20.15	15.5, 44.0	1.99 (1.86, 2.13)
52.	*Aesculus hippocastanum* L.	1	0.31	60.00	-	60.0, 60.0	0.99 (0.93, 1.06)
53.	*Cercis canadensis* L.	4	0.63	8.30	1.23	7.0, 9.5	3.98 (3.72, 4.26)
54.	*Ginkgo biloba* L.	1	0.31	48.00	-	48.0, 48.0	0.99 (0.93, 1.06)
55.	*Carya alba* (L.) Nutt.	2	0.63	16.25	13.08	7.0, 25.5	1.99 (1.86, 2.13)
56.	*Tilia cordata* Mill.	1	0.31	45.50	-	45.5, 45.5	2.98 (2.79, 3.19)
57.	*Fagus grandifolia* Ehrh.	3	0.63	2.40	1.56	1.5, 4.2	0.99 (0.93, 1.06)
58.	*Quercus laevis* Walter	1	0.31	44.00	-	44.0, 44.0	0.99 (0.93, 1.06)
59.	*Prunus virginiana* L.	2	0.63	9.00	0.71	8.5, 9.5	1.99 (1.86, 2.13)
60.	*Quercus prinus* L.	2	0.63	4.75	1.77	3.5, 6.0	1.99 (1.86, 2.13)
61.	*Betula lenta* L.	2	0.63	4.00	0.00	4.0, 4.0	1.99 (1.86, 2.13)
62.	*Ligustrum vulgare* L.	2	0.63	3.00	0.00	3.0, 3.0	1.99 (1.86, 2.13)
63.	*Carpinus caroliniana* Walter.	2	0.31	16.75	12.37	8.0, 25.5	1.99 (1.86, 2.13)
64.	*Pinus nigra* Arnold	1	0.31	33.50	-	33.5, 33.5	0.99 (0.93, 1.06)
65.	*Rhus typhina* L.	2	0.31	4.75	5.30	1.0, 8.5	1.99 (1.86, 2.13)
66.	*Crataegus phaenopyrum* (L.f.) Medik.	1	0.31	26.00	-	26.0, 26.0	0.99 (0.93, 1.06)
67.	*Crataegus x lavallei* Henrincq.	2	0.31	2.50	0.71	2.0, 3.0	1.99 (1.86, 2.13)
68.	*Viburnum setigerum* Hance.	1	0.31	21.00	-	21.0, 21.0	0.99 (0.93, 1.06)
69.	*Cornus mas* L.	1	0.31	16.50	-	16.5, 16.5	0.99 (0.93, 1.06)

70.	*Cornus kousa* Hance	1	0.31	14.00	-	14.0, 14.0	0.99 (0.93, 1.06)
71.	*Quercus macrocarpa* Michx.	1	0.31	11.00	-	11.0, 11.0	0.99 (0.93, 1.06)
72.	*Hamamelis vernalis* Sarg.	1	0.31	10.00	-	10.0, 10.0	0.99 (0.93, 1.06)
73.	*Photinia glabra* (Thunb.) Maxim.	1	0.31	7.50	-	7.5, 7.5	0.99 (0.93, 1.06)
74.	*Catanea dentata* (Marshall) Borkh. (hybrid)	1	0.31	6.00	-	6.0, 6.0	0.99 (0.93, 1.06)
75.	*Viburnum opulus* L.	1	0.31	5.50	-	5.5, 5.5	0.99 (0.93, 1.06)
76.	*Sambucus nigra* L. ssp. *canadensis* (L.) R. Bolli	1	0.31	4.00	-	4.0, 4.0	0.99 (0.93, 1.06)
77.	*Euonymus alatus* (Thunb.) Siebold.	1	0.31	3.00	-	3.0, 3.0	0.99 (0.93, 1.06)
78.	*Evodia daniellii* (Benn.) Hemsl.	1	0.31	3.00	-	3.0, 3.0	0.99 (0.93, 1.06)
79.	*Rhus glabra* L.	1	0.31	1.50	-	1.5, 1.5	0.99 (0.93, 1.06)
80.	*Crataegus viridis* L.	1	0.31	1.50	-	1.5, 1.5	0.99 (0.93, 1.06)
81.	*Vaccinium corymbosum* L.	1	0.31	1.00	-	1.0, 1.0	0.99 (0.93, 1.06)
82.	*Parthenocissus tricuspidata*(Siebold & Zucc.) Planch.	1	0.31	1.00	-	1.0, 1.0	0.99 (0.93, 1.06)

Table 2.3 Ecological dominance assessed by Importance Value analysis for lower DBH quartile of total data set. Cumulative values in parentheses.

	Species	Number of stems	Relative density	Relative frequency	Relative dominance	Importance value
1.	*Acer platanoides* L.	61	19.18 (19.18)	15.91 (15.91)	18.20 (18.20)	53.30 (53.30)
2.	*Prunus serotina* Ehrh.	35	11.01 (30.19)	11.74 (27.65)	12.65 (30.86)	35.40 (88.70)
3.	*Celtis occidentalis* L.	27	8.49 (38.68)	7.95 (35.61)	9.03 (39.89)	25.48 (114.20)
4.	*Quercus palustris* Münchh.	15	4.72 (43.40)	4.55 (40.15)	4.05 (43.94)	13.32 (127.50)
5.	*Ulmus americana* L.	15	4.72 (48.11)	4.92 (45.08)	3.62 (47.56)	13.26 (140.80)
6.	*Ulmus procera* Salisb.	10	3.14 (51.26)	3.03 (48.11)	3.65 (51.21)	9.82 (150.60)
7.	*Acer pseudoplatanus* L.	10	3.14 (54.40)	3.79 (51.89)	2.55 (53.76)	9.48 (160.10)
8.	*Sassafras albidum* (Nutt.) Nees.	11	3.46 (57.86)	3.03 (54.92)	2.75 (56.51)	9.24 (169.30)
9.	*Fraxinus americana* L.	9	2.83 (60.69)	3.41 (58.33)	2.37 (58.88)	8.61 (177.90)
10.	*Lindera benzion* (L.) Blume.	7	2.20 (62.89)	2.65 (60.98)	2.49 (61.37)	7.34 (185.30)
11.	*Aralia elata* (Miq.) Seem	8	2.83 (65.72)	1.52 (62.50)	2.87 (64.24)	7.21 (192.50)
12.	*Acer saccharum* Marshall.	8	2.52 (68.24)	2.65 (65.15)	1.77 (66.01)	6.93 (199.40)
13.	*Photinia villosa* (Thunb.) DC.	6	2.52 (70.75)	1.89 (67.05)	2.11 (68.12)	6.52 (205.90)
14.	*Malus sylvestris* (L.) Mill.	6	1.89 (72.64)	2.27 (69.32)	2.03 (70.15)	6.19 (212.10)
15.	*Styphnolobium japonicum* (L.) Schott	5	1.89 (74.53)	2.27 (71.59)	1.88 (72.03)	6.04 (218.10)
16.	*Viburnum dentatum* var. *lucidum* Ait.	4	1.57 (76.10)	1.89 (73.48)	2.17 (74.20)	5.64 (223.80)
17.	*Philadelphus coronarius* L.	5	1.26 (77.36)	1.52 (75.00)	2.32 (76.52)	5.09 (228.90)
18.	*Carya cordiformis* (Wangenh) K. Koch	4	1.57 (78.93)	1.89 (76.89)	1.22 (77.73)	4.68 (233.60)
19.	*Rhodotypos scandens* (Thunb.) Makino	4	1.26 (80.19)	1.52 (78.41)	1.85 (79.59)	4.63 (238.20)
20.	*Morus alba* L.	5	1.26 (81.45)	1.52 (79.92)	1.77 (81.35)	4.54 (242.70)
21.	*Gymnocladus dioica* (L.) K. Koch	4	1.57 (83.02)	1.52 (81.44)	1.27 (82.63)	4.36 (247.10)
22.	*Quercus rubra* L.	4	1.26 (84.28)	1.52 (82.95)	1.25 (83.87)	4.02 (251.10)
23.	*Frangula alnus* L.	3	1.26 (85.53)	1.14 (84.09)	0.96 (84.83)	3.35 (254.50)
24.	*Ulmus* sp. L.	3	1.26 (86.79)	1.14 (85.23)	0.81 (85.64)	3.20 (257.70)
25.	*Phellodendron amurense* Rupr.	3	0.94 (87.74)	1.14 (86.36)	1.04 (86.68)	3.12 (260.80)
26.	*Crataegus* sp. L.	3	0.94 (88.68)	1.14 (87.50)	1.04 (87.72)	3.12 (263.90)
27.	*Viburnum prunifolium* L.	2	0.94 (89.62)	0.76 (88.26)	1.39 (89.11)	3.09 (267.00)
28.	*Cornus racemosa* Lam.	2	0.94 (90.57)	0.76 (89.02)	0.84 (89.95)	2.54 (269.50)
29.	*Amelanchier canadensis* (L.) Medik.	2	0.63 (91.19)	0.76 (89.77)	0.93 (90.88)	2.31 (271.80)
30.	*Rhododendron sp.* L.	2	0.63 (91.82)	0.76 (90.53)	0.93 (91.81)	2.31 (274.20)
31.	*Quercus phellos* L.	2	0.63 (92.45)	0.76 (91.29)	0.93 (92.73)	2.31 (276.50)

32.	*Prunus* sp. L.	2	0.63 (93.08)	0.76 (92.05)	0.72 (93.46)	2.11 (278.60)
33.	*Koelreuteria paniculata* Laxm.	2	0.63 (93.71)	0.76 (92.80)	0.58 (94.04)	1.97 (280.50)
34.	*Fagus grandifolia* Ehrh.	1	0.63 (94.34)	0.76 (93.56)	0.52 (94.56)	1.91 (282.50)
35.	*Viburnum plicatum* Thunb.	1	0.63 (94.97)	0.38 (93.94)	0.72 (95.28)	1.73 (284.20)
36.	*Acer rubrum* L.	1	0.63 (95.60)	0.76 (94.70)	0.23 (95.51)	1.62 (285.80)
37.	*Ailanthus altissima* (Mill.) Swingle	1	0.31 (95.91)	0.38 (95.08)	0.72 (96.24)	1.42 (287.20)
38.	*Rosa multiflora* Thunb.	1	0.31 (96.23)	0.38 (95.45)	0.46 (96.70)	1.16 (288.40)
39.	*Gleditsia triacanthos* (L.) var. inermis (L.) C.K. Schneid	1	0.31 (96.54)	0.38 (95.83)	0.46 (97.16)	1.16 (289.50)
40.	*Liquidambar styraciflua* L.	1	0.31 (96.86)	0.38 (96.21)	0.46 (97.63)	1.16 (290.70)
41.	*Crataegus* x l*avallei (grignonensis)* Herincq.	1	0.31 (97.17)	0.38 (96.59)	0.46 (98.09)	1.16 (291.80)
42.	*Rhus glabra* L	1	0.31 (97.48)	0.38 (96.97)	0.26 (98.35)	0.95 (292.80)
43.	*Hamamelis virginiana* L.	1	0.31 (97.80)	0.38 (97.35)	0.26 (98.61)	0.95 (293.80)
44.	*Euonymus europaeus* L.	1	0.31 (98.11)	0.38 (97.73)	0.26 (98.87)	0.95 (294.70)
45.	*Acer negundo* L.	1	0.31 (98.43)	0.38 (98.11)	0.26 (99.13)	0.95 (295.70)
46.	*Tilia americana* L.	1	0.31 (98.74)	0.38 (98.48)	0.26 (99.39)	0.95 (296.60)
47.	*Crataegus viridis* L.	1	0.31 (99.06)	0.38 (98.86)	0.26 (99.65)	0.95 (297.60)
48.	*Rhus typhina* L.	1	0.31 (99.37)	0.38 (99.24)	0.12 (99.77)	0.81 (298.40)
49.	*Vaccinium corymbosum* L.	1	0.31 (99.69)	0.38 (99.62)	0.12 (99.88)	0.81 (299.20)
50.	*Parthenocissus tricuspidata* (Siebold & Zucc.) Planch.	1	0.31 (100.00)	0.38 (100.00)	0.12 (100.00)	0.81 (300.00)

Table 2.4 Ecological dominance assessed by Importance Value analysis for families of total data set. Cumulative values in parentheses.

	Family	Relative density	Relative frequency	Relative dominance	Importance value
1.	Rosaceae	32.39 (32.39)	25.50 (25.50)	23.30 (23.30)	81.19 (81.19)
2.	Fagaceae	8.57 (40.96)	9.99 (35.49)	33.62 (56.92)	52.18 (133.36)
3.	Aceraceae	15.25 (56.21)	14.92 (50.41)	8.73 (65.65)	38.91 (172.27)
4.	Ulmaceae	11.08 (67.30)	10.69 (61.10)	3.08 (68.73)	24.86 (197.13)
5.	Caprifoliaceae	5.27 (72.56)	5.88 (66.98)	0.86 (69.60)	12.01 (209.14)
6.	Lauraceae	5.42 (77.99)	5.41 (72.39)	0.53 (70.12)	11.36 (220.50)
7.	Oleaceae	2.67 (80.66)	3.53 (75.91)	3.50 (73.62)	9.69 (230.19)
8.	Moraceae	2.28 (82.94)	2.82 (78.73)	4.34 (77.96)	9.44 (239.63)
9.	Fabaceae	2.28 (85.22)	2.70 (81.43)	3.98 (81.94)	8.96 (248.59)
10.	Rutaceae	1.81 (87.03)	2.23 (83.67)	3.42 (85.35)	7.46 (256.05)
11.	Magnoliaceae	0.86 (87.89)	1.29 (84.96)	3.48 (88.83)	5.64 (261.69)
12.	Caesalpiniaceae	1.49 (89.39)	1.41 (86.37)	1.85 (90.68)	4.75 (266.44)
13.	Simaroubaceae	1.42 (90.80)	1.88 (88.25)	1.38 (92.06)	4.68 (271.12)
14.	Juglandaceae	1.18 (91.98)	1.76 (90.01)	1.17 (93.24)	4.12 (275.23)
15.	Hamamelidaceae	1.18 (93.16)	1.65 (91.66)	1.25 (94.49)	4.08 (279.31)
16.	Platanaceae	0.24 (93.40)	0.35 (92.01)	2.46 (96.95)	3.04 (282.35)
17.	Hydrangeaceae	0.94 (94.34)	1.41 (93.42)	0.27 (97.22)	2.62 (284.97)
18.	Rhamnaceae	1.10 (95.44)	1.18 (94.59)	0.02 (97.24)	2.30 (287.27)
19.	Celastraceae	0.55 (95.99)	0.82 (95.42)	0.31 (97.54)	1.68 (288.95)
20.	Ericaceae	0.71 (96.70)	0.82 (96.24)	0.07 (97.61)	1.60 (290.55)
21.	Araliaceae	0.86 (97.56)	0.59 (96.83)	0.01 (97.61)	1.46 (292.00)
22.	Tiliaceae	0.24 (97.80)	0.35 (97.18)	0.77 (98.38)	1.36 (293.36)
23.	Cornaceae	0.55 (98.35)	0.59 (97.77)	0.04 (98.43)	1.18 (294.54)
24.	Pinaceae	0.24 (98.58)	0.35 (98.12)	0.42 (98.85)	1.01 (295.56)
25.	Sapindaceae	0.31 (98.90)	0.47 (98.59)	0.18 (99.03)	0.96 (296.52)
26.	Aquifoliaceae	0.31 (99.21)	0.47 (99.06)	0.10 (99.13)	0.89 (297.41)
27.	Betulaceae	0.31 (99.53)	0.35 (99.41)	0.10 (99.23)	0.76 (298.17)
28.	Hippocastinaceae	0.08 (99.61)	0.12 (99.53)	0.46 (99.69)	0.66 (298.83)
29.	Ginkgoaceae	0.08 (99.69)	0.12 (99.65)	0.30 (99.99)	0.49 (299.32)
30.	Anacardiaceae	0.24 (99.92)	0.24 (99.88)	0.01 (100.00)	0.48 (299.80)
31.	Vitaceae	0.08 (100.00)	0.12 (100.00)	0.00 (100.00)	0.20 (300.00)

Table 2.5 Ecological dominance assessed by Importance Value analysis for genera of total data set. Cumulative values in parentheses.

	Genera	Relative density	Relative frequency	Relative dominance	Importance value
1.	*Prunus*	25.39 (25.39)	21.25 (21.25)	22.66 (22.66)	69.30 (69.30)
2.	*Quercus*	8.25 (33.65)	9.12 (30.37)	33.61 (56.27)	50.99 (120.30)
3.	*Acer*	15.25 (48.90)	14.13 (44.49)	8.73 (65.01)	38.11 (158.40)
4.	*Ulmus*	6.68 (55.58)	6.34 (50.83)	2.49 (67.49)	15.51 (173.90)
5.	*Viburnum*	5.11 (60.69)	5.34 (56.17)	0.86 (68.35)	11.31 (185.20)
6.	*Morus*	2.28 (62.97)	2.67 (58.84)	4.34 (72.69)	9.29 (194.50)
7.	*Fraxinus*	2.52 (65.49)	3.23 (62.07)	3.49 (76.18)	9.24 (203.70)
8.	*Celtis*	4.40 (69.89)	4.12 (66.18)	0.60 (76.78)	9.12 (212.90)
9.	*Phellodendron*	1.73 (71.62)	2.11 (68.30)	3.41 (80.20)	7.26 (220.10)
10.	*Styphnolobium*	1.73 (73.35)	1.89 (70.19)	2.67 (82.86)	6.29 (226.40)
11.	*Lindera*	2.52 (75.86)	2.89 (73.08)	0.17 (83.03)	5.58 (232.00)
12.	*Liriodendron*	0.86 (76.73)	1.22 (74.30)	3.48 (86.51)	5.57 (237.50)
13.	*Sassafras*	2.91 (79.64)	2.22 (76.53)	0.36 (86.87)	5.49 (243.00)
14.	*Ailanthus*	1.42 (81.05)	1.78 (78.31)	1.38 (88.25)	4.58 (247.60)
15.	*Malus*	1.81 (82.86)	2.45 (80.76)	0.09 (88.34)	4.35 (252.00)
16.	*Carya*	1.18 (84.04)	1.67 (82.42)	1.17 (89.52)	4.02 (256.00)
17.	*Rhodotypos*	1.49 (85.53)	1.56 (83.98)	0.12 (89.64)	3.17 (259.20)
18.	*Platanus*	0.24 (85.77)	0.33 (84.32)	2.46 (92.09)	3.03 (262.20)
19.	*Liquidambar*	0.71 (86.48)	0.89 (85.21)	1.21 (93.31)	2.81 (265.00)
20.	*Photinia*	1.34 (87.81)	1.11 (86.32)	0.12 (93.43)	2.57 (267.60)
21.	*Philadelphus*	0.94 (88.76)	1.33 (87.65)	0.27 (93.70)	2.55 (270.10)
22.	*Robinia*	0.55 (89.31)	0.67 (88.32)	1.31 (95.01)	2.53 (272.60)
23.	*Gymnocladus*	0.79 (90.09)	0.67 (88.99)	0.98 (95.99)	2.43 (275.10)
24.	*Amelanchier*	1.18 (91.27)	1.00 (89.99)	0.10 (96.09)	2.28 (277.30)
25.	*Frangula*	1.10 (92.37)	1.11 (91.10)	0.02 (96.11)	2.23 (279.60)
26.	*Crataegus*	0.79 (93.16)	1.00 (92.10)	0.16 (96.27)	1.95 (281.50)
27.	*Gleditsia*	0.39 (93.55)	0.56 (92.66)	0.83 (97.10)	1.78 (283.30)
28.	*Euonymus*	0.55 (94.10)	0.78 (93.44)	0.31 (97.41)	1.63 (284.90)
29.	*Aralia*	0.86 (94.97)	0.56 (93.99)	0.01 (97.41)	1.43 (286.40)
30.	*Cornus*	0.63 (95.60)	0.67 (94.66)	0.08 (97.49)	1.38 (287.80)
31.	*Rhododendron*	0.63 (96.23)	0.67 (95.33)	0.07 (97.56)	1.36 (289.10)

32.	*Tilia*	0.24 (96.46)	0.33 (95.66)	0.77 (98.33)	1.34 (290.50)
33.	*Hamamelis*	0.47 (96.93)	0.67 (96.33)	0.04 (98.37)	1.18 (291.60)
34.	*Pinus*	0.24 (97.17)	0.33 (96.66)	0.42 (98.79)	0.99 (292.60)
35.	*Koelreuteria*	0.31 (97.48)	0.44 (97.11)	0.18 (98.97)	0.94 (293.60)
36.	*Ilex*	0.31 (97.80)	0.44 (97.55)	0.10 (99.07)	0.86 (294.40)
37.	*Rosa*	0.31 (98.11)	0.44 (98.00)	0.01 (99.08)	0.77 (295.20)
38.	*Aesculus*	0.08 (98.19)	0.11 (98.11)	0.46 (99.55)	0.65 (295.80)
39.	*Cercis*	0.31 (98.51)	0.22 (98.33)	0.04 (99.58)	0.57 (296.40)
40.	*Ginkgo*	0.08 (98.58)	0.11 (98.44)	0.30 (99.88)	0.49 (296.90)
41.	*Rhus*	0.24 (98.82)	0.22 (98.67)	0.01 (99.89)	0.47 (297.40)
42.	*Fagus*	0.24 (99.06)	0.22 (98.89)	0.00 (99.89)	0.46 (297.80)
43.	*Betula*	0.16 (99.21)	0.22 (99.11)	0.00 (99.90)	0.38 (298.20)
44.	*Ligustrum*	0.16 (99.37)	0.22 (99.33)	0.00 (99.90)	0.38 (298.60)
45.	*Carpinus*	0.16 (99.53)	0.11 (99.44)	0.09 (99.99)	0.36 (299.00)
46.	*Castanea*	0.08 (99.61)	0.11 (99.56)	0.00 (100.00)	0.19 (299.20)
47.	*Sambucus*	0.08 (99.69)	0.11 (99.67)	0.00 (100.00)	0.19 (299.40)
48.	*Evodia*	0.08 (99.76)	0.11 (99.78)	0.00 (100.00)	0.19 (299.50)
49.	*Parthenocissus*	0.08 (99.84)	0.11 (99.89)	0.00 (100.00)	0.19 (299.70)
50.	*Vaccinium*	0.08 (99.92)	0.11 (100.00)	0.00 (100.00)	0.19 (299.90)

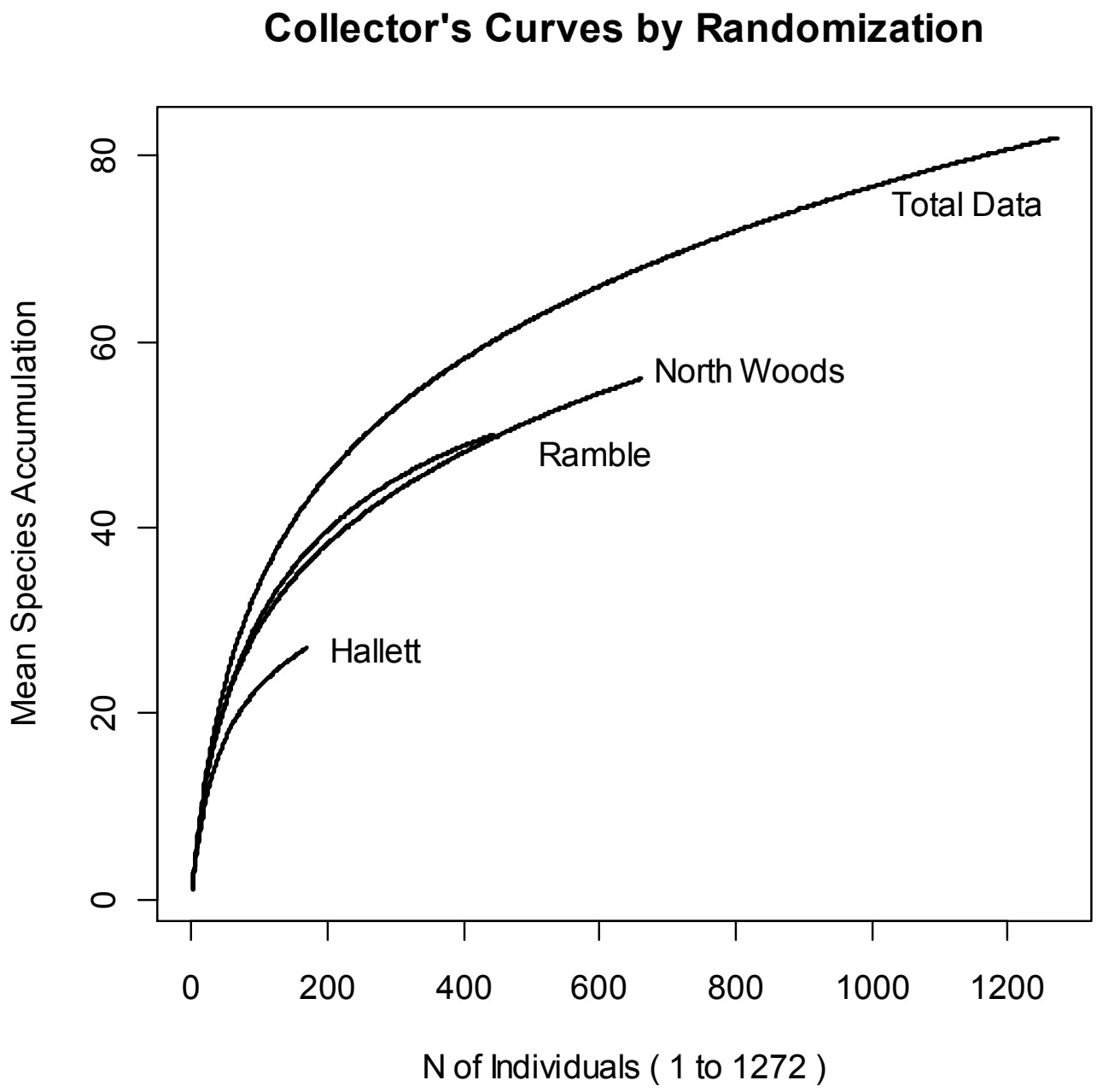


Figure 2.4 Collector's curves of total data set and individual woodland data sets, based on 10,000 randomizations.

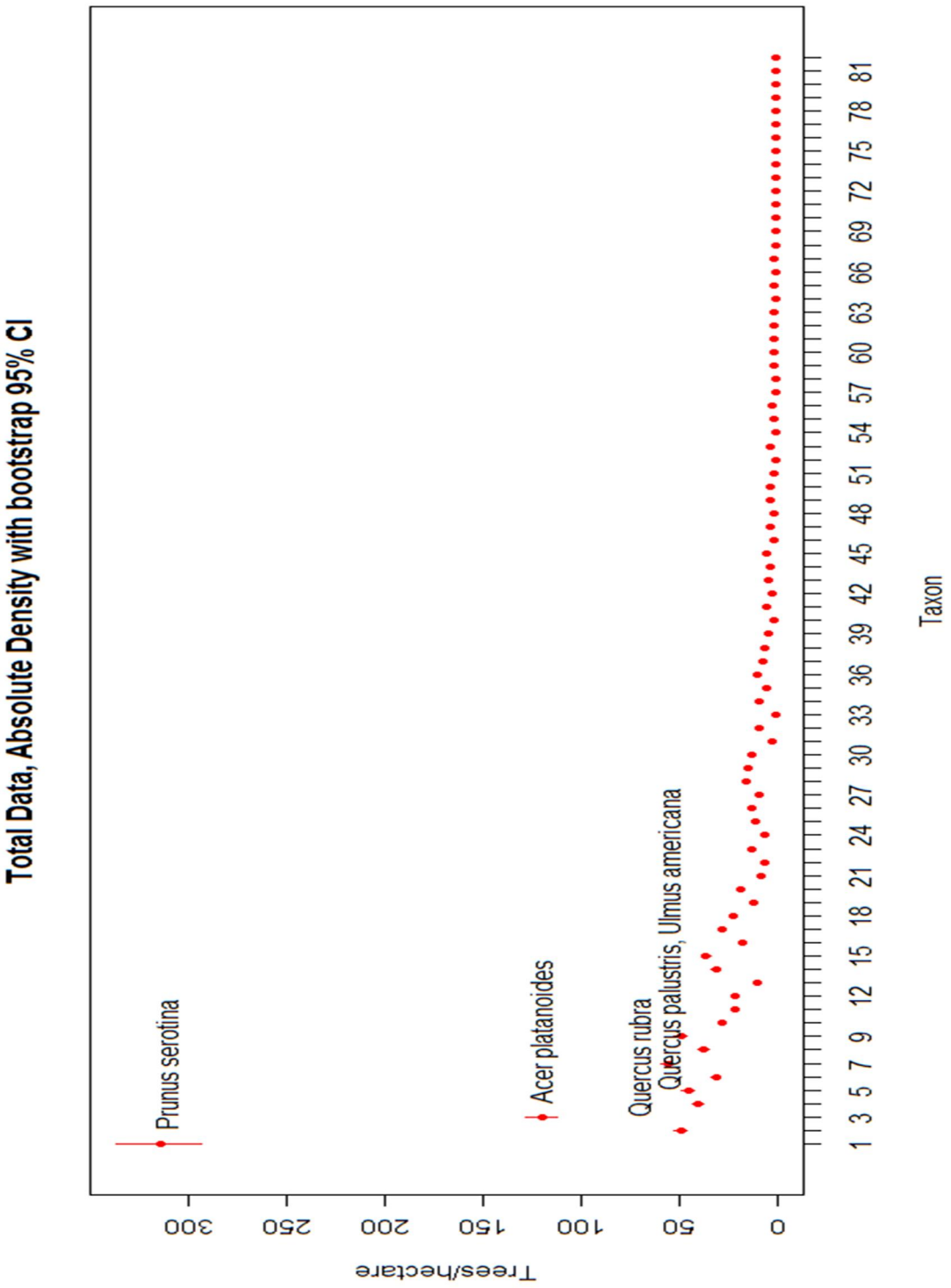
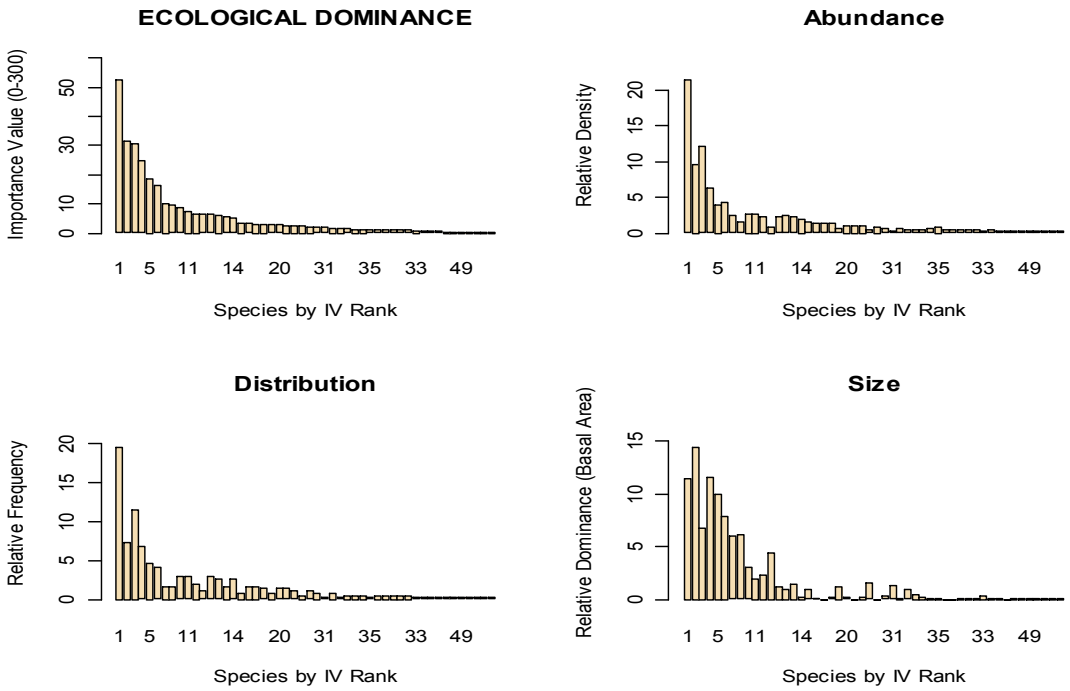
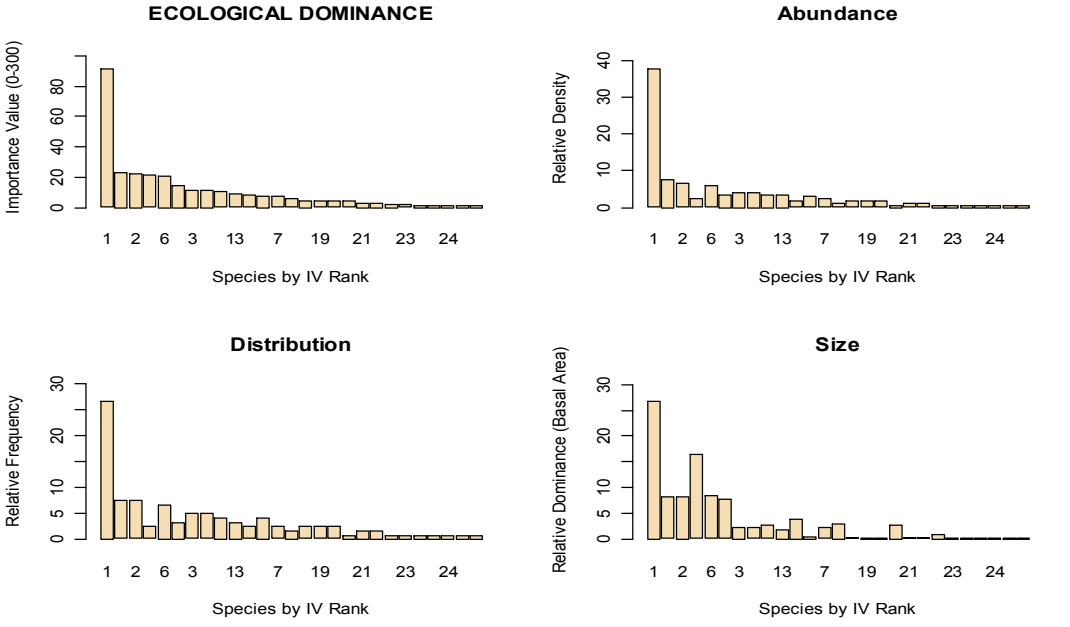


Figure 2.5 Absolute density, Total data

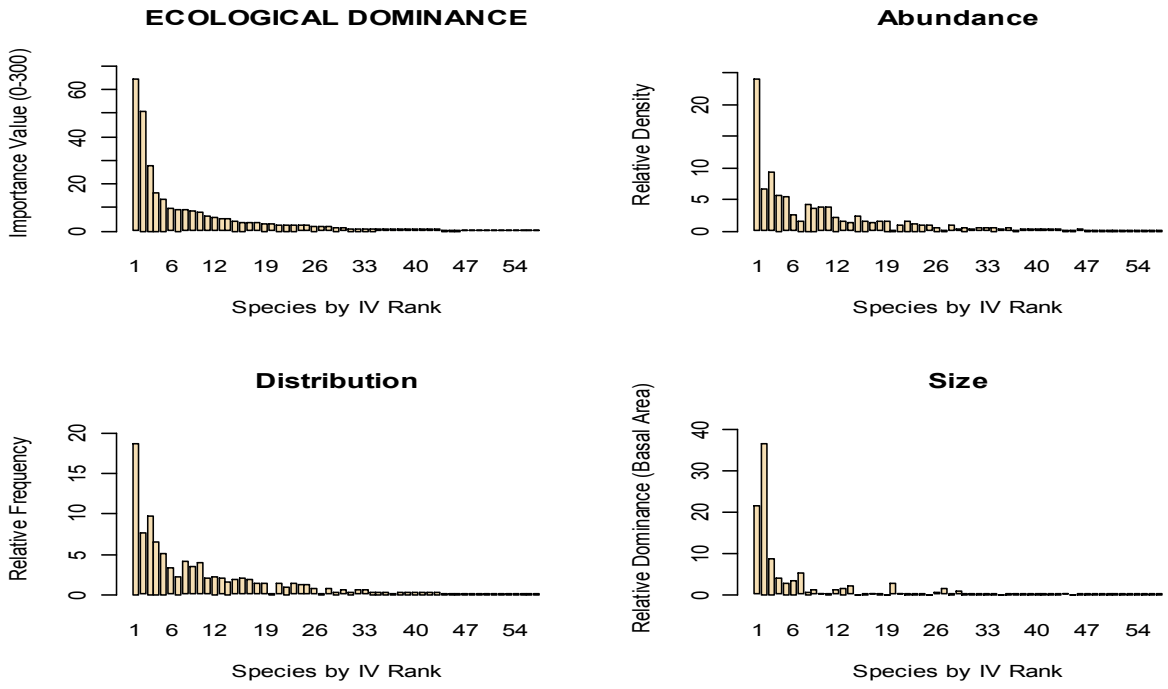


Ramble

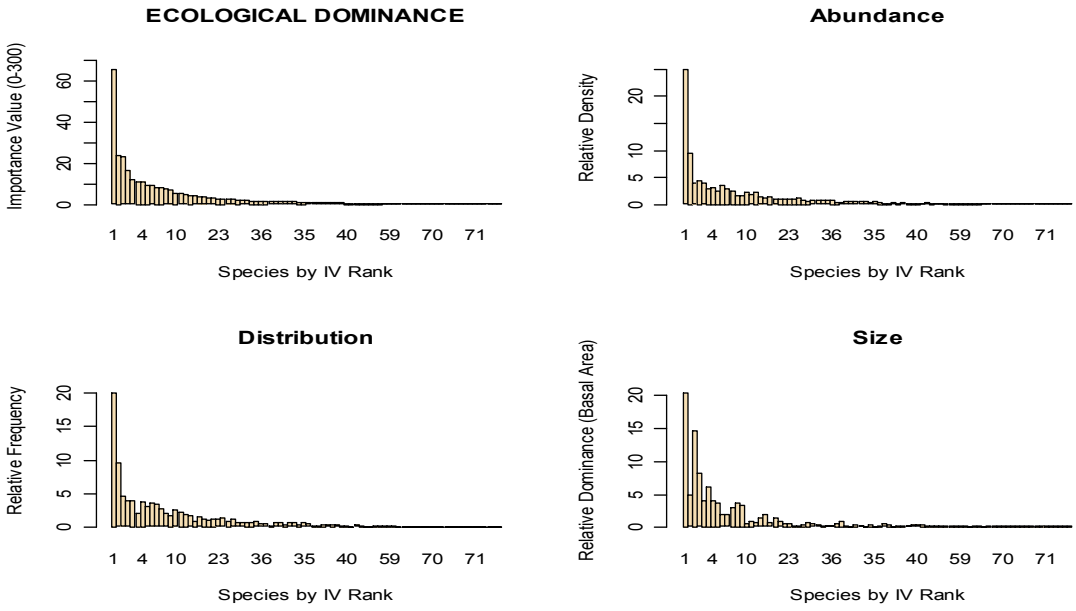


Hallett

Figure 2.6 Comparison of Importance values between woodlands, in order of Importance Value listed in order of IV from table 5.2.



North Woods



Total data

Figure 2.6 (continued) Comparison of Importance values between woodlands, in order of Importance Value Value listed in order of IV from table 5.2.

Chapter 3

The Ramble

3.1 Introduction

The Ramble is a 14.6 hectare woodland located mid-Park, between 72nd and 79th Streets (Figure 3.1). It is bordered by the Lake, the west and east drives and the 79th Street transverse road. The original design intent of this woodland was one of an open landscape with sweeping vistas. The Ramble was the first part of the Park to be opened to the public, at the end of the 1850s, a few years before the start of the Civil War (Kinkead 1990, Rosenzweig and Blackmar 1992). In 1862 Olmsted sent a letter to Ignaz Pilat, the landscape gardener of the Park, with suggestions on how to use native plants, such as skunk cabbage and catbrier, to achieve tropical effects in New York's temperate climate (Rosenzweig and Blackmar 1992, Miller 2003). Non-native species, such as *Wisteria* and *Ailanthus,* were also to be used for this purpose. Some of these species are now considered invasive in the Park (see Chapter 7). The picturesque treatment of the design of the Ramble is in contrast to the more rugged northern park (Rosenzweig and Blackmar 1992).

Olmsted devoted more time and attention to the Ramble than to any other feature of the Park (Conservancy 1989). He had intended a clear line of sight from Belvedere Castle (79th Street, mid-Park) to Bethesda Fountain (72nd Street, mid-Park) through proper botanical maintenance of the intervening turf, shrubbery and trees. The view was meant to be, and was, captivating from either terminus (Kinkead 1990). Olmsted and Vaux, the designers, felt that "the Ramble should be the picture that people would come to see" (Rosenzweig and Blackmar 1992). The view disappeared well within the next ten years as a result of poor maintenance (Kinkead1990). As

happens with ecological succession in areas of the northeastern United States, the areas filled in with trees, mostly with pioneer species, since this was an open and sunny area. Much of the original Olmstedian botany was lost (Kinkead 1990).

Figure 3.1 The Ramble

In July 1858, 15,000 people visited the Ramble. By 1860, that number was 2.5 million and in the following decade the attendance more than tripled (Rosenzweig and Blackmar 1992). In a 1979 user survey (Cook 1979), the site was noted by some as "rundown" and issues of safety were brought up. But, other park users described their experience in the Ramble as being "away from the city", "in a refuge" and in a place that was "natural." The point is that there was consistency in the vocabulary used by the interviewees, indicating that even though this was a period of severe decline in the Park and especially the woodland areas, the Ramble still offered a sense of nature to city dwellers.

Today the Ramble is probably most noted as a good place for birdwatching. Its location at the center of the Park and adjacent to a lake is ideal. As a habitat, the Ramble is indispensable (Conservancy 1989). The Ramble was originally designed to offer a broad range of habitats

from upland to lowland, cave, cove and wetland all compressed in a very small site, all of which make it very attractive to wildlife (Conservancy 1989).

When the Central Park Conservancy was first created (1980), one of its projects on was to restore some of the historic views in the Ramble. In the spring of 1981 trees were cleared on the east side of the Ramble in an area known as "The Point." Birdwatchers were immediately concerned that this work would destroy the Ramble, which had become an unusually rich habitat for birds, and they gathered 3,000 signatures protesting the work (Rosenzweig and Blackmar 1992, Kinkead 1990). Although the Conservancy prevailed in hearings before the Landmarks Commission, it continued very cautiously in order to avoide antagonizing the community (Rosenzweig and Blackmar 1992). Eventually the Conservancy developed an ongoing and good working relationship with the naturalist community (personal experience). Work continued very slowly for many years, and in more recent years, many areas, especially in the Ramble, have undergone ecological restoration. This restoration includes improving the soil, removing invasive species and planting native species.

3.2 Importance Value, Descriptive Statistics

Of the total data set, the Ramble accounts for 444 stems. These comprise 50 species of trees and shrubs in 36 genera and 25 families and were tallied from 111 points at seven different sites.

As in the total data set, *Prunus serotina* in the Ramble stands out with a large ecological dominance although its dominance is smaller than in the total data set. For the Ramble, the value is 60.55, (Table 3.1). Figure 2.6 shows IVs graphed for all data sets. It shows that IVs of the Ramble data fall off less steeply than those of the total data set.

The Ramble differs from the total data with regard to *Quercus rubra*, which in the total data set is ranked second. In this data subset, *Q. rubra* has an IV rank of 20 with a value of 3.57. *Acer platanoides* ranks second in IV for the Ramble, with a value of 27.08. The oak that is present with a higher ecological dominance in the Ramble is *Quercus palustris.* It ranks third with an IV value of 26.05. Although this is very similar to the IV for *A. platanoides,* the difference is in the individual values that make up the IV. *Acer platanoides* has values of relative density and relative frequency of 12.16 and 11.5, whereas *Q. palustris* shows those values at 6.31 and 6.79, respectively. But *Q. palustris* has a relative dominance value of 12.96 compared with *A. platanoides'* value of 3.41, indicating a larger basal area rather than more individuals. Oaks were some of the species planted or existing in the early days of the park. Many of the larger trees throughout the park and especially in the woodlands are oak species.

The fourth ranking species is *Celtis occidentalis,* which is a native plant with high wildlife value (Tallamy 2007, Martin et al. 1951). This species regenerates well on its own. It has never been planted by the Conservancy; yet young saplings can be found throughout the Ramble (personal observation). Although it prefers rich, moist soil, it does well in dry, heavy, rocky soil (Dirr 1990). Much of the Ramble has this type of disturbed soil due to compaction from overuse.

The fifth and sixth ranking species are species of concern as far as maintenance and the health of the woodlands. *Phellodendron amurense* (Figure 3.2), rank five, has been shown to be invasive (Glaeser and Kincaid 2005, Morgan and Borysiewicz 2012). Several large individuals occur in the Ramble, presumably planted as specimens early in the Park's history. Although it has not shown invasive tendencies in Central Park and is not managed in the same manner as invasives such as Norway maple, this study shows that it is a species that merits concern. *Styphnolobium japonicum* (Figure 3.3), rank six, is not usually cited as invasive but from my observations in the

Park, and in those of other park managers, it seems to have the potential to become invasive. An unusually high number of seedlings can be found in areas where mature trees exist. Should the right conditions occur, e.g., large canopy openings from storm damage, both these species may present themselves as management problems. *Ailanthus altissima,* another invasive, ranks ninth in IV but is regularly managed by the Conservancy. Future studies will show how successful is the management of these and other invasives.

Figure 3.2 *Phellodendron amurense*, large specimen in the Ramble

Figure 3.3 *Styphnolobium japonicum* in flower

Table 3.2 lists descriptive statistics for the Ramble data set. *Prunus serotina* has the highest abundance with 95 of the 444 stems. This species appears in 59.46 of the sampling units. The largest specimen of this species in the Ramble has a diameter at breast height (DBH) of 69 cm. The largest of all the stems in the Ramble is a *Morus alba*, with a DBH of 111. However, there are only 10 *M. alba* stems tallied in the Ramble, so it has a lower overall IV, with a rank of seven.

Because of the difference in basal area (relative dominance), *Q. palustris* ranks third in IV, but *Celtis occidentalis* ranks third in absolute density, with a value of 151.35 stems per hectare compared with 98.56 stems per hectare for *Q. palustris.* My personal experience with these two

species in the Park over a period of 19 years has been that *C. occidentalis* will regenerate even in disturbed and compacted soil whereas most of the oaks do not.

3.3 Families, Genera and Lower DBH Quartile

Importance Values for families within the Ramble data set are shown in Table 3.3. Of the 25 families in this woodland, Rosaceae again dominates ecologically with a value of 75.12. Nine species represent the Rosaceae in the Ramble with *Prunus serotina* being the most numerous. There are three *Crataegus* species. *Crataegus phaenopyrum,* the Washington hawthorn, is native from Virginia to Alabama and Missouri (Dirr 1990). *Crataegus lavallei* is a hybrid planted mainly because it is fairly free of rust that plagues other *Crataegus* species. The third species is listed as *Crataegus* sp. The thorny branches of *Crataegus* are good nesting sites for birds and their leaves are host to 159 species of eastern caterpillars (Martin et al. 1951, Tallamy 2007). The fruit are consumed mainly by sparrows and cedar waxwings (Martin et al. 1951) and by some mammals as well (Tallamy 2007). *Rosa multiflora*, which is native to Japan and Korea (Dirr 1990), was introduced into the United States in 1866 as a rootstock for rose cultivation and in the 1930s was promoted for use in erosion control (Sarver et al. 20080). Although *R. multiflora* does provide cover for wildlife, it is an aggressive invasive that is regularly removed from Central Park. Other Rosaceae include *Amelanchier canadensis, Malus* sp., *Prunus* sp., and *Rhodotypos scandens.*

Fagaceae is second in ecological dominance with *Quercus palustris* being the most numerous species. *Quercus palustris* is listed in the floral survey of DeCandido et al. (2007) and that study indicates that it was present in the 1857 survey. Eight specimens of *Q. palustris* are described in Peet (1903); however, he does not give sizes of the trees, but merely points out

"some…representative types". This genus has some of the larger specimens of oak in the Ramble with several being over 80cm in diameter. There is one specimen of *Q. alba* that is 90.5 cm in diameter.

In the total data for this study, Aceraceae is third in ecological dominance, but in the Ramble, Ulmaceae takes that place as a result of proliferation of *Celtis occidentalis*. There are 67 stems in Ulmaceae in the Ramble, and 43 of those are *Celtis*. However, Aceraceae is very close in IV (30.71) to Ulmaceae (31.99), even though it ranks one below in dominance.

Rutaceae, which is 10th in the total data set ranks fifth in the Ramble. As noted above, *Phellodendron amurense* is considered an invasive species, and several large specimens (Figure 3.3) in the Ramble are the seed source from which the saplings are arising.

The IVs of the genera (Table 3.4) for the Ramble show results similar to those for families. The top five are *Prunus, Quercus, Acer, Celtis* and *Phellodendron.* At number six is *Styphnolobium.* As stated above, this species is not usually characterized as invasive. However, based on my own observations and its movement from rank 10 in the total data set for genera (Table 2.5) to rank six in the Ramble data set for genera (Table 3.4), I believe it is a species of concern.

An analysis of the lower quartile DBH values of the Ramble (Table 3.5) show that, as in the total data, *Acer platanoides* is most dominant, even after many years of removal by Park managers. Future studies will be needed to see if this management will eventually bring down this number or if it is a futile effort. Surprisingly, *Prunus serotina* falls to 6th in this category, surpassed by *Celtis occidentalis, Quercus palustris, Sassafras albidum and Gymnocladus dioicus. Sassafras albidum* does well in acid rocky soil, in full sun or light shade and forms dense thickets, although as a pioneer species, it is somewhat intolerant and does not do as well as other species, e.g.,

Prunus serotina (Dirr 1990). *Sassfrass* is host to the Spicebush swallowtail caterpillar (Tallamy 2007) and the fruit are eaten by many songbirds, including several members of the flycatcher family (Martin et al. 1951). The spectacular fall colors of *Sassafrass* make dense stands a welcome addition to the Park. *Gymnocladus dioicus* is another species that is tolerant of drought and other city conditions, perhaps the reason it does well in the Ramble.

3.4 Conclusions

Prunus serotina and the Rosaceae dominate the ecology of the Ramble. Although *Acer platanoides* is second in dominance, Aceraceae comes in third as a result of the large *Quercus* species found in the Ramble. *Celtis occidentalis* plays a larger role in the Ramble than in the total data. The number of *Celtis* stems brings Ulmaceae up to third in dominance. The data for this woodland and experience in the field indicate that *Phellodendron amurense* and *Styphnolobium japonicum* are species of concern for future management.

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Table 3.1 Ecological dominance assessed by Importance Value analysis for Ramble data set. Cumulative values in parentheses.

	Species	Relative density	Relative frequency	Relative dominance	Importance value
1.	*Prunus serotina* Ehrh.	21.40 (21.40)	19.47 (19.47)	19.68 (19.68)	60.55 (60.55)
2.	*Acer platanoides* L.	12.16 (33.56)	11.50 (30.97)	3.41 (23.10)	27.08 (87.63)
3.	*Quercus palustris* Muenchh.	6.31 (39.86)	6.79 (37.76)	12.96 (36.05)	26.05 (113.68)
4.	*Celtis occidentalis* L.	9.68 (49.55)	7.38 (45.13)	1.73 (37.78)	18.79 (132.46)
5.	*Phellodendron amurense* Rupr.	4.05 (53.60)	4.72 (49.85)	10.00 (47.78)	18.77 (151.24)
6.	*Styphnolobium japonicum* (L.) Schott	4.28 (57.88)	4.13 (53.98)	7.92 (55.70)	16.33 (167.56)
7.	*Morus alba* L.	2.25 (60.14)	2.95 (56.93)	8.46 (64.16)	13.66 (181.22)
8.	*Liriodendron tulipifera* L.	0.90 (61.04)	1.18 (58.11)	9.88 (74.04)	11.96 (193.19)
9.	*Ailanthus altissima* (Miller) Swingle.	2.48 (63.51)	2.66 (60.77)	3.01 (77.04)	8.14 (201.32)
10.	*Gymnocladus dioicus* (L.) K. Koch.	2.25 (65.77)	1.77 (62.54)	2.91 (79.95)	6.93 (208.25)
11.	*Viburnum dentatum* var. *lucidum* Ait.	2.70 (68.47)	2.95 (65.49)	0.72 (80.67)	6.37 (214.63)
12.	*Sassafras albidum* (Nutt.) Nees.	2.70 (71.17)	2.95 (68.44)	0.19 (80.86)	5.85 (220.47)
13.	*Ulmus* sp. L.	2.25 (73.42)	2.07 (70.50)	0.74 (81.60)	5.05 (225.52)
14.	*Malus sylvestris* (L.) Mill.	2.03 (75.45)	2.66 (73.16)	0.05 (81.65)	4.73 (230.26)
15.	*Quercus phellos* L.	1.35 (76.80)	1.48 (74.63)	1.76 (83.41)	4.58 (234.84)
16.	*Amelanchier canadensis* (L.) Medikus.	2.48 (79.28)	1.77 (76.40)	0.21 (83.62)	4.46 (239.30)
17.	*Ulmus americana* L.	1.58 (80.86)	1.77 (78.17)	1.08 (84.70)	4.43 (243.72)
18.	*Euonymus europaeus* L.	1.35 (82.21)	1.77 (79.94)	0.90 (85.60)	4.02 (247.74)
19.	*Quercus alba* L.	0.23 (82.43)	0.30 (80.24)	3.13 (88.73)	3.65 (251.40)
20.	*Quercus rubra* L.	1.13 (83.56)	1.48 (81.71)	0.97 (89.70)	3.57 (254.96)
21.	*Lindera benzoin* (L.) Blume.	1.35 (84.91)	1.77 (83.48)	0.04 (89.74)	3.16 (258.13)
22.	*Platanus* x *hybrida* Brot.	0.23 (85.14)	0.30 (83.78)	2.45 (92.18)	2.97 (261.09)
23.	*Ulmus procera* Salisb.	1.58 (86.71)	0.89 (84.66)	0.50 (92.68)	2.96 (264.05)
24.	*Prunus* sp. L.	1.13 (87.84)	1.48 (86.14)	0.04 (92.72)	2.64 (266.69)
25.	*Acer saccharum* Marshall.	1.13 (88.96)	1.18 (87.32)	0.00 (92.73)	2.31 (269.00)
26.	*Gleditsia triacanthos* var. *inermis* Willd.	0.45 (89.41)	0.59 (87.91)	1.26 (93.99)	2.30 (271.31)

27.	*Gleditsia triacanthos* L.	0.45 (89.86)	0.59 (88.50)	1.21 (95.20)	2.25 (273.56)
28.	*Rosa multiflora* Thunb.	0.90 (90.77)	1.18 (89.68)	0.03 (95.23)	2.11 (275.67)
29.	*Carya cordiformis* (Wangenh) K. Koch.	0.68 (91.44)	0.89 (90.56)	0.42 (95.65)	1.98 (277.65)
30.	*Koelreuteria paniculata* Laxm.	0.68 (92.12)	0.89 (91.45)	0.38 (96.03)	1.94 (279.59)
31.	*Aesculus hippocastanum* L.	0.23 (92.34)	0.30 (91.74)	1.38 (97.41)	1.90 (281.49)
32.	*Philadelphus coronarius* L.	0.68 (93.02)	0.89 (92.63)	0.21 (97.61)	1.77 (283.26)
33.	*Tilia cordata* Miller.	0.23 (93.24)	0.30 (92.92)	0.79 (98.40)	1.31 (284.57)
34.	*Viburnum plicatum* Thunb.	0.68 (93.92)	0.59 (93.51)	0.02 (98.42)	1.28 (285.85)
35.	*Viburnum prunifolium* L.	0.90 (94.82)	0.30 (93.81)	0.01 (98.43)	1.21 (287.06)
36.	*Fraxinus americana* L.	0.45 (95.27)	0.59 (94.40)	0.17 (98.60)	1.21 (288.27)
37.	*Crataegus* sp. L.	0.45 (95.72)	0.59 (94.99)	0.16 (98.76)	1.20 (289.47)
38.	*Rhodotypos scandens* Makino.	0.45 (96.17)	0.59 (95.58)	0.09 (98.85)	1.13 (290.60)
39.	*Acer rubrum* L.	0.45 (96.62)	0.59 (96.17)	0.05 (98.90)	1.09 (291.68)
40.	*Hamamelis virginiana* L.	0.45 (97.07)	0.59 (96.76)	0.01 (98.91)	1.05 (292.73)
41.	*Rhododendron* sp. L.	0.45 (97.52)	0.59 (97.35)	0.00 (98.91)	1.05 (293.78)
42.	*Carpinus caroliniana* Walter.	0.45 (97.97)	0.30 (97.64)	0.27 (99.18)	1.02 (294.80)
43.	*Ilex opaca* Aiton.	0.23 (98.20)	0.30 (97.94)	0.29 (99.47)	0.81 (295.61)
44.	*Crataegus phaenopyrum* (L.f.) Medikus.	0.23 (98.42)	0.30 (98.23)	0.26 (99.73)	0.78 (296.38)
45.	*Crataegus x lavallei (grignonensis)* herincq.	0.45 (98.87)	0.30 (98.53)	0.00 (99.74)	0.75 (297.14)
46.	*Viburnum setigerum* Hance.	0.23 (99.10)	0.30 (98.82)	0.17 (99.90)	0.69 (297.82)
47.	*Cornus kousa* Hance	0.23 (99.32)	0.30 (99.12)	0.07 (99.98)	0.60 (298.42)
48.	*Castanea dentata* (Marshall) Borkh. (hybrid)	0.23 (99.55)	0.30 (99.41)	0.01 (99.99)	0.53 (298.95)
49.	*Sambucus nigra* L. ssp *canadensis* (L.) R, Bolli	0.23 (99.77)	0.30 (99.71)	0.01 (100.00)	0.53 (299.48)
50.	*Vaccinium corymbosum* L.	0.23 (100.00)	0.30 (100.00)	0.00 (100.00)	0.52 (300.00)

Table 3.2 Descriptive statistics for the Ramble data. Species listed in order of Importance Value. Diameter in centimeters. Absolute density from point centered quarter data in meters, with bootstrap 95% confidence intervals (NS=10,000 bootstrap samples), upper and lower bound in parentheses.

	Species	Abundance	% sampling units	Mean DBH	Standard deviation	Min, max	Absolute density (Upper bound, lower bound)
1.	*Prunus serotina* Ehrh.	95	59.46	16.81	16.19	1.0, 69.0	334.39 (298.36, 375.79)
2.	*Acer platanoides* L.	54	35.14	5.66	11.65	1.0, 56.0	190.07 (169.60, 213.61)
3.	*Quercus palustris* Muenchh.	28	20.72	18.57	29.97	1.0, 96.0	98.56 (87.94, 110.76)
4.	*Celtis occidentalis* L.	43	22.52	5.81	8.54	1.0, 42.0	151.35 (135.05, 170.10)
5.	*Phellodendron amurense* Rupr.	18	14.41	24.69	29.89	1.0, 109.5	63.36 (56.53, 71.20)
6.	*Styphnolobium japonicum* (L.) Schott	19	12.61	17.47	28.78	1.0, 100.0	66.88 (59.67, 75.16)
7.	*Morus alba* L.	10	9.01	24.25	42.49	1.0, 111.0	35.20 (31.41, 39.56)
8.	*Liriodendron tulipifera* L.	4	3.60	70.00	45.66	5.0, 108.0	14.08 (12.56, 15.82)
9.	*Ailanthus altissima* (Miller) Swingle.	11	8.11	21.17	17.13	2.5, 67.5	38.72 (34.55, 43.51)
10.	*Gymnocladus dioicus* (L.) K. Koch.	10	5.41	15.95	23.71	1.0, 61.0	35.20 (31.41, 39.56)
11.	*Viburnum dentatum* var. *lucidum* Ait.	12	9.01	9.41	8.64	1.5, 24.5	42.24 (37.69, 47.47)
12.	*Sassafras albidum* (Nutt.) Nees.	12	9.01	4.33	5.08	1.0, 16.0	42.24 (37.69, 47.47)
13.	*Ulmus* sp. L.	10	6.31	7.90	12.01	1.0, 41.0	35.20 (31.41, 39.56)
14.	*Malus sylvestris* (L.) Mill.	9	8.11	3.50	1.73	1.0, 6.0	31.68 (28.27, 35.60)
15.	*Quercus phellos* L.	6	4.50	18.62	22.44	2.0, 52.7	21.12 (18.84, 23.73)
16.	*Amelanchier canadensis* (L.) Medikus.	11	5.41	6.36	3.16	2.0, 11.5	38.72 (34.55, 43.51)
17.	*Ulmus americana* L.	7	5.41	10.50	18.50	1.0, 52.0	24.64 (21.98, 27.69)
18.	*Euonymus europaeus* L.	6	5.41	13.75	15.65	1.5, 40.0	21.12 (18.84, 23.73)
19.	*Quercus alba* L.	1	0.90	90.50	-	90.5, 90.5	3.52 (3.14, 3.96)
20.	*Quercus rubra* L.	5	4.50	12.00	21.29	1.5, 50.0	17.60 (15.70, 19.78)
21.	*Lindera benzoin* (L.) Blume.	6	5.41	3.83	2.04	1.5, 7.5	21.12 (18.84, 23.73)
22.	*Platanus* x *hybrida* Brot.	1	0.90	80.00	-	80.0, 80.0	3.52 (3.14, 3.96)
23.	*Ulmus procera* Salisb.	7	2.70	8.64	11.40	1.0, 34.0	24.64 (21.98, 27.69)
24.	*Prunus* sp. L.	5	4.50	3.70	3.03	1.5, 9.0	17.60 (15.70, 19.78)
25.	*Acer saccharum* Marshall.	5	3.60	1.40	0.55	1.0, 2.0	17.60 (15.70, 19.78)
26.	*Gleditsia triacanthos* var. *inermis* Willd.	2	1.80	40.50	4.24	37.5, 43.5	7.04 (6.28, 7.91)
27.	*Gleditsia triacanthos* L.	2	1.80	38.00	16.97	26.0, 50.0	7.04 (6.28, 7.91)
28.	*Rosa multiflora* Thunb.	4	3.60	4.00	2.71	2.0, 8.0	14.08 (12.56, 15.82)
29.	*Carya cordiformis* (Wangenh) K. Koch.	3	2.70	11.83	18.33	1.0, 33.0	10.56 (9.42, 11.87)
30.	*Koelreuteria paniculata* Laxm.	3	2.70	11.50	17.33	1.0, 31.5	10.56 (9.42, 11.87)

31.	*Aesculus hippocastanum* L.	1	0.90	60.00	-	60.0, 60.0	3.52 (3.14, 3.96)
32.	*Philadelphus coronarius* L.	3	2.70	9.17	11.98	2.0, 23.0	10.56 (9.42, 11.87)
33.	*Tilia cordata* Miller.	1	0.90	45.50	-	45.5, 45.5	3.52 (3.14, 3.96)
34.	*Viburnum plicatum* Thunb.	3	1.80	3.17	2.47	1.5, 6.0	10.56 (9.42, 11.87)
35.	*Viburnum prunifolium* L.	4	0.90	2.88	1.18	2.0, 4.5	14.08 (12.56, 15.82)
36.	*Fraxinus americana* L.	2	1.80	12.00	12.02	3.5, 20.5	7.04 (6.28, 7.91)
37.	*Crataegus* sp. L.	2	1.80	10.75	13.79	1.0, 20.5	7.04 (6.28, 7.91)
38.	*Rhodotypos scandens* Makino.	2	1.80	8.60	9.33	2.0, 15.2	7.04 (6.28, 7.91)
39.	*Acer rubrum* L.	2	1.80	6.00	7.07	1.0, 11.0	7.04 (6.28, 7.91)
40.	*Hamamelis virginiana* L.	2	1.80	3.00	2.12	1.5, 4.5	7.04 (6.28, 7.91)
41.	*Rhododendron* sp. L.	2	1.80	2.50	0.71	2.0, 3.0	7.04 (6.28, 7.91)
42.	*Carpinus caroliniana* Walter.	2	0.90	16.75	12.37	8.0, 25.5	7.04 (6.28, 7.91)
43.	*Ilex opaca* Aiton.	1	0.90	27.50	-	27.5, 27.5	3.52 (3.14, 3.96)
44.	*Crataegus phaenopyrum* (L.f.) Medikus.	1	0.90	26.00	-	26.0, 26.0	3.52 (3.14, 3.96)
45.	*Crataegus x lavallei (grignonensis)* Herincq.	2	0.90	2.50	0.71	2.0, 3.0	7.04 (6.28, 7.91)
46.	*Viburnum setigerum* Hance.	1	0.90	21.00	-	21.0, 21.0	3.52 (3.14, 3.96)
47.	*Cornus kousa* Hance	1	0.90	14.00	-	14.0, 14.0	3.52 (3.14, 3.96)
48.	*Castanea dentata* (Marshall) Borkh. (hybrid)	1	0.90	6.00	-	6.0, 6.0	3.52 (3.14, 3.96)
49.	*Sambucus nigra* L. ssp. *canadensis* (L.) R. Bolli	1	0.90	4.00	-	4.0, 4.0	3.52 (3.14, 3.96)
50.	*Vaccinium corymbosum* L.	1	0.90	1.00	-	1.0, 1.0	3.52 (3.14, 3.96)

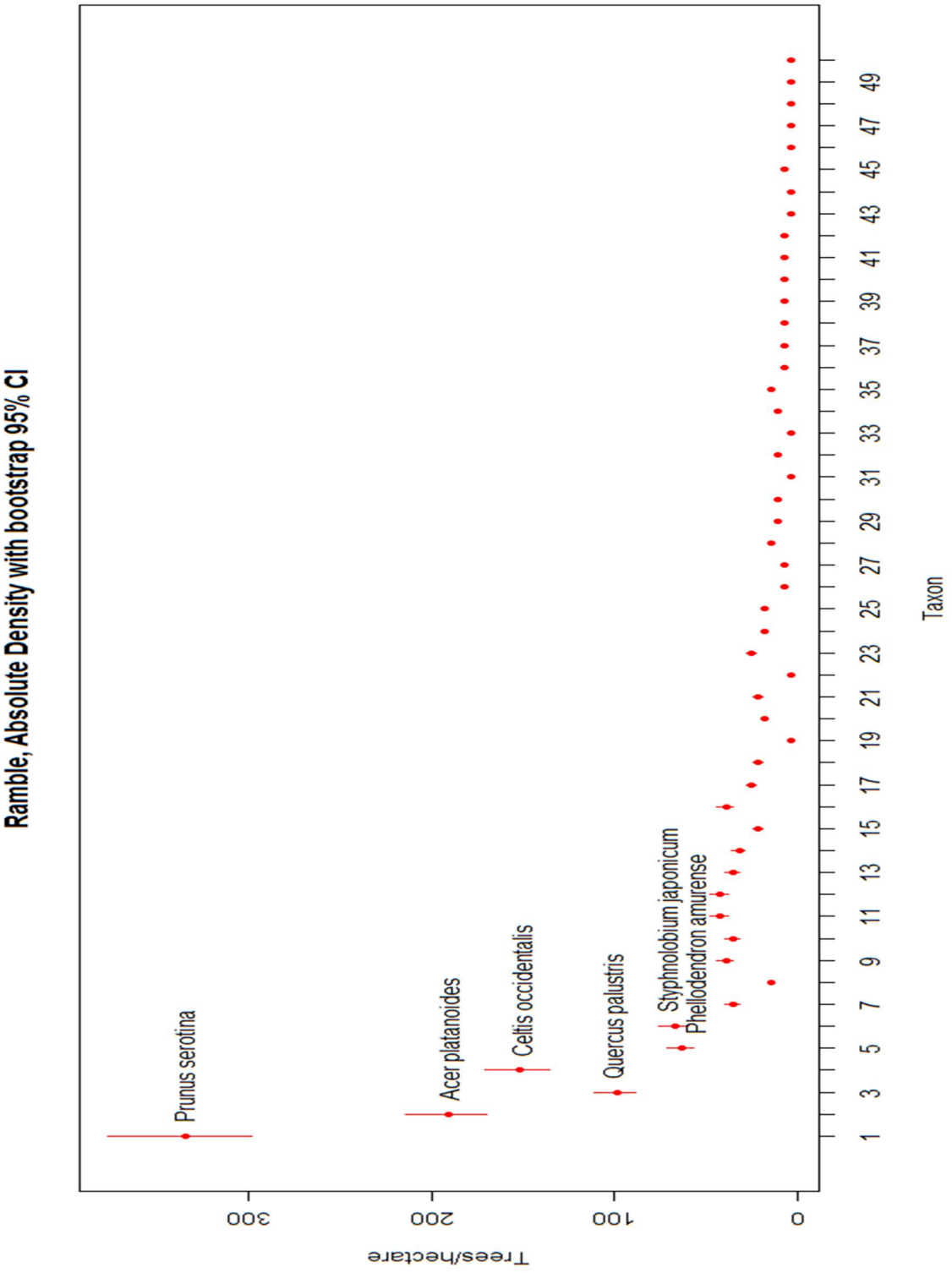

Figure 3.4 Absolute density of Ramble data.

Table 3.3 Ecological dominance assessed by Importance Value analysis for families in the Ramble. Cumulative values in parentheses.

	Family	Relative density	Relative frequency	Relative dominance	Importance value
1.	Rosaceae	29.50 (29.50)	25.08 (25.08)	20.53 (20.53)	75.12 (75.12)
2.	Fagaceae	9.23 (38.74)	9.65 (34.73)	18.83 (39.36)	37.71 (112.82)
3.	Ulmaceae	15.09 (53.83)	12.86 (47.59)	4.04 (43.40)	31.99 (144.81)
4.	Aceraceae	13.74 (67.57)	13.50 (61.09)	3.46 (46.86)	30.71 (175.52)
5.	Rutaceae	4.05 (71.62)	5.14 (66.24)	10.00 (56.86)	19.20 (194.72)
6.	Fabaceae	4.28 (75.90)	4.50 (70.74)	7.92 (64.78)	16.70 (211.42)
7.	Moraceae	2.25 (78.15)	3.22 (73.95)	8.46 (73.24)	13.93 (225.34)
8.	Magnoliaceae	0.90 (79.05)	1.29 (75.24)	9.88 (83.12)	12.07 (237.41)
9.	Caesalpiniaceae	3.15 (82.21)	2.89 (78.14)	5.38 (88.50)	11.43 (248.84)
10.	Caprifoliaceae	4.73 (86.94)	4.82 (82.96)	0.92 (89.42)	10.48 (259.32)
11.	Lauraceae	4.05 (90.99)	5.14 (88.10)	0.24 (89.66)	9.43 (268.75)
12.	Simaroubaceae	2.48 (93.47)	2.89 (91.00)	3.01 (92.66)	8.38 (277.13)
13.	Celastraceae	1.35 (94.82)	1.93 (92.93)	0.90 (93.57)	4.18 (281.31)
14.	Platanaceae	0.23 (95.05)	0.32 (93.25)	2.45 (96.01)	2.99 (284.30)
15.	Juglandaceae	0.68 (95.72)	0.96 (94.21)	0.42 (96.43)	2.06 (286.36)
16.	Sapindaceae	0.68 (96.40)	0.96 (95.18)	0.38 (96.81)	2.02 (288.38)
17.	Hippocastinaceae	0.23 (96.62)	0.32 (95.50)	1.38 (98.19)	1.92 (290.31)
18.	Hydrangeaceae	0.68 (97.30)	0.96 (96.46)	0.21 (98.39)	1.85 (292.15)
19.	Ericaceae	0.68 (97.97)	0.96 (97.43)	0.01 (98.40)	1.65 (293.80)
20.	Tiliaceae	0.23 (98.20)	0.32 (97.75)	0.79 (99.19)	1.34 (295.14)
21.	Oleaceae	0.45 (98.65)	0.64 (98.39)	0.17 (99.35)	1.26 (296.40)
22.	Hamamelidaceae	0.45 (99.10)	0.64 (99.04)	0.01 (99.36)	1.10 (297.50)
23.	Betulaceae	0.45 (99.55)	0.32 (99.36)	0.27 (99.64)	1.05 (298.54)
24.	Aquifoliaceae	0.23 (99.77)	0.32 (99.68)	0.29 (99.93)	0.84 (299.38)
25.	Cornaceae	0.23 (100.00)	0.32 (100.00)	0.07 (100.00)	0.62 (300.00)

Table 3.4 Ecological dominance assessed by Importance Value analysis for genera of the Ramble. Cumulative values in parentheses.

	Genera	Relative density	Relative frequency	Relative dominance	Importance value
1.	*Prunus*	22.52 (22.52)	20.73 (20.73)	19.72 (19.72)	62.98 (62.98)
2.	*Quercus*	9.01 (31.53)	8.84 (29.57)	18.81 (38.54)	36.66 (99.64)
3.	*Acer*	13.74 (45.27)	12.80 (42.38)	3.46 (42.00)	30.01 (129.65)
4.	*Celtis*	9.68 (54.95)	7.62 (50.00)	1.73 (43.73)	19.03 (148.68)
5.	*Phellodendron*	4.05 (59.01)	4.88 (54.88)	10.00 (53.73)	18.93 (167.61)
6.	*Styphnolobium*	4.28 (63.29)	4.27 (59.15)	7.92 (61.64)	16.46 (184.08)
7.	*Morus*	2.25 (65.54)	3.05 (62.20)	8.46 (70.10)	13.76 (197.84)
8.	*Ulmus*	5.41 (70.95)	4.88 (67.07)	2.31 (72.42)	12.60 (210.43)
9.	*Liriodendron*	0.90 (71.85)	1.22 (68.29)	9.88 (82.30)	12.00 (222.44)
10.	*Viburnum*	4.50 (76.35)	4.27 (72.56)	0.92 (83.22)	9.69 (232.13)
11.	*Ailanthus*	2.48 (78.83)	2.74 (75.30)	3.01 (86.22)	8.23 (240.35)
12.	*Gymnocladus*	2.25 (81.08)	1.83 (77.13)	2.91 (89.13)	6.99 (247.34)
13.	*Sassafras*	2.70 (83.78)	3.05 (80.18)	0.19 (89.32)	5.95 (253.29)
14.	*Malus*	2.03 (85.81)	2.74 (82.93)	0.05 (89.37)	4.82 (258.11)
15.	*Gleditsia*	0.90 (86.71)	1.22 (84.15)	2.47 (91.85)	4.59 (262.71)
16.	*Amelanchier*	2.48 (89.19)	1.83 (85.98)	0.21 (92.06)	4.52 (267.22)
17.	*Euonymus*	1.35 (90.54)	1.83 (87.80)	0.90 (92.96)	4.08 (271.30)
18.	*Lindera*	1.35 (91.89)	1.83 (89.63)	0.04 (93.00)	3.22 (274.53)
19.	*Platanus*	0.23 (92.12)	0.30 (89.94)	2.45 (95.45)	2.98 (277.50)
20.	*Crataegus*	1.13 (93.24)	1.22 (91.16)	0.42 (95.87)	2.77 (280.27)
21.	*Rosa*	0.90 (94.14)	1.22 (92.38)	0.03 (95.90)	2.15 (282.42)
22.	*Carya*	0.68 (94.82)	0.91 (93.29)	0.42 (96.32)	2.01 (284.43)
23.	*Koelreuteria*	0.68 (95.50)	0.91 (94.21)	0.38 (96.70)	1.97 (286.40)
24.	*Aesculus*	0.23 (95.72)	0.30 (94.51)	1.38 (98.08)	1.91 (288.31)
25.	*Philadelphus*	0.68 (96.40)	0.91 (95.43)	0.21 (98.28)	1.80 (290.11)
26.	*Tilia*	0.23 (96.62)	0.30 (95.73)	0.79 (99.07)	1.32 (291.43)
27.	*Fraxinus*	0.45 (97.07)	0.61 (96.34)	0.17 (99.24)	1.23 (292.65)
28.	*Rhodotypos*	0.45 (97.52)	0.61 (96.95)	0.09 (99.33)	1.15 (293.80)
29.	*Hamamelis*	0.45 (97.97)	0.61 (97.56)	0.01 (99.34)	1.07 (294.87)
30.	*Rhododendron*	0.45 (98.42)	0.61 (98.17)	0.00 (99.34)	1.07 (295.94)
31.	*Carpinus*	0.45 (98.87)	0.30 (98.48)	0.27 (99.62)	1.03 (296.97)
32.	*Ilex*	0.23 (99.10)	0.30 (98.78)	0.29 (99.90)	0.82 (297.78)

33.	*Cornus*	0.23 (99.32)	0.30 (99.09)	0.07 (99.98)	0.61 (298.39)
34.	*Castanea*	0.23 (99.55)	0.30 (99.39)	0.01 (99.99)	0.54 (298.93)
35.	*Sambucus*	0.23 (99.77)	0.30 (99.70)	0.01 (100.00)	0.54 (299.47)
36.	*Vaccinium*	0.23 (100.00)	0.30 (100.00)	0.00 (100.00)	0.53 (300.00)

Table 3.5 Ecological dominance assessed by Importance Value analysis for lower quartile DBH Ramble. Cumulative values in parentheses.

	Species	Relative density	Relative frequency	Relative dominance	Importance value
1.	*Acer platanoides* L.	22.52 (22.52)	18.28 (18.28)	18.97 (18.97)	59.78 (59.77)
2.	*Celtis occidentalis* L.	14.41 (36.94)	11.83 (30.11)	16.09 (35.07)	42.34 (102.11)
3.	*Quercus palustris* Muenchh.	9.01 (45.95)	9.68 (39.78)	8.05 (43.11)	26.73 (128.84)
4.	*Sassafras albidum* (Nutt.) Nees.	5.41 (51.35)	5.38 (45.16)	3.80 (46.91)	14.58 (143.43)
5.	*Gymnocladus dioica* (L.) K. Koch.	4.50 (55.86)	4.30 (49.46)	4.92 (51.83)	13.72 (157.15)
6.	*Prunus serotina* Ehrh.	4.50 (60.36)	5.38 (54.84)	3.58 (55.41)	13.46 (170.61)
7.	*Acer saccharum* Marshall.	3.60 (63.96)	4.30 (59.14)	3.13 (58.54)	11.03 (181.64)
8.	*Phellodendron amurense* Rupr.	2.70 (66.67)	3.23 (62.37)	4.02 (62.56)	9.95 (191.59)
9.	*Quercus rubra* L.	2.70 (69.37)	3.23 (65.59)	3.80 (66.36)	9.73 (201.32)
10.	*Ulmus americana* L.	2.70 (72.07)	3.23 (68.82)	1.90 (68.26)	7.83 (209.15)
11.	*Amelanchier canadensis* (L.) Medikus	1.80 (73.87)	2.15 (70.97)	3.58 (71.84)	7.53 (216.68)
12.	*Prunus sp.* L.	1.80 (75.68)	2.15 (73.12)	2.79 (74.63)	6.75 (223.42)
13.	*Ulmus sp.* L.	2.70 (78.38)	2.15 (75.27)	1.34 (75.97)	6.19 (229.62)
14.	*Morus alba* L.	1.80 (80.18)	2.15 (77.42)	2.24 (78.21)	6.19 (235.81)
15.	*Koelreuteria paniculata* Laxm.	1.80 (81.98)	2.15 (79.57)	2.24 (80.44)	6.19 (241.99)
16.	*Viburnum plicatum* Thunb.	1.80 (83.78)	1.08 (80.65)	2.79 (83.24)	5.67 (247.66)
17.	*Malus sylvestris* (L.) Mill.	1.80 (85.59)	2.15 (82.80)	1.45 (84.69)	5.41 (253.07)
18.	*Carya cordiformis* (Wangenh) K. Koch	1.80 (87.39)	2.15 (84.95)	1.45 (86.14)	5.41 (258.48)
19.	*Styphnolobium japonicum* (L.) Schott	1.80 (89.19)	2.15 (87.10)	0.89 (87.04)	4.85 (263.32)
20.	*Rhododendron sp.* L.	0.90 (90.09)	1.08 (88.17)	1.79 (88.82)	3.76 (267.09)
21.	*Rosa multiflora* Thunb.	0.90 (90.99)	1.08 (89.25)	1.79 (90.61)	3.76 (270.85)
22.	*Rhodotypos scandens* Makino.	0.90 (91.89)	1.08 (90.32)	1.79 (92.40)	3.76 (274.61)
23.	*Philadelphus coronarius* L.	0.90 (92.79)	1.08 (91.40)	1.79 (94.19)	3.76 (278.38)
24.	*Hamamelis virginiana* L.	0.90 (93.69)	1.08 (92.47)	1.01 (95.19)	2.98 (281.36)
25.	*Viburnum dentatum* var. *lucidum* Ait.	0.90 (94.59)	1.08 (93.55)	1.01 (96.20)	2.98 (284.34)
26.	*Euonymus europaeus* L.	0.90 (95.50)	1.08 (94.62)	1.01 (97.21)	2.98 (287.33)
27.	*Lindera benzion* (L.) Blume.	0.90 (96.40)	1.08 (95.70)	1.01 (98.21)	2.98 (290.31)
28.	*Crataegus sp.* L.	0.90 (97.30)	1.08 (96.77)	0.45 (98.66)	2.42 (292.73)
29.	*Acer rubrum* L.	0.90 (98.20)	1.08 (97.85)	0.45 (99.11)	2.42 (295.15)
30.	*Vaccinium corymbosum* L.	0.90 (99.10)	1.08 (98.92)	0.45 (99.55)	2.42 (297.58)
31.	*Ulmus procera* Salisb.	0.90 (100.00)	1.08 (100.00)	0.45 (100.00)	2.42 (300.00)

Chapter 4

The North Woods

4.1 Introduction

The North Woods is a 36.4 hectare woodland located in the northern end of the Park spanning from 110th Street down to 103rd Street bordered on all sides by the Park drives. This section was added on later in the construction of the Park. The original park went up only to 106th Street. The section from 106th Street to 110th Street was added in 1863 to encompass the high point of the northwest rocky ridge (Rosenzweig and Blackmar 1992). The Loch, the water body that runs through the southern part of the woodland, was created out of a natural stream in the area called Montayne's Rivulet, which ran through Harlem to the Rivulet's mouth at Hell Gate Bay (Rogers1971, Miller 2003). The Rivulet emerged from a high ridge along the western border of the Park at about 101st Street and Central Park West, and crossed a deep valley (Kinkead 1990). First it flowed into what is now The Pool, then into the Loch along the Ravine in the south part of the North Woods and finally into the Meer before leaving the Park.

At the time of its construction, the Park in this area was rugged, and modifying it to any extent would have been prohibitively expensive. Any plan had to be naturalistic. However, the Loch was carved from Montayne's Rivulet and waterfalls were created at both ends of this water body on the east and west sides of the North Woods, whose northern part is high on a ridge.

In the North woods I tallied 660 stems, from 165 sampling points in 7 sampling sites. This included 57 species, in 36 genera and 24 families.

4.2 Importance Value, descriptive statistics, lower quartile DBH

In the North Woods a species is found that begins to rival the *Prunus serotina* for dominance which ranks first in IV dominance with a value of 64.09. However, there is much less separation between it and the number two rank, *Quercus rubra,* which has an IV of 50.87 (Compare with the total data *P. serotina*, 67.45 and *Q. rubra,* 29.99). Further, *Q. rubra* has a higher relative dominance than *P. serotina,* those values being 36.53 and 21.47 respectively. Figure 2.6 shows this comparison in chart format. Ecological IVs for all species in the North Woods are listed in Table 4.1. However, in the table of descriptive statistics (Table 4.2), *P. serotina* far exceeds *Q. rubra* in absolute density (256.17 vs. 71.34 stems per hectare, respectively). Figure 4.1, which shows absolute density, also illustrates this point clearly. This difference can be attributed to the regeneration of these species. At the lower quartile DBHs (Table 4.3), *Q. rubra* moves down to 28th in dominance. *Prunus serotina* is surpassed only by *Acer platanoides* which, as noted, is an aggressive invasive and difficult to eradicate.

As might be expected from looking at the total data set, *Acer platanoides* in the North Woods ranks third. However, what differs from the total data set is that *A. pseudoplatanus* ranks fourth compared with ninth on the total data set. This species seems to prefer moist soil, and is more susceptible than *A. platanoides* to drastic changes in climate (Barnes and Wagner 1983). During the years of severe drought, the species of large trees that sustained the greatest losses in Central Park were *Fraxinus americana* and *A. pseudoplatanus.* In the North Woods, these species can be found in areas near and around the Loch, in the lower areas of the North Woods. *Fraxinus. americana* is high on the list, at rank six, despite the high losses to drought over the years.

Aralia elata ranks 22 in IV for the North Woods. However, as discussed in chapter 2, this is a species of concern. It shows up at rank seven in the analysis of lower quartile stems and the North Woods was the only woodland in which I found this species.

The largest trees were found in the North Woods, the largest being a *Q. rubra* with a DBH of 218 cm. Other large trees include *P. serotina* 189 cm, *Ulmus americana* 104 cm, *Platanus occidentalis* 108.5 cm (Figure 4.2).

Figure 4.2 *Platanus occidentalis,* 108.5cm DBH specimen tallied in the North Woods

4.3 Families and Genera

Tables 4.4 and 4.5 show ecological dominance for families and genera of the North Woods. Rosaceae and *Prunus* dominate this woodland, as they do the others. Fagaceae and *Quercus* follow as a very close second. Aceraceae and *Acer* are third, unlike the Ramble data set, where they are fourth. This is because of the large number of *Celtis* seedlings in the Ramble, which brought Ulmaceae up to third. In this data set, Lauraceae is more dominant than Caprifoliaceae. There are more and larger specimens of *Lindera benzoin* here than in the Ramble. Hamamelidaceae is also higher in dominance than in the total data set. This is due to the much

higher dominance of *Liquidambar styraciflua* in the North Woods data set. Here it has an Importance Value of 14, whereas in the total data set it is 40. This is a species Park managers generally do not plant, but there are several very large specimens in the North Woods (the largest diameter I captured was 71 cm, but others may be larger). This species regenerates very well in the North Woods (personal obersvation). The genus *Carya* is more dominant in the North Woods than in the total data set. The Ramble data set captured only three specimens and the Hallett data set none at all. *Carya* is a genus that was present when the Park was created and was also used in subsequent plantings. The largest specimens in Central Park occur in the North Woods.

4.4 Conclusions

The North Woods is the largest of the three woodlands. It was the only one of the three woodland sites that did not undergo drastic landscape changes in its original design. Some of the largest tree specimens are in this woodland. *Quercus rubra* is a more dominant species here than in the Ramble, having a higher relative dominance than *Prunus serotina*. However, despite this dominance, the fact that oaks do not regenerate as well as other species in Central Park's disturbed environment leads *P. serotina* and *Acer platanoides* to have much higher absolute densities than *Q. rubra. Aralia elata* is a species of concern in this woodland and could be an invasive problem, should canopy openings bring light to the forest floor.

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Table 4.1 Ecological dominance assessed by Importance Value analysis for North Woods data set. Cumulative values in parentheses.

	Species	Relative density	Relative frequency	Relative dominance	Importance value
1.	*Prunus serotina* Ehrh.	23.94 (23.94)	18.67 (18.67)	21.47 (21.47)	64.09 (64.09)
2.	*Quercus rubra* L.	6.67 (30.61)	7.68 (26.35)	36.53 (58.00)	50.87 (114.96)
3.	*Acer platanoides* L.	9.24 (39.85)	9.75 (36.10)	8.84 (66.84)	27.83 (142.79)
4.	*Acer pseudoplatanus* L.	5.76 (45.61)	6.64 (42.74)	4.08 (70.93)	16.48 (159.27)
5.	*Ulmus americana* L.	5.45 (51.06)	5.19 (47.93)	2.90 (73.82)	13.54 (172.81)
6.	*Fraxinus americana* L.	2.88 (53.94)	3.73 (51.66)	4.71 (78.53)	11.32 (184.13)
7.	*Quercus palustris* Muenchh.	1.67 (55.61)	2.28 (53.94)	5.30 (83.83)	9.25 (193.38)
8.	*Viburnum dentatum* var. *lucidum* Ait.	4.24 (59.85)	4.15 (58.09)	0.70 (84.53)	9.09 (202.47)
9.	*Lindera benzoin* (L.) Blume.	3.79 (63.64)	3.94 (62.03)	0.28 (84.81)	8.00 (210.48)
10.	*Ulmus procera* Salisb.	3.33 (66.97)	3.11 (65.15)	0.11 (84.92)	6.55 (217.03)
11.	*Sassafras albidum* (Nutt.) Nees.	3.79 (70.76)	2.07 (67.22)	0.53 (85.45)	6.39 (223.42)
12.	*Morus alba* L.	2.27 (73.03)	2.28 (69.50)	1.24 (86.69)	5.79 (229.22)
13.	*Carya cordiformis* (Wangenh) K. Koch.	1.52 (74.55)	2.07 (71.58)	1.69 (88.38)	5.28 (234.50)
14.	*Liquidambar styraciflua* L.	1.36 (75.91)	1.66 (73.24)	2.18 (90.55)	5.20 (239.70)
15.	*Photinia villosa* (Thunb.) DC.	2.42 (78.33)	1.87 (75.10)	0.20 (90.76)	4.49 (244.19)
16.	*Malus sylvestris* (L.) Mill.	1.67 (80.00)	2.07 (77.18)	0.04 (90.80)	3.78 (247.98)
17.	*Philadelphus coronarius* L.	1.36 (81.36)	1.87 (79.05)	0.36 (91.16)	3.59 (251.57)
18.	*Acer rubrum* L.	1.52 (82.88)	1.45 (80.50)	0.44 (91.60)	3.41 (254.98)
19.	*Rhodotypos scandens* Makino.	1.67 (84.55)	1.45 (81.95)	0.09 (91.69)	3.21 (258.18)
20.	*Platanus occidentalis* L.	0.15 (84.70)	0.21 (82.16)	2.72 (94.41)	3.08 (261.26)
21.	*Liriodendron tulipifera* L.	1.06 (85.76)	1.45 (83.61)	0.27 (94.68)	2.78 (264.04)
22.	*Aralia elata* (Miq.) Seem.	1.67 (87.42)	1.04 (84.65)	0.01 (94.69)	2.71 (266.76)
23.	*Celtis occidentalis* L.	1.21 (88.64)	1.45 (86.10)	0.02 (94.71)	2.68 (269.44)
24.	*Acer negundo L.*	1.06 (89.70)	1.24 (87.34)	0.04 (94.75)	2.35 (271.79)
25.	*Viburnum prunifolium* L.	0.91 (90.61)	1.24 (88.59)	0.17 (94.91)	2.32 (274.11)
26.	*Ailanthus altissima* (Miller) Swingle.	0.61 (91.21)	0.83 (89.42)	0.63 (95.55)	2.07 (276.18)
27.	*Quercus phellos* L.	0.15 (91.36)	0.21 (89.63)	1.59 (97.14)	1.95 (278.13)
28.	*Cornus racemosa* Lam.	0.91 (92.27)	0.83 (90.46)	0.03 (97.17)	1.77 (279.90)
29.	*Tilia americana* L.	0.30 (92.58)	0.41 (90.87)	0.90 (98.07)	1.62 (281.52)
30.	*Amelanchier canadensis* (L.) Medikus.	0.61 (93.18)	0.62 (91.49)	0.05 (98.12)	1.28 (282.80)
31.	*Quercus alba* L.	0.30 (93.48)	0.41 (91.91)	0.45 (98.57)	1.17 (283.97)

32.	*Hamamelis virginiana* L.	0.45 (93.94)	0.62 (92.53)	0.04 (98.61)	1.12 (285.08)
33.	*Crataegus* sp. L.	0.45 (94.39)	0.62 (93.15)	0.03 (98.65)	1.11 (286.19)
34.	*Cercis canadensis* L.	0.61 (95.00)	0.41 (93.57)	0.06 (98.71)	1.09 (287.28)
35.	*Carya alba* (L.) Nutt.	0.30 (95.30)	0.41 (93.98)	0.16 (98.87)	0.88 (288.16)
36.	*Fagus grandifolia* Ehrh.	0.45 (95.76)	0.41 (94.40)	0.01 (98.88)	0.87 (289.03)
37.	*Quercus laevis* Walter.	0.15 (95.91)	0.21 (94.61)	0.45 (99.32)	0.81 (289.84)
38.	*Prunus virginiana* L.	0.30 (96.21)	0.41 (95.02)	0.04 (99.36)	0.76 (290.59)
39.	*Acer saccharum* Marshall.	0.30 (96.52)	0.41 (95.44)	0.02 (99.38)	0.74 (291.33)
40.	*Quercus prinus* L.	0.30 (96.82)	0.41 (95.85)	0.01 (99.39)	0.73 (292.06)
41.	*Betula lenta* L.	0.30 (97.12)	0.41 (96.27)	0.01 (99.40)	0.73 (292.79)
42.	*Ligustrum vulgare* L.	0.30 (97.42)	0.41 (96.68)	0.00 (99.40)	0.72 (293.51)
43.	*Styphnolobium japonicum* (L.) Schott	0.30 (97.73)	0.41 (97.10)	0.00 (99.41)	0.72 (294.23)
44.	*Pinus nigra* Arnold.	0.15 (97.88)	0.21 (97.30)	0.26 (99.67)	0.62 (294.85)
45.	*Platanus hybrida* Brot.	0.15 (98.03)	0.21 (97.51)	0.21 (99.87)	0.57 (295.41)
46.	*Rhus typhina* L.	0.30 (98.33)	0.21 (97.72)	0.02 (99.89)	0.53 (295.94)
47.	*Viburnum plicatum* Thunb.	0.15 (98.48)	0.21 (97.93)	0.03 (99.92)	0.39 (296.33)
48.	*Quercus macrocarpa* Michx.	0.15 (98.64)	0.21 (98.13)	0.03 (99.95)	0.39 (296.72)
49.	*Hamamelis vernalis* Sarg.	0.15 (98.79)	0.21 (98.34)	0.02 (99.97)	0.38 (297.10)
50.	*Photinia glabra* Maxim.	0.15 (98.94)	0.21 (98.55)	0.01 (99.99)	0.37 (297.47)
51.	*Vibunum opulus* var. *opulus* L.	0.15 (99.09)	0.21 (98.76)	0.01 (99.99)	0.37 (297.84)
52.	*Frangula alnus* Mill.	0.15 (99.24)	0.21 (98.96)	0.00 (100.00)	0.36 (298.20)
53.	*Euonymus alatus* (Thunb.) Siebold.	0.15 (99.39)	0.21 (99.17)	0.00 (100.00)	0.36 (298.56)
54.	*Gleditsia triacanthos* var. *inermis* Willd.	0.15 (99.55)	0.21 (99.38)	0.00 (100.00)	0.36 (298.92)
55.	*Rhus glabra* L.	0.15 (99.70)	0.21 (99.59)	0.00 (100.00)	0.36 (299.28)
56.	*Crataegus viridis* L.	0.15 (99.85)	0.21 (99.79)	0.00 (100.00)	0.36 (299.64)
57.	*Parthenocissus tricuspidata* (Siebold & Zucc.) Planchon	0.15 (100.00)	0.21 (100.00)	0.00 (100.00)	0.36 (300.00)

Table 4.2 Descriptive statistics for the North Woods data. Species listed in order of Importance Value. Diameter in centimeters. Absolute density from point centered quarter data in meters, with bootstrap 95% confidence intervals (NS = 10,000 bootstrap samples), upper and lower bound in parentheses.

	Species	**Abundance**	**% sampling units**	**Mean DBH**	**Standard deviation**	Min, max	Absolute density (Upper bound, lower bound)
1.	*Prunus serotina* Ehrh.	158	54.55	15.54	18.69	1.0, 189.0	256.17 (232.96, 281.61)
2.	*Quercus rubra* L.	44	22.42	43.75	41.48	1.5, 218.0	71.34 (64.88, 78.42)
3.	*Acer platanoides* L.	61	28.48	16.85	18.69	1.0, 63.5	98.90 (89.94, 108.72)
4.	*Acer pseudoplatanus* L.	38	19.39	14.46	16.22	1.0, 49.5	61.61 (56.03, 67.73)
5.	*Ulmus americana* L.	36	15.15	7.647	17.28	1.0, 104.0	58.37 (53.08, 64.16)
6.	*Fraxinus americana* L.	17	9.70	20.15	25.23	1.0, 68.0	27.56 (25.07, 30.30)
7.	*Quercus palustris* Muenchh.	11	6.67	36.91	28.23	1.0, 82.0	17.83 (16.22, 19.61)
8.	*Viburnum dentatum* var. *lucidum* Ait.	28	12.12	6.718	8.12	1.5, 45.5	45.40 (41.28, 49.91)
9.	*Lindera benzoin* (L.) Blume.	24	10.30	5.996	4.28	1.0, 21.0	40.53 (36.86, 44.56)
10.	*Ulmus procera* Salisb.	25	11.52	5.484	3.25	1.0, 17.0	38.91 (35.39, 42.78)
11.	*Sassafras albidum* (Nutt.) Nees.	25	6.06	7.524	6.02	1.0, 22.0	40.53 (36.86, 44.56)
12.	*Morus alba* L.	15	6.67	15.2	11.65	2.0, 38.0	24.32 (22.12, 26.74)
13.	*Carya cordiformis* (Wangenh) K. Koch.	10	6.06	19.9	19.32	1.0, 48.0	16.21 (14.74, 17.82)
14.	*Liquidambar styraciflua* L.	9	4.85	25.39	21.29	2.0, 71.0	14.59 (13.27, 16.04)
15.	*Photinia villosa* (Thunb.) DC.	16	5.45	4.406	6.14	1.0, 24.5	25.94 (23.59, 28.52)
16.	*Pyrus malus* L.	11	6.06	3.645	2.06	1.5, 8.5	17.83 (16.22, 19.61)
17.	*Philadelphus coronarius* L.	9	5.45	8.156	10.92	2.0, 33.5	14.59 (13.27, 16.04)
18.	*Acer rubrum* L.	10	4.24	9.16	10.98	1.0, 38.5	16.21 (14.74, 17.82)
19.	*Rhodotypos scandens* Makino.	11	4.24	4.909	3.33	2.0, 11.5	17.83 (16.22, 19.61)
20.	*Platanus occidentalis* L.	1	0.61	108.5	-	108.5, 108.5	1.62 (1.47, 1.78)
21.	*Liriodendron tulipifera* L.	7	4.24	11.36	6.59	3.5, 22.5	11.35 (10.32, 12.48)
22.	*Aralia spinosa* L.	11	3.03	1.909	0.83	1.0, 4.0	17.83 (16.22, 19.61)
23.	*Celtis occidentalis* L.	8	4.24	2.812	1.77	1.0, 5.5	12.97 (11.80, 14.26)
24.	*Acer negundo L.*	7	3.64	4.643	2.17	1.5, 7.5	11.35 (10.32, 12.48)
25.	*Viburnum prunifolium*L.	6	3.64	9.333	6.35	2.0, 19.5	9.73 (8.85, 10.69)
26.	*Ailanthus altissima* (Miller) Swingle.	4	2.42	24.15	11.71	13.6, 35.5	6.49 (5.90, 7.13)
27.	*Quercus phellos* L.	1	0.61	83	-	83.0, 83.0	1.62 (1.47, 1.78)
28.	*Cornus racemosa* Lam.	6	2.42	3.5	3.74	1.0, 11.0	9.73 (8.85, 10.69)
29.	*Tilia americana* L.	2	1.21	32	43.13	1.5, 62.5	3.24 (2.95, 3.56)
30.	*Amelanchier canadensis* (L.) Medikus.	4	1.82	6	4.53	2.5, 12.0	6.49 (5.90, 7.13)
31.	*Quercus alba* L.	2	1.21	24	28.28	4.0, 44.0	3.24 (2.95, 3.56)
32.	*Hamamalis virginiana* L.	3	1.82	7	3.50	4.5, 11.0	4.86 (4.42, 5.35)
33.	*Crataegus* sp. L.	3	1.82	5.5	5.22	2.0, 11.5	4.86 (4.42, 5.35)
34.	*Cercis canadensis* L.	4	1.21	8.3	1.23	7.0, 9.5	6.49 (5.90, 7.13)
35.	*Carya tomentosa* (Poiret) Nutt.	2	1.21	16.25	13.08	7.0, 25.5	3.24 (2.95, 3.56)

36.	*Fagus grandifolia* Ehrh.	3	1.21	2.4	1.56	1.5, 4.2	4.86 (4.42, 5.35)
37.	*Quercus laevis* Walter.	1	0.61	44	-	44.0, 44.0	1.62 (1.47, 1.78)
38.	*Prunus virginiana* L.	2	1.21	9	0.71	8.5, 9.5	3.24 (2.95, 3.56)
39.	*Acer saccharum* Marshall.	2	1.21	5.25	5.30	1.5, 9.0	3.24 (2.95, 3.56)
40.	*Quercus prinus* L.	2	1.21	4.75	1.77	3.5, 6.0	3.24 (2.95, 3.56)
41.	*Betula lenta* L.	2	1.21	4	0.00	4.0, 4.0	3.24 (2.95, 3.56)
42.	*Ligustrum vulgare* L.	2	1.21	3	0.00	3.0, 3.0	3.24 (2.95, 3.56)
43.	*Sophora japonica* L.	2	1.21	2.5	0.71	2.0, 3.0	3.24 (2.95, 3.56)
44.	*Pinus nigra* Arnold.	1	0.61	33.5	-	33.5, 33.5	1.62 (1.47, 1.78)
45.	*Platanus* x *hybrida* Brot.	1	0.61	30	-	30.0, 30.0	1.62 (1.47, 1.78)
46.	*Rhus typhina* L.	2	0.61	4.75	5.30	1.0, 8.5	3.24 (2.95, 3.56)
47.	*Viburnum plicatum* Thunb.	1	0.61	11.5	-!	11.5, 11.5	1.62 (1.47, 1.78)
48.	*Quercus macrocarpa* Michx.	1	0.61	11	-	11.0, 11.0	1.62 (1.47, 1.78)
49.	*Hamamalis vernalis* Sarg.	1	0.61	10	-	10.0, 10.0	1.62 (1.47, 1.78)
50.	*Photinia glabra* Maxim.	1	0.61	7.5	-	7.5, 7.5	1.62 (1.47, 1.78)
51.	*Vibunum opulus* var. *opulus* L.	1	0.61	5.5	-	5.5, 5.5	1.62 (1.47, 1.78)
52.	*Rhamnus frangula* L.	1	0.61	4	-	4.0, 4.0	1.62 (1.47, 1.78)
53.	*Euonymus alatus* (Thunb.) Siebold.	1	0.61	3	-	3.0, 3.0	1.62 (1.47, 1.78)
54.	*Gleditsia triacanthos* var. *inermis* Willd.	1	0.61	2	-	2.0, 2.0	1.62 (1.47, 1.78)
55.	*Rhus glabra* L.	1	0.61	1.5	-	1.5, 1.5	1.62 (1.47, 1.78)
56.	*Crataegus viridis* L.	1	0.61	1.5	-	1.5, 1.5	1.62 (1.47, 1.78)
57.	*Parthenocissus tricuspidata* (Siebold & Zucc.) Planchon	1	0.61	1	-	1.0, 1.0	1.62 (1.47, 1.78)

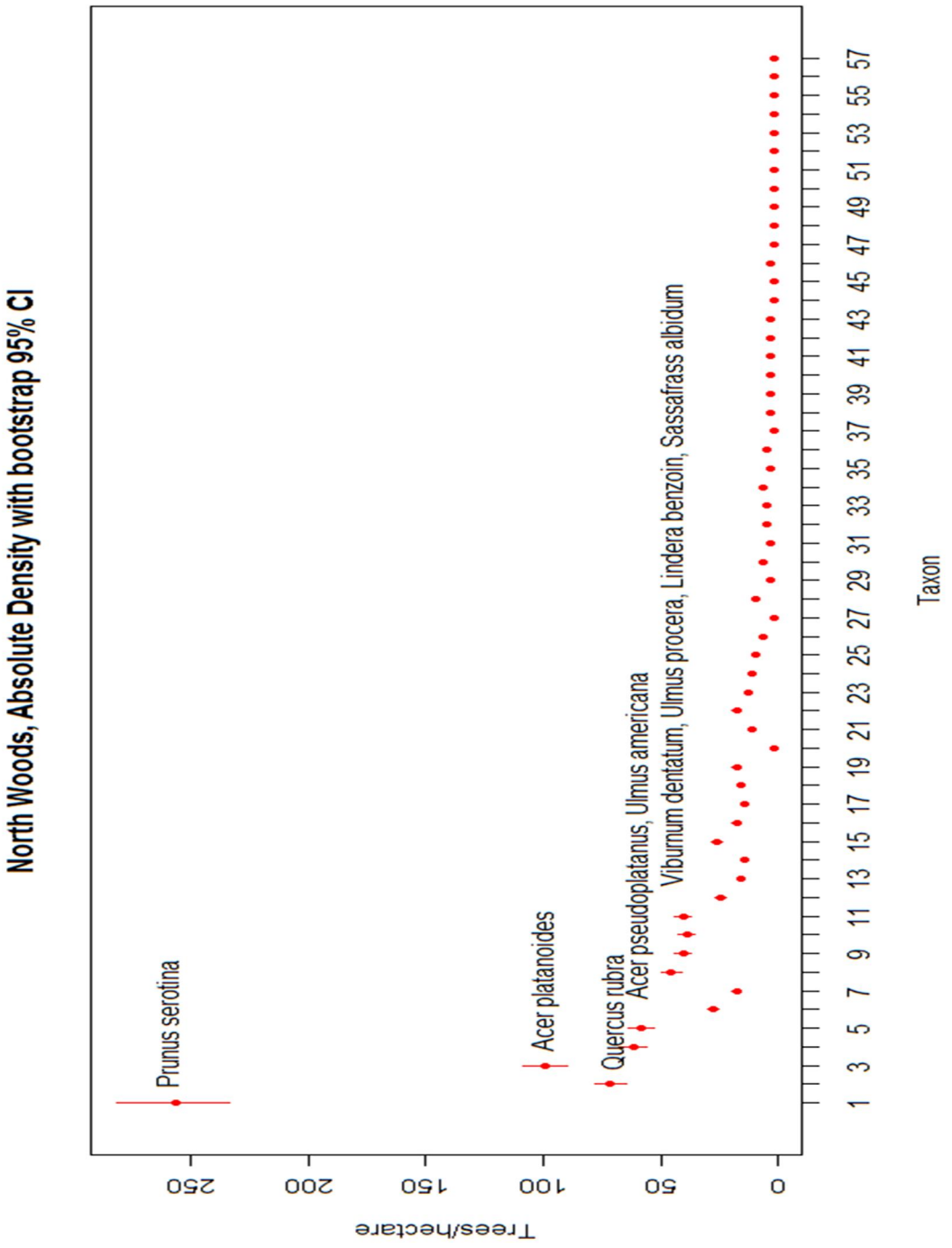

Figure 4.1Absolute density, North Woods

Table 4.3 Ecological dominance assessed by Importance Value analysis for Lower quartile of DBH of the North Woods. Cumulative values in parentheses.

Rank	Species	Relative density	Relative frequency	Relative dominance	Importance value
1.	*Acer platanoides* L.	13.94 (13.94)	12.23 (12.23)	12.94 (12.94)	39.12 (39.11)
2.	*Prunus serotina* Ehrh.	10.91 (24.85)	11.51 (23.74)	7.65 (20.60)	30.07 (69.19)
3.	*Ulmus procera* Salisb.	6.67 (31.52)	5.76 (29.50)	8.28 (28.87)	20.70 (89.88)
4.	*Acer pseudoplatanus* L.	6.67 (38.18)	7.91 (37.41)	5.44 (34.31)	20.02 (109.90)
5.	*Ulmus americana* L.	7.27 (45.45)	7.19 (44.60)	5.20 (39.51)	19.66 (129.57)
6.	*Photinia villosa* (Thunb.) DC.	6.06 (51.52)	4.32 (48.92)	5.92 (45.43)	16.30 (145.86)
7.	*Aralia elata* (Miq.) Seem.	6.06 (57.58)	3.60 (52.52)	5.97 (51.39)	15.63 (161.49)
8.	*Fraxinus americana* L.	4.85 (62.42)	5.76 (58.27)	3.75 (55.15)	14.36 (175.85)
9.	*Lindera benzion* (L.) Blume.	4.24 (66.67)	5.04 (63.31)	4.91 (60.06)	14.19 (190.03)
10.	*Philadelphus coronarius* L.	2.42 (69.09)	2.88 (66.19)	4.28 (64.34)	9.59 (199.62)
11.	*Sassafras albidum* (Nutt.) Nees.	3.03 (72.12)	2.16 (68.35)	3.80 (68.14)	8.99 (208.61)
12.	*Celtis occidentalis* L.	3.03 (75.15)	2.88 (71.22)	3.03 (71.17)	8.94 (217.55)
13.	*Malus sylvestris* (L.) Mill.	2.42 (77.58)	2.88 (74.10)	3.61 (74.78)	8.91 (226.46)
14.	*Viburnum dentatum* var. *lucidum* Ait.	2.42 (80.00)	2.88 (76.98)	3.18 (77.96)	8.48 (234.94)
15.	*Cornus racemosa* Lam.	2.42 (82.42)	2.16 (79.14)	2.60 (80.56)	7.18 (242.12)
16.	*Acer rubrum* L.	1.82 (84.24)	2.16 (81.29)	2.60 (83.16)	6.58 (248.69)
17.	*Carya cordiformis* (Wangenh) K. Koch	1.82 (86.06)	2.16 (83.45)	1.40 (84.55)	5.37 (254.07)
18.	*Amelanchier canadensis* (L.) Medikus	1.21 (87.27)	1.44 (84.89)	2.41 (86.96)	5.06 (259.12)
19.	*Morus alba* L.	1.21 (88.48)	1.44 (86.33)	1.97 (88.93)	4.62 (263.75)
20.	*Rhodotypos scandens* Makino.	1.21 (89.70)	1.44 (87.77)	1.97 (90.90)	4.62 (268.37)
21.	*Acer negundo* L.	1.21 (90.91)	1.44 (89.21)	1.64 (92.54)	4.29 (272.66)
22.	*Fagus grandifolia* Ehrh.	1.21 (92.12)	1.44 (90.65)	0.87 (93.41)	3.52 (276.18)
23.	*Crataegus sp.* L.	0.61 (92.73)	0.72 (91.37)	0.77 (94.18)	2.10 (278.27)
24.	*Styphnolobium japonicum* (L.) Schott	0.61 (93.33)	0.72 (92.09)	0.77 (94.95)	2.10 (280.37)
25.	*Gleditsia triacanthos* var. *inermis* Willd.	0.61 (93.94)	0.72 (92.81)	0.77 (95.72)	2.10 (282.46)
26.	*Liquidambar styraciflua* L.	0.61 (94.55)	0.72 (93.53)	0.77 (96.49)	2.10 (284.56)
27.	*Viburnum prunifolium* L.	0.61 (95.15)	0.72 (94.24)	0.77 (97.26)	2.10 (286.65)
28.	*Quercus rubra* L.	0.61 (95.76)	0.72 (94.96)	0.43 (97.69)	1.76 (288.41)
29.	*Rhus glabra* L.	0.61 (96.36)	0.72 (95.68)	0.43 (98.12)	1.76 (290.17)
30.	*Acer saccharum* Marshall.	0.61 (96.97)	0.72 (96.40)	0.43 (98.56)	1.76 (291.93)
31.	*Tilia americana* L.	0.61 (97.58)	0.72 (97.12)	0.43 (98.99)	1.76 (293.69)
32.	*Crataegus viridis* L.	0.61 (98.18)	0.72 (97.84)	0.43 (99.42)	1.76 (295.45)
33.	*Quercus palustris* Muenchh.	0.61 (98.79)	0.72 (98.56)	0.19 (99.62)	1.52 (296.96)
34.	*Rhus typhina* L.	0.61 (99.39)	0.72 (99.28)	0.19 (99.81)	1.52 (298.48)
35.	*Parthenocissus tricuspidata* (Siebold & Zucc.) Planchon.	0.61 (100.00)	0.72 (100.00)	0.19 (100.00)	1.52 (300.00)

Table 4.4 Ecological dominance assessed by Importance Value analysis for families of the North Woods. Cumulative values in parentheses.

	Family	Relative density	Relative frequency	Relative dominance	Importance value
1.	Rosaceae	31.36 (31.36)	24.07 (24.07)	21.94 (21.94)	77.37 (77.37)
2.	Fagaceae	9.85 (41.21)	12.15 (36.21)	44.36 (66.30)	66.36 (143.73)
3.	Aceraceae	17.88 (59.09)	17.29 (53.50)	13.43 (79.73)	48.60 (192.32)
4.	Ulmaceae	10.00 (69.09)	10.05 (63.55)	3.03 (82.76)	23.07 (215.40)
5.	Lauraceae	7.58 (76.67)	6.78 (70.33)	0.80 (83.56)	15.15 (230.55)
6.	Caprifoliaceae	5.45 (82.12)	6.31 (76.64)	0.91 (84.47)	12.67 (243.22)
7.	Oleaceae	3.18 (85.30)	4.44 (81.07)	4.71 (89.18)	12.33 (255.56)
8.	Hamamelidaceae	1.97 (87.27)	2.80 (83.88)	2.24 (91.42)	7.01 (262.57)
9.	Juglandaceae	1.82 (89.09)	2.80 (86.68)	1.85 (93.27)	6.47 (269.04)
10.	Moraceae	2.27 (91.36)	2.57 (89.25)	1.24 (94.51)	6.08 (275.12)
11.	Hydrangeaceae	1.36 (92.73)	2.10 (91.36)	0.36 (94.87)	3.83 (278.95)
12.	Platanaceae	0.30 (93.03)	0.47 (91.82)	2.93 (97.79)	3.70 (282.65)
13.	Magnoliaceae	1.06 (94.09)	1.64 (93.46)	0.27 (98.06)	2.96 (285.61)
14.	Araliaceae	1.67 (95.76)	1.17 (94.63)	0.01 (98.07)	2.85 (288.46)
15.	Fabaceae	1.06 (96.82)	1.17 (95.79)	0.07 (98.14)	2.30 (290.75)
16.	Simaroubaceae	0.61 (97.42)	0.93 (96.73)	0.63 (98.77)	2.17 (292.93)
17.	Cornaceae	0.91 (98.33)	0.93 (97.66)	0.03 (98.81)	1.88 (294.80)
18.	Tiliaceae	0.30 (98.64)	0.47 (98.13)	0.90 (99.71)	1.67 (296.48)
19.	Anacardiaceae	0.45 (99.09)	0.47 (98.60)	0.02 (99.73)	0.94 (297.42)
20.	Betulaceae	0.30 (99.39)	0.47 (99.07)	0.01 (99.73)	0.78 (298.19)
21.	Pinaceae	0.15 (99.55)	0.23 (99.30)	0.26 (99.99)	0.64 (298.84)
22.	Rhamnaceae	0.15 (99.70)	0.23 (99.53)	0.00 (100.00)	0.39 (299.23)
23.	Celastraceae	0.15 (99.85)	0.23 (99.77)	0.00 (100.00)	0.39 (299.61)
24.	Vitaceae	0.15 (100.00)	0.23 (100.00)	0.00 (100.00)	0.39 (300.00)

Table 4.5 Ecological dominance assessed by Importance Value analysis for genera of the North Woods. Cumulative values in parentheses.

	Genera	Relative density	Relative frequency	Relative dominance	Importance Value
1.	*Prunus*	24.24 (24.24)	20.09 (20.09)	21.51 (21.51)	65.84 (65.84)
2.	*Quercus*	9.39 (33.64)	11.04 (31.13)	44.35 (65.87)	64.79 (130.63)
3.	*Acer*	17.88 (51.52)	16.34 (47.46)	13.43 (79.30)	47.64 (178.27)
4.	*Ulmus*	8.79 (60.30)	8.39 (55.85)	3.01 (82.30)	20.18 (198.46)
5.	*Viburnum*	5.45 (65.76)	5.96 (61.81)	0.91 (83.21)	12.32 (210.78)
6.	*Fraxinus*	2.88 (68.64)	3.97 (65.78)	4.71 (87.92)	11.56 (222.34)
7.	*Lindera*	3.79 (72.42)	4.19 (69.98)	0.28 (88.19)	8.26 (230.60)
8.	*Sassafras*	3.79 (76.21)	2.21 (72.19)	0.53 (88.72)	6.52 (237.12)
9.	*Carya*	1.82 (78.03)	2.65 (74.83)	1.85 (90.57)	6.32 (243.44)
10.	*Morus*	2.27 (80.30)	2.43 (77.26)	1.24 (91.81)	5.94 (249.38)
11.	*Liquidambar*	1.36 (81.67)	1.77 (79.03)	2.18 (93.99)	5.31 (254.68)
12.	*Photinia*	2.58 (84.24)	2.21 (81.24)	0.22 (94.20)	5.00 (259.68)
13.	*Malus*	1.67 (85.91)	2.21 (83.44)	0.04 (94.25)	3.92 (263.60)
14.	*Philadelphus*	1.36 (87.27)	1.99 (85.43)	0.36 (94.61)	3.71 (267.31)
15.	*Platanus*	0.30 (87.58)	0.44 (85.87)	2.93 (97.53)	3.67 (270.98)
16.	*Rhodotypos*	1.67 (89.24)	1.55 (87.42)	0.09 (97.62)	3.30 (274.28)
17.	*Liriodendron*	1.06 (90.30)	1.55 (88.96)	0.27 (97.89)	2.87 (277.15)
18.	*Aralia*	1.67 (91.97)	1.10 (90.07)	0.01 (97.90)	2.78 (279.93)
19.	*Celtis*	1.21 (93.18)	1.55 (91.61)	0.02 (97.92)	2.78 (282.71)
20.	*Ailanthus*	0.61 (93.79)	0.88 (92.49)	0.63 (98.55)	2.12 (284.83)
21.	*Cornus*	0.91 (94.70)	0.88 (93.38)	0.03 (98.59)	1.83 (286.66)
22.	*Tilia*	0.30 (95.00)	0.44 (93.82)	0.90 (99.49)	1.65 (288.31)
23.	*Hamamelis*	0.61 (95.61)	0.88 (94.70)	0.06 (99.55)	1.55 (289.86)
24.	*Crataegus*	0.61 (96.21)	0.88 (95.58)	0.03 (99.58)	1.52 (291.38)
25.	*Amelanchier*	0.61 (96.82)	0.66 (96.25)	0.05 (99.63)	1.32 (292.70)
26.	*Cercis*	0.61 (97.42)	0.44 (96.69)	0.06 (99.70)	1.11 (293.81)
27.	*Rhus*	0.45 (97.88)	0.44 (97.13)	0.02 (99.71)	0.91 (294.72)
28.	*Fagus*	0.45 (98.33)	0.44 (97.57)	0.01 (99.72)	0.90 (295.62)
29.	*Betula*	0.30 (98.64)	0.44 (98.01)	0.01 (99.73)	0.75 (296.38)

30.	*Ligustrum*	0.30 (98.94)	0.44 (98.45)	0.00 (99.73)	0.75 (297.13)
31.	*Styphnolobium*	0.30 (99.24)	0.44 (98.90)	0.00 (99.73)	0.75 (297.87)
32.	*Pinus*	0.15 (99.39)	0.22 (99.12)	0.26 (99.99)	0.63 (298.50)
33.	*Frangula*	0.15 (99.55)	0.22 (99.34)	0.00 (100.00)	0.38 (298.88)
34.	*Euonymus*	0.15 (99.70)	0.22 (99.56)	0.00 (100.00)	0.37 (299.25)
35.	*Gleditsia*	0.15 (99.85)	0.22 (99.78)	0.00 (100.00)	0.37 (299.63)
36.	*Parthenocissus*	0.15 (100.00)	0.22 (100.00)	0.00 (100.00)	0.37 (300.00)

Chapter 5

The Hallett Nature Sanctuary

5.1 Introduction

The Hallett Nature Sanctuary (Hallett) is a woodland of approximately 1.6 hectares, surrounded by water (The Pond) and chain link fence. It is located in the southeast corner of the Park (Figure 5.1) and is closed to the public. As with most of the rest of the Park, the topography of Hallett is mostly artificial, with the main exception being the rock outcroppings. Originally called the Promontory, Hallett has no path system, since it was designed only to be a visual backdrop to the Pond. This area was a naturally occurring wetland and there was never a native forest here. The Pond was artificially created from low-lying swampland and the native rock outcrops were filled with topsoil and landscaped. These upland areas and rock outcrops were originally planted with evergreen trees and shrubs. After a subsequent period of neglect and decline, the landscape then became overgrown and resulted in the woodland that is now Hallett. Several horticultural species and disturbance species have naturalized from the original plantings, such as *Wisteria sinensis* (Sims) DC., *Acer platanoides*, *Ailanthus altissima*, and *Rhodotypos scandens*. Several native species have proliferated, such as *Viburnum dentatum* var. *lucidum,* which forms dense stands along the south and east of the area. Fast-growing native species such as *Prunus serotina* and *Fraxinus americana* make up a large percentage of tree species. Understory and herbaceous layers are sparse in many areas. Conifers are few and spindly.

Hallett is located near one of the more important entrances to the Park, the south end, which hosts more visitors than all the rest of the Park (Conservancy 2011). It also has the least

naturalistic landscapes in the park. Hallett, along with the Pond, is one of the few areas in this part of the Park that supports wildlife, however limited. In New York City, any freshwater body is valuable for nesting and migratory waterfowl, and many species of birds use the Pond throughout the year. Since it is one of the only areas in the south end of the Park where fallen deadwood and leaf litter are allowed to accumulate, and it is near a water body, Hallett serves as shelter and cover for these birds in a very densely populated part of the Park. It was classified as primary wildlife habitat (Hecklau 1982).

The Pond underwent many changes over the years but the Promontory was mostly left alone with the exception of some azalea plantings that were made in the 1930s. In 1934 the area was fenced off, designated a sanctuary and named after George Hervey Hallett, Jr., a prominent nature-loving New Yorker. From 1934 to 2002, little or no work was done in Hallett save for litter removal from homeless activity, and safety pruning of tree limbs overhanging the surrounding pathways. From 2002 onward, following the same protocols as in the other woodlands, restoration began. However, much of this restoration work was done by high school students as part of the Conservancy's internship program to teach youngsters about urban ecology and restoration.

Figure 5.1 Southeast corner of Central Park, including the Hallett Nature Sanctuary and The Pond

5.2 Importance Value, Descriptive Statistics and Lower DBH Quartile

As is the case in the other woodlands, *Prunus serotina* dominates ecologically (Table 5.1). It has an IV exceptionally higher than *Fraxinus americana,* which ranks second, 102.3 vs. 21.76. *Prunus serotina* is found in 76.19% of the sampling units and has an estimated absolute density of 557.08 stems per hectare, a number substantially higher than the estimation of 314.15 stems per hectare for the total woodlands (Table 5.2). Hallett's small size, the original open design of the area and the fact that it was left untended for so many years is probably the reason *P. serotina* is able to dominate so extensively.

In this case we see *Fraxinus americana* second in ecological dominance, whereas in the North Woods it is sixth in ecological dominance and in the Ramble it is 36th. Despite being succeptible to drought, this species regenerates well thoughout the park (personal experience). In Hallett there is a large specimen (66 cm DBH, see Table 5.2) that is likely the major source of seeds for this area.

The species that is third in ecological dominance in Hallett is *Robinia pseudoacacia*. Despite this species being native to other regions of the United States, it is considered an invasive in our area (Brown 2001), as the natural northern extent of its range is Pennsylvania (Gleason and Cronquist 1991). However, it does not appear in the Ramble or North Woods data sets. There is one stand of *R. pseudoacacia* in the Ramble in the eastern area known as "The Point," the same area where the large stand of *Celtis occidentalis* is found and there are also other areas in the Park outside of the woodlands where *R. pseudoacacia* can be found, most notably the west side of the Great Lawn. The Red-headed woodpecker, during the few times that it visits the park, frequents this area and uses the deep grooves in the bark of this species to store acorns.

Although *Quercus palustris* ranks fourth in ecological dominance, it has a higher dominance in basal area than both *Fraxinus americana* and *Robinia pseudoacacia*. *Quercus palustris* represents the largest DBHs in this data set, ranging from 47 cm to 106 cm. As is the case in the other woodlands and throughout the Park, oaks were present at the time of the Park's creation and had been some of the species planted throughout Park history.

Frangula alnus, which ranks 30th in IV for the total data set, is fifth for Hallett. This non-native species, which originated in Eurasia and North Africa, is considered invasive, (Heneghan et al. 2004). However, this is another case in which a species is showing invasive tendencies only in Hallett and not in the other woodlands. In the North Woods there is only one stem of four cm and in the Ramble there are none at all.

Another species found in Hallett's top ten that is considered invasive is *Rhodotypos scandens*. This is an old fashioned ornamental that was planted extensively in the park.

Acer saccharum shows somewhat strong ecological dominance in that it appears in the top ten. In the total data, it is number 26 (Table 2.1). All of the stems representing the Hallett population are small, from 1 to 7 cm. When the Asian Longhorned Beetle infestation was discovered in Hallett (see Chapter 7), it was found on two sugar maples of substantial size. These were removed, along with nine large Norway maples surrounding this site. However, the many young *A. saccharum* saplings in this area indicate regeneration of the species.

5.3 Conclusions, Hallett PCQ

The Hallett Nature Sanctuary is the smallest of the three woodlands and originally was not meant to be a woodland at all, but only a visual backdrop to the Pond. Even though it was closed off in 1934 and protected by a chain-link fence, it still is an ecologically disturbed area. The woodland that grew up during those years of decline is populated mostly by *Prunus serotina*, a native pioneer species found in over 76% of the study's sample sites, a figure substantially higher than that for the total data set. *Fraxinus americana* is second in ecological dominance, despite large losses of this species throughout the park due to years of drought and blight. Third in dominance is *Robinia pseudoacacia*. This species is native to the United States but not to our region and is considered an invasive species in the Park. However, the survey captured this species only in the Hallett woodland. Instead of *Quercus rubra*, the *Quercus* species that shows highest dominance in this area is *Q. palustris*. As in the other woodlands, the oak species are some of the largest species; however, they show poor regeneration in disturbed areas.

The species of interest with regard to invasiveness in this area are *Frangula alnus* and *Rhodotypos scandens*. Hallett is the site of one of two Asian longhorned beetle infestations in Central Park. Despite the removal of two large sugar maples, *Acer saccharum* is within the top ten in dominance. A result of strong regeneration of this species.

5.4 Central Park's Hallett Nature Sanctuary, 26 Years of Change in Tree Composition*

Introduction

As noted earlier in this study, there have been several papers documenting the floristic change over time in Central Park (Loeb 1993), but none have used quantitative scientific methods. This kind of documentation can help study the effects of human activities on urban habitats. Many of the studies done were just lists of species present or species planted. What are needed are quantitative ecological inventories that follow scientific protocols such that the inventories can be repeated every 5 to 10 years and comparisons can be made.

There are two surveys of tree species that were done by the Central Park Conservancy (Conservancy), one in 1982 and one in 2008. These surveys identified by species and measured diameter at breast height (DBH) for all tree species in the Park 15 cm (six inches) DBH and larger. The fact that these surveys include DBHs makes them much more valuable than earlier surveys; additionally, the 2008 survey included GPS locations for each tree, adding another valuable and replicable dimension to the survey. However, as was noted earlier and as this section will reinforce, surveys need to capture smaller stems to be able to examine regeneration of species.

*This section is based on a paper being prepared for publication by Regina V. Alvarez and Dr. Tanja Schuster, East Carolina University.

Methods

In 2002, working with Tanja Schuster, I surveyed all tree species in Hallett 2.5 cm DBH and larger. This paper compares these three surveys done in Hallett, showing change in tree species over a 26-year period. Documentation of temporal change in a species is an essential tool for managers to develop proper management strategies.

The 1982 survey tallied 24,000 trees (Rogers 1987), of which, 301 were in Hallett. The 2008 survey tallied 24,131 trees, 452 of which are in Hallett. The 2002 survey tallied trees 2.5 cm and larger for a total of 1,344 trees. For a proper comparison, this data was truncated to include only stems 15 cm and larger, leaving a total of 504 trees. Nomenclature follows Gleason and Cronquist (1991), verified by the USDA Plant Database

Results and Discussion

The number of families and species remained relatively consistent across the 26 years (Table 5.3). The total number of stems increased from 1982 to 2002, as one might expect of an area left unmanaged. The number decreased from 2002 to 2008 probably as a result of the management practices that began in 2002. In that year, the Conservancy began managing this woodland in a manner similar to the other two woodlands in Central Park (the Ramble and North Woods). Up until that time, other than occasional litter removal and removal of hazardous branches overhanging walkways, no maintenance was done inside Hallett. Part of the present management strategy is to remove invasive species such as *A. altissima* and *A. platanoides*, mostly through removal of smaller trees that can be handled by volunteers and student interns. Due to an Asian longhorned beetle (ALB) infestation, in January of 2002, 11 trees of significant

size were removed, two *Acer saccharum* and nine *A. platanoides,* by the USDA. Although *A. saccharum* no longer shows on the 2008 inventory, this species is still present in stems smaller than 15 cm DBH. They occur mostly in the area where the larger species were removed, indicating natural regeneration was occurring at the time.

	1982	2002	2008
Families	14	15	15
Species	23	25	24
Stems	301	464	452

Table 5.3 Hallett comparison of flora by year

Prunus serotina remains the most numerous species for all three surveys. Table 5.4 compares taxa by year. *Prunus serotina* is a native pioneer species that regenerates quickly in disturbed environments, and since Central Park is a disturbed environment, this species does exceptionally well. Although *P. serotina* is in no way treated as an invasive, management practices involve minor control of the species in areas where other desired species need less competition to thrive.

Ailanthus altissima does not appear at all in the 1982 survey. By 2002 it is the second most numerous, as might be expected from an invasive species. It falls to third place in the 2008 survey, as a result of management practices that regularly remove *A. altissima* trees up to a size that is manageable by volunteers and student interns.

Acer platanoides fell out of the top eight by 2008 in part because of regular removal of smaller trees as part of management practices but also because of removal by the USDA of nine large *A. platanoides* and two *A. saccharum* surrounding the ALB infestation site.

Frequency of *Fraxinus americana* increased through the three surveys. This is interesting since in general throughout the park, *F. americana* has been dying back over the years as a result of blight aggravated by drought. However, the high number of seedlings found throughout the woodlands indicates it is a species that regenerates easily in this environment. *Quercus palustris* and *Robinia pseudoacacia* abundance stayed essentially the same. *Pinus* sp. fell from the top eight by the second survey. Pines in general do poorly in urban environments, although in recent years, the Conservancy has had some success planting *Pinus strobus* and *Pinus rigida* in various areas throughout the Park. *Pinus nigra* has done particularly poorly over the years, possibly from Sphaeropsis blight caused by the fungus *Diplodia pinea* (Desm.) Kickx., as well as from stress (Neil Calvanese, personal communication).

The 1982 survey listed all mulberries as *Morus rubra,* a species native to this area. However, the two subsequent surveys listed mulberries as *Morus alba*. In addition, DeCandido et al. (2007) list *Morus alba* as extant and *Morus rubra* as historic. For this paper, we are treating all mulberries in all three surveys and *Morus alba*. Similarly, the ash tree is identified differently in the three surveys. The 1982 and the 2002 surveys list *Fraxinus americana* whereas the 2008 survey simply uses *Fraxinus* sp. with one stem of *Fraxinus pennsylvanica*. Both *F. americana* and *F. pennsylvanica* are listed in DeCandido et al. (2007). Table 5.5 shows the full 2002 species list.

A very simple mathematical expression for the similarity of plant communities is the community coefficient of Jaccard. It is based on the presence-absence relationship between the number of species common to two areas or communities and the total number of species, in a standard 2 x 2 contingency table. Therefore, the coefficient expresses the ratio of the common species to all species found in two vegetation segments. It can be used to compare two communities simply

on the basis of their species lists for presence and absence of common and unique species (Mueller-Dombois and Elenberg 2002).

Jaccard similarity ranges from 0 to 1, with 1 indicating that the two systems being compared are the same. This type of index is very sensitive to variation in sample size. For example, small communities may have relatively high similarity coefficients even in the absence of any unusual biotic forces because their faunas are dominated by a handful of common, widespread species. Rare species are found mostly in larger floras, and they will tend to reduce the similarity index for two communities if the rare species also occur at random. Probability calculations can be used to determine the expected value of a biodiversity or similarity index at small sample sizes. (Gotelli and Ellison 2004). Calculation of the Jaccard similarity coefficient gives the values shown in table 5.6.

Species list	**1982**	**2002**	**2008**
Acer platanoides L.	12	13	3
Acer rubrum L.	1	0	4
Acer saccharum Marsh.	2	1	0
Ailanthus altissima (Mill.) Swingle	1	65	54
Betula alleghaniensis Britton	0	0	1
Betula lenta L.	0	1	0
Betula pendula Roth	3	0	15
Betula populifolia Marsh.	6	20	0
Carpinus caroliniana Walter	2	2	2
Celtis occidentalis L.	1	2	3
Crataegus sp. L.	0	1	0
Fraxinus americana L.	4	11	16
Ginkgo biloba L.	3	3	3
Gymnocladus dioicus (L.) K. Koch	0	1	1
Koelreuteria paniculata Laxm.	0	1	1
Liquidambar styraciflua L.	0	2	3
Morus alba L.	22	16	11
Phellodendron amurense Rupr.	1	1	0
Pinus nigra Arnold	7	4	3
Pinus strobus L.	1	2	3
Platanus hybrida Brot.	2	1	2
Prunus serotina Ehrh.	157	241	221
Quercus alba L.	1	0	0
Quercus palustris Münchh.	11	11	11
Quercus rubra L.	1	1	2
Quercus velutina Lam.	0	0	1
Robinia pseudoacacia L.	58	59	54
Salix babylonica L.	3	0	0
Styphnolobium japonicum (L.) Schott	0	0	1
Ulmus americana L.	2	2	0
Ulmus pumila L.	0	1	2
Ulmus sp. L.	0	3	7

Table 5.4 Comparison of three surveys using truncated 2002 data, integers indicate abundances

Species	Frequency
Acer platanoides L.	13
Acer saccharum Marshall	1
Betula lenta L	1
Betula populifolia Marshall	20
Carpinus caroliniana Walter	2
Gymnocladus dioica (L.) K. Koch	1
Robinia pseudoacacia L.	59
Quercus palustris Muenchh.	11
Quercus rubra L.	1
Ginkgo biloba L.	3
Liquidambar styraciflua L.	2
Morus alba L.	14
Fraxinus americana L.	11
Pinus nigra Arnold	4
Pinus strobus L.	2
Platanus hybrida Brot.	1
Crataegus sp.	1
Malus sylvestris	2
Prunus serotina Ehrh.	241
Phellodendron amurense Maxim.	1
Koelreuteria paniculata Laxm.	1
Ailanthus altissima (Miller) Swingle	65
Celtis occidentalis L.	2
Ulmus americana L.	2
Ulmus pumila L.	1
Ulmus sp.	3

Table 5.5 Full data set 2002 survey includes all stems down to 2.5 cm

2002

1982		Present	Absent
	Present	31	5
	Absent	8	

J=31/(5 + 8 +31) =.7045

2008

2002		Present	Absent
	Present	18	8
	Absent	7	

J=18/(18+7+8)=0.5454

2008

1982		Present	Absent
	Present	32	7
	Absent	9	

J=32/(32+7+8)=0.6808

Table 5.6 Jaccard similiarty coefficient for Hallet by year

Diversity indices

	1982	2002	2008	2002 full data
Species richness	23	26	24	35
Total N	301	504	424	1344
Shannon diversity	1.753217	1.748464	1.790236	1.92453
Shannon evenness	0.5591516	0.5366521	0.5633121	0.5413055
Margalef diversity	3.854841	4.017629	3.80182	4.71999
Simpson D	0.3178662	0.312563	0.3089178	0.2569633
Simpson 1-D	0.6821338	0.687437	0.6910822	0.7430367
Simpson 1/D	3.145977	3.199355	3.237107	3.891607

Table 5.7 Comparison of diversity indices of Hallett by year

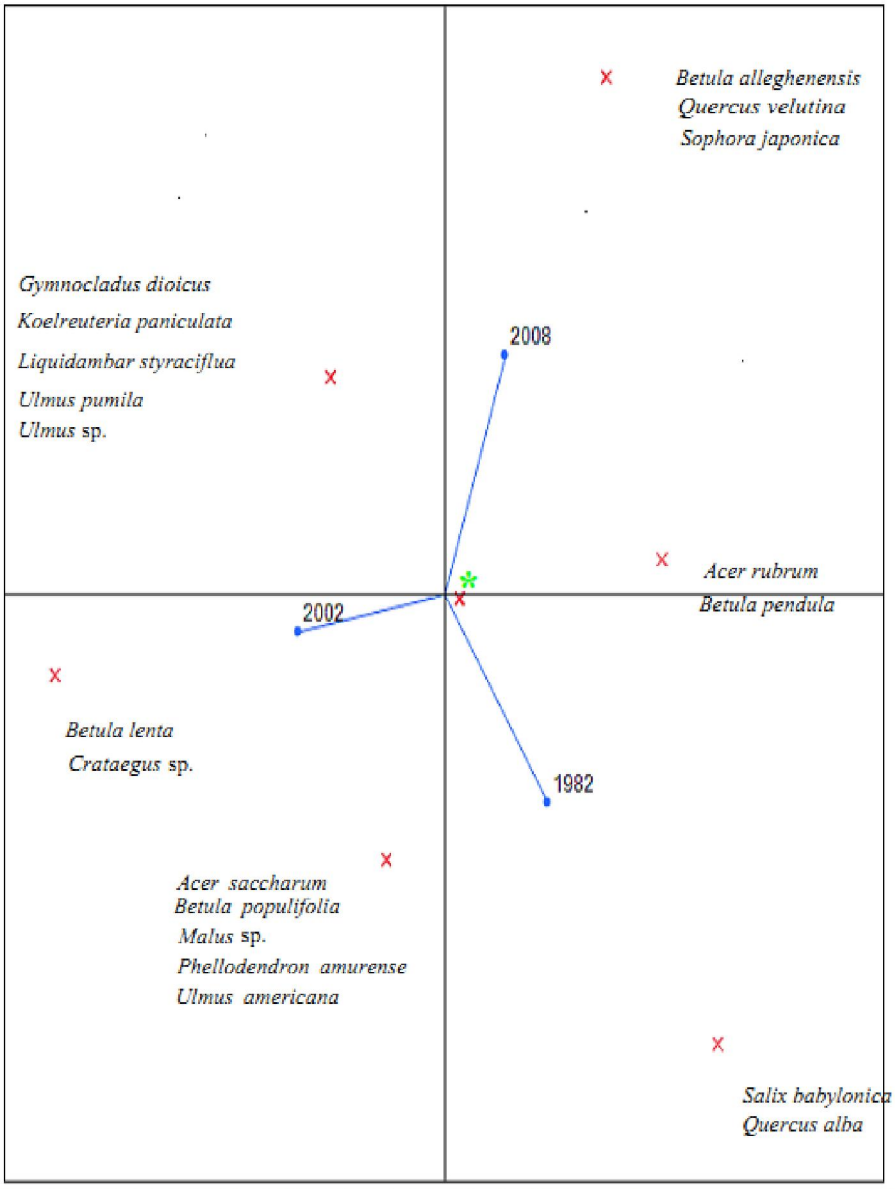

Figure 5.3 Correspondence analysis of Hallett by years. Jmp 9 (SAS)

* Species common to all three years

Acer platanoides
Ailanthus altissima
Carpinus caroliniana
Celtis occidentalis
Fraxinus americana
Ginkgo biloba
Morus rubra
Pinus nigra
Pinus strobus
Platanus x hybrida
Prunus serotina
Quercus palustris
Quercus rubra
Robinia pseudoacacia

Conclusions, Hallet, 26 Years of Change

Two park-wide surveys of Central Park were done by the Conservancy in 1982 and 2008. Those surveys inventoried all trees with a DBH of 15 cm (six inches) and larger. In 2002 Tanja Schuster and I did a full survey of all the trees in just the Hallett Nature Sanctuary, including all woody species down to 2.5 cm DBH.

Truncating our data to 15 cm and larger, I compared our data set with the data from the two other surveys within Hallett. The number of families and species remained relatively consistent within the 26-year span. The number of stems increased from 1982 to 2002, a result consistent for an area left unmanaged, whereas the number of stems decreased from 2002 to 2008, a result consistent with the fact that management of the area began in 2002 after our survey and included the removal of invasive species.

Prunus serotina remains the most numerous species for all three data sets. *Ailanthus altissima* does not appear in the 1982 survey yet by 2002 is the second most numerous species. This finding is consistent with the presence of a species that is considered an invasive, which *Ailanthus altissima* is.

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Table 5.1 Ecological dominance assessed by Importance Value analysis for Hallett data set. Cumulative values in parentheses.

	Species	Relative density	Relative frequency	Relative dominance	Importance value
1.	*Prunus serotina* Ehrh.	37.50 (37.50)	26.67 (26.67)	38.13 (38.13)	102.30 (102.30)
2.	*Fraxinus americana* L.	6.55 (44.05)	7.50 (34.17)	7.71 (45.84)	21.76 (124.10)
3.	*Robinia pseudoacacia* L.	4.17 (48.21)	5.00 (39.17)	12.44 (58.29)	21.61 (145.70)
4.	*Quercus palustris* Muenchh.	1.19 (49.40)	1.67 (40.83)	16.56 (74.85)	19.42 (165.10)
5.	*Frangula alnus* Mill.	7.74 (57.14)	7.50 (48.33)	0.17 (75.02)	15.41 (180.50)
6.	*Viburnum dentatum* var. *lucidum* Ait.	5.95 (63.10)	6.67 (55.00)	0.43 (75.45)	13.05 (193.50)
7.	*Morus alba* L.	2.38 (65.48)	2.50 (57.50)	7.57 (83.02)	12.45 (206.00)
8.	*Acer saccharum* Marshall.	4.17 (69.64)	5.00 (62.50)	0.17 (83.19)	9.34 (215.30)
9.	*Quercus rubra* L.	0.60 (70.24)	0.83 (63.33)	7.53 (90.72)	8.96 (224.30)
10.	*Rhodotypos scandens* Makino.	3.57 (73.81)	4.17 (67.50)	0.40 (91.12)	8.14 (232.40)
11.	*Rhododendron* sp. L.	3.57 (77.38)	3.33 (70.83)	0.62 (91.74)	7.52 (240.00)
12.	*Celtis occidentalis* L.	2.98 (80.36)	4.17 (75.00)	0.05 (91.79)	7.19 (247.10)
13.	*Acer platanoides* L.	3.57 (83.93)	3.33 (78.33)	0.09 (91.88)	7.00 (254.10)
14.	*Pinus strobus* L.	1.19 (85.12)	1.67 (80.00)	2.66 (94.54)	5.52 (259.70)
15.	*Phellodendron amurense* Rupr.	2.38 (87.50)	2.50 (82.50)	0.42 (94.96)	5.30 (265.00)
16.	*Malus sylvestris* (L.) Mill.	1.79 (89.29)	2.50 (85.00)	0.46 (95.42)	4.75 (269.70)
17.	*Ulmus americana* L.	1.79 (91.07)	2.50 (87.50)	0.28 (95.69)	4.56 (274.30)
18.	*Ailanthus altissima* (Miller) Swingle.	1.79 (92.86)	2.50 (90.00)	0.14 (95.84)	4.43 (278.70)
19.	*Ilex opaca* Aiton.	1.79 (94.64)	2.50 (92.50)	0.04 (95.88)	4.33 (283.00)
20.	*Ginkgo biloba* L.	0.60 (95.24)	0.83 (93.33)	2.82 (98.70)	4.25 (287.30)
21.	*Acer rubrum* L.	1.19 (96.43)	1.67 (95.00)	0.45 (99.14)	3.31 (290.60)
22.	*Koelreuteria paniculata* Laxm.	0.60 (97.02)	0.83 (95.83)	0.49 (99.63)	1.92 (292.50)
23.	*Cornus mas* L.	0.60 (97.62)	0.83 (96.67)	0.33 (99.97)	1.76 (294.30)
24.	*Lindera benzoin* (L.) Blume.	0.60 (98.21)	0.83 (97.50)	0.01 (99.98)	1.44 (295.70)
25.	*Evodia daniellii* (Benn.) Hemsl.	0.60 (98.81)	0.83 (98.33)	0.01 (99.99)	1.44 (297.10)
26.	*Crataegus* sp. L.	0.60 (99.40)	0.83 (99.17)	0.00 (100.00)	1.43 (298.60)
27.	*Styphnolobium japonicum* (L.) Schott	0.60 (100.00)	0.83 (100.00)	0.00 (100.00)	1.43 (300.00)

Table 5.2 Descriptive statistics for the Hallett data. Species listed in order of Importance Value. Diameter in centimeters. Absolute density from point centered quarter data in meters, with bootstrap 95% confidence intervals(NS=10,000 bootstrap samples), upper and lower bound in parentheses.

	Species	Abundance	% sampling units	Mean DBH	Standard deviation	Min, max	Absolute density (Upper bound, lower bound)
1.	*Prunus serotina* Ehrh.	63	76.19	17.15	14.29	2.0, 72.0	557.08 (476.53, 653.31)
2.	*Fraxinus americana* L.	11	21.43	15.91	18.77	1.0, 66.0	97.27 (83.20, 114.07)
3.	*Robinia pseudoacacia* L.	7	14.29	35.93	13.82	13.0, 56.5	61.90 (52.95, 72.59)
4.	*Quercus palustris* Muenchh.	2	4.76	76.75	42.07	47.0, 106.5	17.69 (15.13, 20.74)
5.	*Frangula alnus* Mill.	13	21.43	3.04	1.35	1.0, 5.0	114.95 (98.33, 134.81)
6.	*Viburnum dentatum* var. *lucidum* Ait.	10	19.05	4.40	4.16	2.5, 16.0	88.43 (75.64, 103.70)
7.	*Morus alba* L.	4	7.14	38.63	8.67	31.0, 51.0	35.37 (30.26, 41.48)
8.	*Acer saccharum* Marshall.	7	14.29	3.86	2.38	1.0, 7.0	61.90 (52.95, 72.59)
9.	*Quercus rubra* L.	1	2.38	78.50	-	78.5, 78.5	8.84 (7.56, 10.37)
10.	*Rhodotypos scandens* Makino.	6	11.90	5.08	5.87	2.0, 17.0	53.06 (45.38, 62.22)
11.	*Rhododendron* sp. L.	6	9.52	7.58	5.67	2.0, 18.5	53.06 (45.38, 62.22)
12.	*Celtis occidentalis* L.	5	11.90	2.70	0.84	2.0, 4.0	44.21 (37.82, 51.85)
13.	*Acer platanoides* L.	6	9.52	2.75	2.40	1.0, 7.0	53.06 (45.38, 62.22)
14.	*Pinus strobus* L.	2	4.76	29.75	20.15	15.5, 44.0	17.69 (15.13, 20.74)
15.	*Phellodendron amurense* Rupr.	4	7.14	8.88	3.04	4.5, 11.5	35.37 (30.26, 41.48)
16.	*Malus sylvestris* (L.) Mill.	3	7.14	9.00	8.19	2.0, 18.0	26.53 (22.69, 31.11)
17.	*Ulmus americana* L.	3	7.14	7.83	4.65	4.0, 13.0	26.53 (22.69, 31.11)
18.	*Ailanthus altissima* (Miller) Swingle.	3	7.14	6.17	1.43	4.5, 7.0	26.53 (22.69, 31.11)
19.	*Ilex opaca* Aiton.	3	7.14	3.33	0.29	3.0, 3.5	26.53 (22.69, 31.11)
20.	*Ginkgo biloba* L.	1	2.38	48.00	-	48.0, 48.0	8.84 (7.56, 10.37)
21.	*Acer rubrum* L.	2	4.76	10.75	11.67	2.5, 19.0	17.69 (15.13, 20.74)
22.	*Koelreuteria paniculata* Laxm.	1	2.38	20.00	-	20.0, 20.0	8.84 (7.56, 10.37)
23.	*Cornus mas* L.	1	2.38	16.50	-	16.5, 16.5	8.84 (7.56, 10.37)
24.	*Lindera benzoin* (L.) Blume.	1	2.38	3.50	-	3.5, 3.5	8.84 (7.56, 10.37)
25.	*Evodia daniellii* (Benn.) Hemsl.	1	2.38	3.00	-	3.0, 3.0	8.84 (7.56, 10.37)
26.	*Crataegus* sp. L.	1	2.38	2.00	-	2.0, 2.0	8.84 (7.56, 10.37)
27.	*Styphnolobium japonicum* (L.) Schott	1	2.38	1.50	-	1.5, 1.5	8.84 (7.56, 10.37)

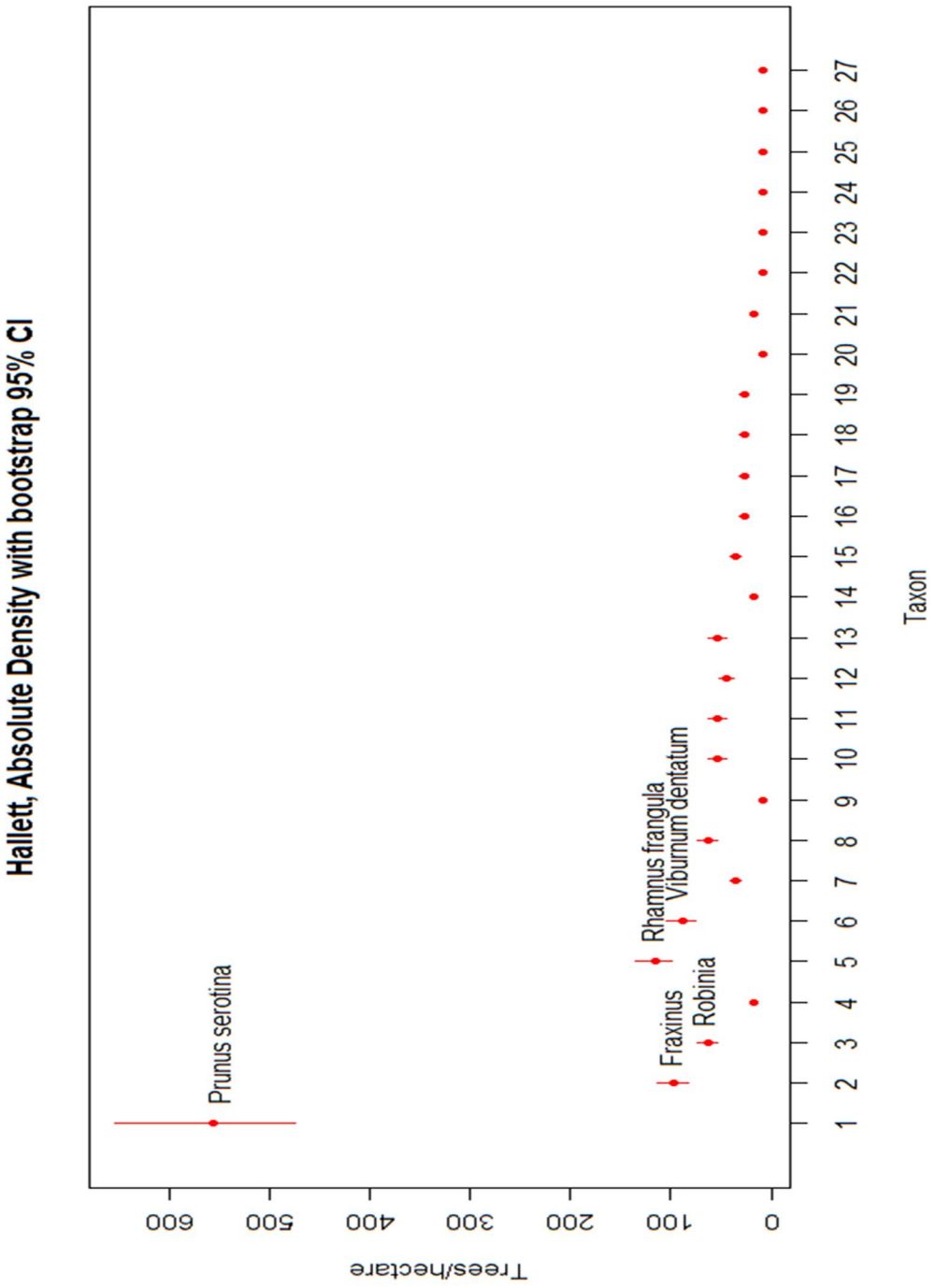

Figure 5.2 Absolute data Hallett

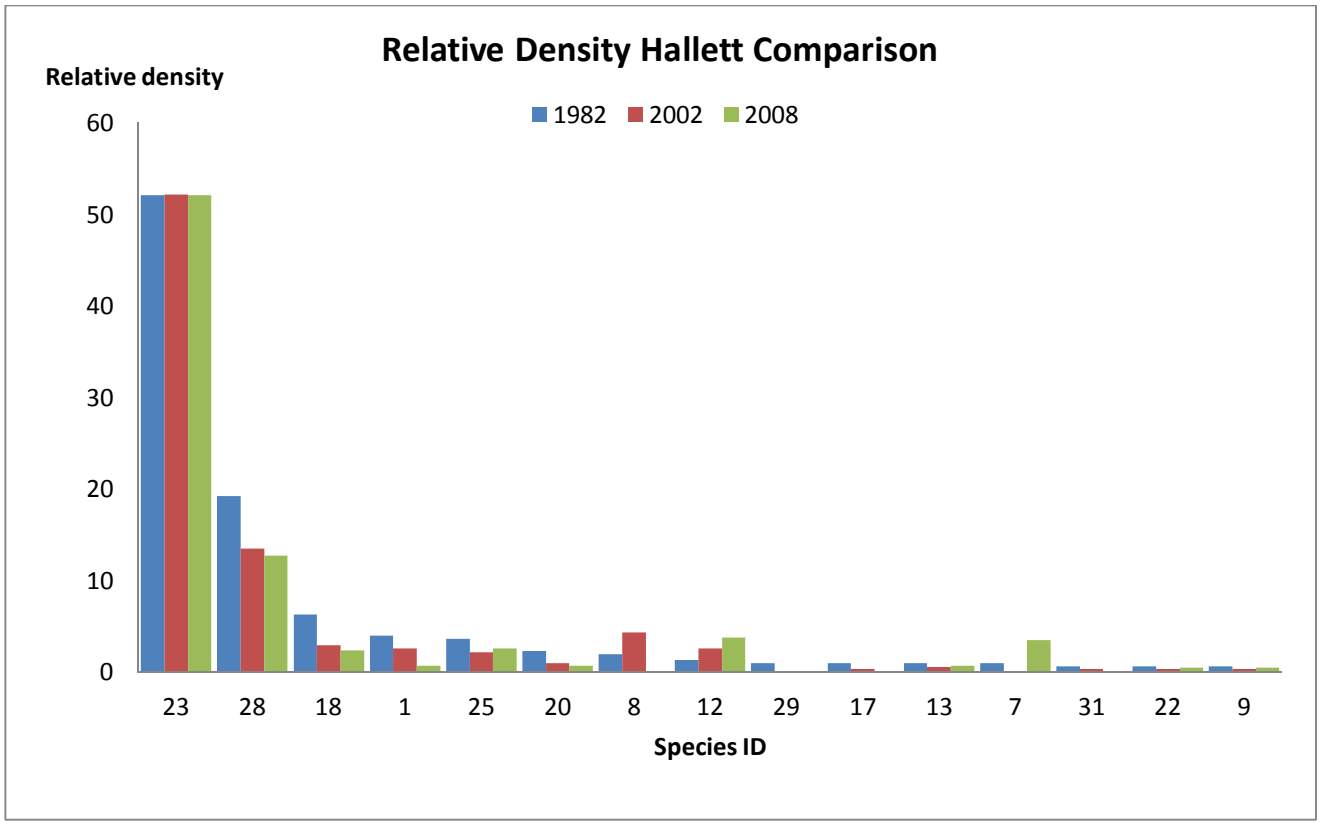

Figure 5.4

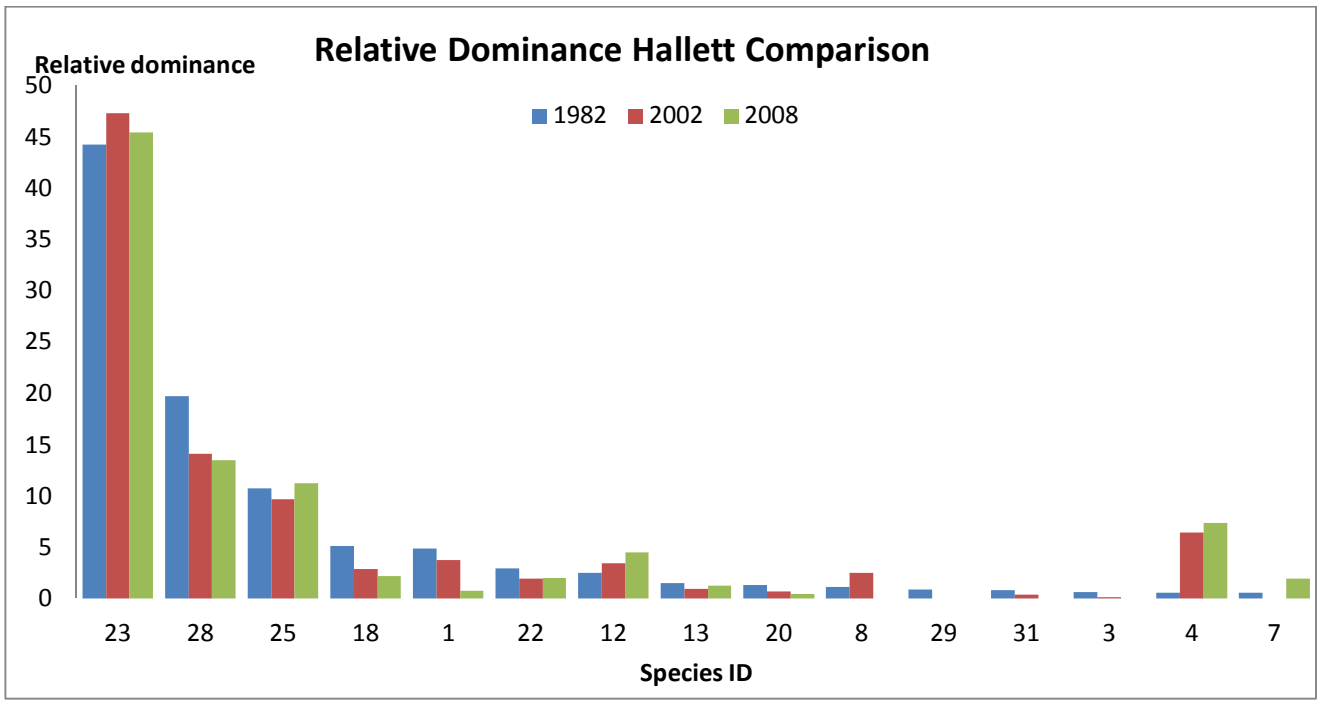

Figure 5.5

Chapter 6 Biodiversity

6.1 Introduction

As was stated in Chapter 1, New York City is not the first place that comes to mind when one thinks of native plants and wildlife habitats. Furthermore, because Central Park is an entirely human-made and highly managed park, it is not the first place that comes to mind to do an ecological study. However, as urban sprawl continues to expand and we lose more natural spaces, urban parks are increasingly important for the conservation of wildlife. This wildlife includes not only the resident wildlife but also wildlife that follow migration routes and need natural areas between their starting and ending points. As will be see in this chapter, even relatively small areas can be important for this type of urban conservation. Although Central Park is the largest park in Manhattan, it is only the fifth largest park in New York City and, compared to other areas such as National Parks, it is relatively small.

At first glance, most people see only the most common animals in Central Park; the pigeon, sparrow and starling; the rat and the squirrel. Many people do not know the myriad other animals in the Park and most city dwellers do not distinguish one plant from another. As this chapter will show, there are many species that depend on Central Park for their survival. Having all this wildlife in the middle of Manhattan is also useful for teaching people about biodiversity and wildlife conservation. Central Park receives more than 35 million visits per year. Many of these visitors are eager to learn about the Park; they attend lectures and go on tours and walks in the Park. They are a good audience to teach about which wildlife resides in cities and what we can do to preserve that wildlife.

6.2 Bryophytes*

Introduction

Despite the fact that they represent an important part of the ecosystem, bryophytes are often overlooked in surveys (Smith 2006). However, the life cycle of bryophytes lends itself nicely to ecological studies, i.e., they have fast colonization/extinction rates; high substrate specificity; simplified dispersal systems--all of which can provide insights into how fragmented landscapes affect plant distribution (Pharo et al. 2004). In contrast to longer-lived organisms, bryophytes can be resampled more often in the short periods of a multi-year study (Pharo and Zartman 2007). In northern Europe they are used as indicator species to identify key areas for preservation (Norden et al. 2007). Bryophytes are sensitive to pollution and trampling. Urban areas have suitable habitat for bryophytes--rock surfaces for colonization (brick, concrete or stone) as well as other habitats – water bodies, parks, gardens, and areas of woodlands (Stevenson and Hill 2008). Many of these areas are important fragments of habitats that are being lost throughout many regions.

Several floristic studies and descriptions have been done about Central Park but none involving bryophytes. This study is the first formal collection of bryophytes in Central Park and can be used as a baseline to compare future collections to examine changes in species diversity. Due to the fact that Central Park is a highly disturbed and managed park, we expected low bryophyte flora.

*This section is based on a study being prepared for publication by Regina V. Alvarez, Graduate Center, City University of New York; Dr. Jon Sperling, Queens College, City University of New York and Dr. Eric Morgan, SUNY Farmingdale.

Methods

Throughout 2007 and 2008, the authors collected mosses and liverworts throughout Central Park. The specimes were identified by one of us (Sperling). Voucher specimens were taken for all species and deposited in the Herbarium of Queens College, Department of Biology, Flushing, NY. Nomenclature for Class Musci follows that of Ketchledge (1980), and Hepaticae follows Schuster (1953). Identification in the field and Lab was done using the keys provided by Andurs (1980), Cruym (1983), Grout (1916), Conard and Redfearn (1979) and Schuster (1949, 1953).

The online herbaria of the New York Botanical Garden and the Brooklyn Botanic Garden were searched for records of byrophytes in New York City and Central Park specifically.

Results and Discussion

A total of 29 species of mosses (in 16 genera) and 4 species of liverworts (in 4 genera) were identified within Central Park. Many of the species were common to the greater New York area.

The online herbaria show no records of collections made in Central Park and very few collections made in New York City.

A comprehensive list of the bryophytes follows.

Class Musci

Amblystegiaceae	*Amblystegium varium* (Hedw.) Lindb.
Amblystegiaceae	*Amblystegium trichopodium* (Schultz) Hartm.
Aulcomniaceae	*Aulcomnium palustre* (Hedw.) Schwaegr.
Brachytheciaceae	*Rhyncostegium serrulatum* (Hedw.) Jaeg. &
Bryaceae	*Bryum argenteum* Hedw.
Bryaceae	*Bryum argenteum* var. *lanatum* (P.-Beauv.)

Bryaceae	*Bryum lisae* var. *cuspidatum* (BSG) Marg.
Bryaceae	*Leptobryum pyriforme* (Hedw.) Wils.
Bryaceae	*Pohlia nutans* (Hedw.) Lindb.
Dicranaceae	*Dicranella heteromalla* (Hedw.) Schimp.
Ditrichaceae	*Cerotodon purpureus* (Hedw.) Brid.
Fissidentaceae	*Fissidens bryoides* Hedw.
Fissidentaceae	*Fissidens taxifolius* Hedw.
Funariaceae	*Funaria hygrometrica* Hedw.
Grimmiaceae	*Grimmia apocarpa* Hedw.
Hypnaceae	*Calicladium haldanianum* (Grev.) Crum
Hypnaceae	*Platydictya subtile* (Hedw.) Crum
Leucobryaceae	*Leucobryum glaucum* (Hedw.) Angstr. *ex.* Fr.
Mniaceae	*Mnium cuspidatum* Hedw.
Orthotrichaceae	*Orthotrichum pumilum* Sw.
Pottiaceae	*Barbula unguiculata* Hedw.
Pottiaceae	*Desmatodon plinthobius* Sull. & Lesq.
Pottiaceae	*Weissia controversa* Hedw.
Polytrichaceae	*Atrichum angustatum* (Brid.) BSG
Polytrichaceae	*Atrichum crispum* (James) Sull.
Polytrichaceae	*Atrichum undulatum* (Hedw.) P. - Beauv.
Polytrichaceae	*Polytrichum commune* Hedw.
Thuidiaceae	*Haplocladium microphyllum* (Hedw.) Broth.
Thuidiaceae	*Thuidium delicatulum* (Hedw.) BSG
Class Hepaticae	
Cephaloziaceae	*Cephalozia bicuspidata* (L.) Dumort.
Lophocoleaceae	*Lophocolea heterophylla* (Shrad.) Dumort.
Pallaviciniaceae	*Pallavicinia leyellii* (Hook.) Caruth.
Marchantiaceae	*Marchantia polymorpha* L.

Table 6.1 Bryological taxa found in Central Park, New York City, NY

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6.3 Flora of Central Park*

Central Park is one of the best known urban parks in North America. At 341.2 hectares (ha), it is the fifth largest green space in New York City (NYC). The park was established in 1853 when the land was obtained by decree of the New York State legislature. After substantial construction, landscaping and planting, the Park was opened to the public in 1858 (Richards 1861, Cook 1869). By 2000, it was estimated that 25 million people visited Central Park each year (The Trust for Public Land 2006).

People have a long association with Central Park. In 1853, there were approximately 1600 residents in the area that would become the Park (Rosenzweig and Blackmar 1992). At that time, a community of mostly African-American citizens lived in Seneca Village, which was between present day 82nd and 86th Streets near the west side. Businesses, including leather tanning works and slaughterhouses, also operated in the Park.

*This section draws upon, corrects and is a significant update to the following publication: DeCandido, R., N. Calvanese, R.Alvarez, M.Brown and T. Nelson. 2007. The naturally occurring historical and extant flora of Central Park, New York City 1857-2007. Journal of the Torrey Botanical Society. 134(4) 552-569.

Up until 1858, it is likely that anthropogenic activities such as cutting wood for fuel, fire and shelter maintained a diversity of habitats in the area of Central Park, including open fields, swamps, meadows and early successional woodlands. During the construction phase beginning in 1858, almost 1000 workers were hired for landscaping projects. By 1873, at least 10 million cartloads of material had been hauled through the Park. Approximately four million trees, shrubs and plants, representing more than 1000 species were planted (Barlow 1977, Graff 1985, Rosenzweig and Blackmar 1992). Today, there are about 200 workers employed by the Central Park Conservancy as gardeners and others working directly with the Park's plants and landscape.

Beginning in the mid-19th century, researchers documented the biodiversity of Central Park including its terrestrial plant species (Rawolle and Pilat 1857), fresh water flora and fauna (Gratacap and Woodward 1884), and breeding birds (Woodruff and Paine 1886). In the past 25 years, geologists have mapped the rock formations and geologic history of the Park (Taterka 1987, Merguerian and Sanders 1993). Other research has assessed long-term changes in woody plant species of the Park (Loeb 1993) as well as atmospheric particulates found in sediment cores extracted from the Central Park Lake (Chillrud et al. 1999, Yan et al. 2005). However, since the 19th century, botanists have not compiled a complete flora of the Park.

Most people are unaware of the great diversity of plant species found in NYC. Sanderson and Brown (2007) mapped 54 ecological communities that once existed on Manhattan Island prior to the 18th century. As recently as the late 19th century, 30 of the 58 native orchids of New York State could be found in NYC, with 21 species occurring on Manhattan Island (Denslow 1924, DeCandido et al. 2004, Lamont 2007).

McKinney (2006) has shown that urbanization produces biotic homogenization of plant species diversity in cities and suburbs in North America and elsewhere. Uncommon and rare native plant species are often extirpated locally as urbanization increases, while on a regional scale, synanthropic (primarily non-native) plants become more widespread (see Chocholouskova and Pysek 2003, Standley 2003, Clemants and Moore 2005). This process has been especially pronounced in port cities of the northeastern United States (Clemants and Moore 2003). The establishment of gardens or other exotic plantings further augments diversity of alien species in cities (Smith et al. 2006). Also, urbanization creates barriers to migration by eliminating direct biotic corridors that native plant species can utilize to re-establish populations in city parks. As a result, despite the overall increase in alpha-level biodiversity in cities, the loss of unique native plants impoverishes urban parks and other natural areas. Urban habitats most affected have been wetlands, moist meadows and woods, with certain plant groups such as orchids and ferns having significantly high extirpation rates (Drayton and Primack 1996, Bertin 2000, DeCandido et al. (2004).

Central Park, the largest green space on Manhattan Island, presented an ideal opportunity to examine the effects of rapid urbanization upon native flora. We had two goals in our research: (1) to document extant plant species diversity of the Park; and (2) to understand how the Park's flora has changed through time. In addition to these goals, we had specific research questions: Were native herbaceous plants, such as wildflowers and ferns, significantly more likely to have been extirpated than native woody species? Were species of certain habitats such as moist meadows, swamps, and mesic woodlands more likely to have been extirpated than species found in upland (dry) woods and meadows? What unique native species were present in Central Park in the past? Are any New York State-listed native plants found in the Park today? By answering

such questions, we could provide guidance to park managers interested in restoring native plant species diversity to natural areas of the Park, and trace an environmental history of Central Park since the mid-19th century.

Materials and Methods. STUDY SITE. Central Park is located in the center of Manhattan (New York County) in the southeastern part of New York State (40 46' 12" N, 73 58' 1" W Fig. 1) The park is rectangular, approximately 4.0 km long and 0.8 km wide, trending 29 NE (Taterka 1987) stretching from 59th street (Central Park South) north to 110th Street. The original northern boundary of the Park was at 106th Street in 1853, but in 1863 additional land was added up to 110th street (Olmsted and Kimball 1928). The lowest point of the Park is 4.5 meters above sea level (masl) at the Harlem Meer at the northeastern section of the Park. The highest point (excluding man-made structures) is 41.3 masl atop Summit Rock near Central Park West and 83rd Street. Today, ballfields, lawns, formal gardens, paved recreational areas and roadways form the major part of the Park. However, there still remain three significant natural areas managed by Central Park Conservancy staff: the North Woods and adjacent Wildflower Meadow (36.4 ha), the Ramble (14.6 ha), and Hallett Sanctuary (1.6 ha).

The topography, flora, and fauna of Central Park have been dramatically affected by landscaping construction that commenced in 1858 under the Greensward plan designed by F. L. Olmsted and C. Vaux (Richards 1861, Cook 1869). Approximately 150 km of underground drainage pipe was installed to eliminate the extensive wetlands of the area (Simpson and Hern 1981). In the southern two-thirds of the Park, most of the exposed Pleistocene boulders were cleared, or moved from their original location in order to create unobstructed vistas that would give visitors

a sense of expanse (Rosenzweig and Blackmar 1992). Both a lake and a reservoir were built in the Park, and four smaller ponds were added or expanded near 59th, 79th, 105th, and 110th Streets.

The geology and soils of Central Park have a long history of investigation (see Mather 1843, Maynadier 1911, Warner and Hanna 1982, Merguerian and Sanders 1993). The Park's bedrock consists of metamorphosed sedimentary rock, originally named Manhattan schist by Merrill (1890) and now considered a complex of three types of schist (Merguerian and Sanders 1993). Other significant geological features in the Park include Cameron's Line located south of 86th Street and the Hartland Formation located primarily south of 70th Street (Taterka 1987, Merguerian and Merguerian 2004). From the Ramble south there remain several glacial erratics derived from the nearby Palisades of western New Jersey (Taterka 1987, Merguerian and Merguerian 2004).

METHODS. From early March through late October 2006, Central Park was surveyed by one observer (R. DeCandido) three to four days per week in March, and again one to two days per week in September-October. Further investigations, usually one to two days per week, were made in April through August 2007. All sections of the park were monitored at least once every other week. Certain areas received more attention than others: the protected walls surrounding the Reservoir, the North Woods, Ramble and Hallett Sanctuary areas, and the margins of Turtle Pond and the Harlem Meer. By comparison, some sections of the Park that are frequently mowed or maintained received less attention: playgrounds, lawns and the southwestern section of Central Park that was undergoing extensive renovations during our study. Voucher specimens were deposited at the Soil, Water and Ecology Lab at the North meadow complex in Central Park. Additional voucher specimens of rare or significant plants collected (e.g., *Eclipta*

prostratra, Polygonum perfoliatum) were deposited at the Brooklyn Botanic Garden for their New York Metropolitan Flora Project.

We focused our efforts on identifying and collecting plant species growing wild (uncultivated) in the Park. We disregarded cultivated plants found in formal gardens, or other areas actively maintained by Park personnel, but did collect weeds in these sites. Most of the plants we expected to find were opportunistic, so we devoted particular attention to a variety of urban habitats that were not frequently mowed, including the edges of sports fields, walkways, bases of walls and buildings, and ephemeral riparian zones. Volunteers N. Wagerik, E. Levine, L. Miller, H. Stillman and R. Lieberman, who have a long-term interest in the Park's flora, helped us find and collect less common species. We also used a tree species list compiled by N. Calvanese, and a list of native species planted in the park by R. V. Alvarez et al. since 2000 (N. Calvanese, unpubl. data, R. V. Alvarez, unpubl. data, DeCandido et al. 2007).

For the historical flora of Central Park we consulted three published lists (Rawolle and Pilat 1857, Viele 1857, Gratacap 1880). Rawolle and Pilat (1857) collected in August and September 1857, and it is likely that many spring and early summer flowering plants were missed. Totals reported for Central Park for historical species occurrence in each of the three 19th century publications should be considered minimum estimates. We also searched on-line databases of the plant collections held at the Brooklyn Botanic Garden (BBG) as well as the New York Botanical Garden (NYBG). We examined the NYBG plant collection for species collected in Central Park. If we found a species at these herbaria not listed on any of the three historical lists or found in our field research in 2006-2007, we included it in this study along with its collection number. If an extirpated or extant plant species had a special state designation as determined by

the Natural Heritage Program (see Young and Weldy 2006), we noted this information in the Appendix.

We did not attempt to assess the current diversity of the Park's planted flora (e.g., Peet 1903) unless a species in question had escaped from cultivation. Additionally, a few (less than five) species that were found in bloom in the Park from 1995 to 2005 but could not be relocated in 2006-2007, were included as extirpated species. We have omitted from the Appendix native species that were planted by Central Park Conservancy staff since 1995 as part of restoration efforts, unless the species in question had also established a significant population outside of restoration sites, gardens or areas that were mostly cultivated.

To update outdated scientific names, we consulted the 5th edition of Gray's *Manual* (Gray 1880), as well as the 8th edition of the *Manual* (Fernald 1950), and Kartesz (1994). We identified plant species using Gleason and Cronquist (1991). We also consulted Mitchell (1978, 1993) and Clemants (1992). Several species of Poaceae were determined by N. Dicker of the Brooklyn Botanic Garden.

From the 19th century plant lists and late 19th and early 20th century herbarium specimens, we compiled an historical database of the flora of Central Park. We classified each species as native or non-native (alien). We then compared these historical species to a database of extant plants we had identified in Central Park in 2006-2007 along with a few additional species collected in the Park since 1985 and held at BBG or NYBG. Nomenclature follows Mitchell and Tucker (1997) with minor revisions found in Mitchell (2000).

In order to understand how the Park's flora and environment changed through time, we classified plants in the Appendix as woody or herbaceous, according to our experience with the species in the Park (see also Gleason and Cronquist 1991), as well as native or non-native to New York State (Mitchell and Tucker 1997, Mitchell 2000). We also categorized each species as one of five general habitat types: dry vs. moist (mesic) woods, dry vs. moist meadow, or wasteland.

We used chi-square tests (see Preacher 2001) with one degree of freedom to test two hypotheses: (1) there are significantly more non-native than native species found in Central Park from 1985 through 2007 than in the 19th century; and (2) in the historical period, there were significantly more native plants species indicative of mesic habitats (moist or wet meadows and woodlands) than native species characteristic of dry (upland) meadows and woods.

	Pteridophytes		Conifers		Dicots		Monocots		Total		Total All
	1857–1910	1985–2007	1857–1910	1985–2007	1857–1910	1985–2007	1857–1910	1985–2007	1857–1910	1985–2007	1857–2007
Native Species	18	6	1	0	220	119	16	20	255	145	331
Non-native Species	0	0	0	0	89	191	2	26	91	217	252
Total Species	18	6	1	0	309	310	18	46	346	362	583

Table1 Number of plant species found in Central Park in the 19th and early 20th centuries compared to species found from 1985-2007

Results. The vascular flora of Central Park (Appendix 4) contains 106 families, 351 genera, and 583 species. Of the 583 species ever identified in the Park, 331 (57%) are native and 252 (43%) are non-native (Table 1). In the 19th century and early 20th century at least 346 species were found in Central Park. Most (255; 74%) were native species and most (221; 64%) were herbaceous plants. Native plants of Central Park in the historical period were significantly more likely to be species that preferred mesic conditions than species that preferred dry habitats (χ^2 =

11.1, $P < 0.05$). By comparison, we found 362 species in our field work in 2006-2007 combined with research of herbarium specimens collected in Central Park since 1985. Of these, 145 are native (40%) and 217 are non-native species (60%). Overall, the proportion of native vs. non-native species in Central Park has significantly changed since the 19th century ($\chi^2 = 81.5$, $P < 0.05$).

New plant records for Central Park since 1985 but not present on earlier lists number 260 species. Most (167, 64%) are non-native species. By comparison, 198 (57%) of the plants listed for the park since the historical time period have been extirpated, including 179 native species (90% of extirpated species). Most of these native extirpated species (117, 65%) were herbaceous plants. Native herbaceous plants were significantly more likely to be extirpated than native woody species ($\chi^2 = 11.4$, $P < 0.05$).

In Central Park in the 19th and early 20th centuries, the plant families with the greatest species richness were the Asteraceae with 30 genera and 42 species (28 native); the Rosaceae, with 11 genera and 21 species (17 native); and the Polygonaceae with 2 genera and 15 species (6 native). Together, they composed 23% of all species known from the historical time period. The largest genera were *Polygonum* (12 species), *Quercus* (10 species), and *Aster* (6 species). For the 1985-2007 period, the families with the greatest species richness were the Asteraceae with 31 genera and 55 species (25 native); the Poaceae, with 20 genera and 24 species (6 native); and the Rosaceae with 11 genera and 21 species (7 native). Together, they composed 28% of all extant species. The largest genera were *Polygonum* (10 species), *Aster* (8 species), *Ranunculus* (6 species) and *Solanum* (5 species). In 2006-2007, of the 339 vascular plant species for which we could determine the time of first bloom, most (132) began flowering in the month of May.

In our field work in 2006-2007, we found 10 of the 12 most invasive species in southeastern New York State (Zimmerman et al. 2006). Six of these pose significant threats to native species and restoration efforts in Central Park: *Acer platanoides, Alliaria petiolata, Polygonum cuspidatum, Ranunculus ficaria* var. *bulbifera, Robinia pseudoacacia,* and *Wisteria sinensis.*

When the 19th century Central Park plant list is analyzed, there are 21 native species (14 herbaceous) listed in the Appendix that, if extant today, would have special status designations in New York State, (see Young and Weldy 2006). During the course of the 2006-2007 survey, 43 (12%) of the 362 extant plant species were judged to be uncommon or rare in Central Park. Of these, 38 (88%) are herbaceous species. Three species we collected have special status designation in New York State: *Eclipta prostrata, Eupatorium serotinum,* and *Ptelea trifoliata.* Seventeen native species (15 herbaceous) have been reduced to a population of a few individuals (less than 10) in Central Park. These are: *Amelanchier arborea, Anemone virginiana* var. *lateriflorous, Boehmeria cylindrica, Cystopteris fragilis, Epilobium ciliatum* ssp. *ciliatum, Equisetum arvense, Lactuca biennis, Linaria canadensis, Lobelia inflata, Onoclea sensibilis, Osmorhiza longistylis, Ptelea trifoliata, Sanicula canadensis, Teucrium canadense* var. *canadense, Triodanis perfoliata* var. *perfoliata,* and *Urtica dioica* ssp. *gracilis.* Three other native herbaceous species were extirpated between 1995 and 2005: *Datura stramonium, Lindernia dubia* var. *dubia,* and *Monotropa uniflora.*

Discussion Our research documents the vascular flora known from Central Park including 106 plant families, 351 genera and 583 species (Table 1). In the 19th century, native plants composed 74% of the species identified in Central Park. However, substantial changes in plant species diversity have occurred in the past 150 years. At least 178 native plants have probably been

extirpated. Native herbaceous species (111 extirpated; 62%) were significantly more likely to be extirpated than native woody species. By comparison, non-native plants today are much more common in Central Park than in the 19th century, accounting for 60% of all species identified from 1985-2007. Of the 165 non-native herbaceous species identified in 2006-2007, only 8 (5%) are considered rare in the Park.

The loss of native plant species diversity in Central Park reflects similar changes that occurred in many other parts of NYC. Historically, Manhattan Island had significant plant species diversity: approximately 50% (704) of the native plants identified in NYC have been found in this borough (DeCandido, unpubl. data). Since the 19th century, Manhattan Island has lost 21 native orchid spp., 24 native fern spp., 24 spp. of native sedges and rushes, 37 spp. of native grasses, and at least 14 spp. of native plants found nowhere else in NYC (DeCandido, unpubl. data).

Changes in plant species diversity occurred rapidly in the new Park. Soon after the first plant inventory was completed by Pilat and Rawolle (1857), landscape-level changes were made to Central Park according to the Greensward Plan designed by Olmsted and Vaux (Cook 1869, Rosenzweig and Blackmar 1992). Many of the Park's wet meadows and mesic woodlands were eliminated. From 1858-1860, gardeners and landscapers systematically removed most of the herbaceous plants from the Park, transplanting a few in other areas but disposing of the majority (Rosenzweig and Blackmar 1992). These landscape-level changes also eliminated several native woody species in the Park: *Populus gradidentata, Prunus virginiana, Quercus alba* and *Q. velutina.* Today, plant species that prefer dry meadows, woodland edges, and upland, rocky woods dominate the flora of the Park. Weedy (primarily non-native) species are now significantly more common in the Park than in the 19th century. Many of the alien species

collected in Central Park since 1985 are widespread throughout the city (DeCandido et al. 2004). The landscape-level changes made to Central Park beginning in 1858 reflect development that subsequently occurred throughout NYC, even affecting areas set aside as park land. This process of biotic homogenization, the loss of unique native species and the simultaneous spread of synanthropic non-native species, will continue to affect parks and other natural areas throughout the city. Currently, only one of NYC's five counties (Staten Island) has more extant native plant species than extirpated native ones (Robinson et al. 1994, DeCandido et al. 2004). Other studies from the northeastern United States have reported similar trends: the decline of uncommon to rare native plants, particularly herbaceous species, and a sharp increase in alien plants (see Brown 1913, Bertin 2000, Standley 2003, DeCandido 2004).

Historically, in the pre-Park era, both the native plants and the habitats they composed were very different from the ones people encounter in Central Park today. Using the three 19th century plant species lists and herbarium specimens at BBG and NYBG, we describe two distinct habitats of the Park as they might have appeared before construction began in 1858. We also examine plant species diversity in typical environments of Central Park today.

Historical Era. Human settlements were scattered through the Park pre-1858, and native plant species far exceeded non-natives. Wetlands were extensive and diverse, and most native plants preferred mesic conditions rather than dry habitats (Rawolle and Pilat 1857). Species indicative of wet meadows, riparian areas, and swamps included *Alisma subcordatum, Alnus serrulata, Andromeda glaucophylla, Asclepias incarnata, Boehmeria cylindrica, Cephalanthus occidentalis, Cornus sericea, Epilobium coloratum, Getiana andrewsii, Leucothoe racemosa, Lysimachia terrestris, Mimulus alatus, Osmunda regalis* var. *spectabilis, Parietaria*

pensylvanica, Penthorum sedoides, Physostegia virginiana, Polygonum amphibium var. *stipulaceum, Ranunculus amigens, Rubus hispidus, Salix humilis* var. *humilis, Samubucus canadensis, Saururus cernuuns, Spiranthes lacera* var. *gracilis,* and *Toxicodendron vernix.*

Species indicative of rich, mesic woodlands in the 19th century were *Acer rubrum* var. *rubrum, Agrimonia parviflora, Aralia racemosa, Arisaema triphyllum* ssp. *triphyllum, Betula nigra, Botrychium dissectum, Clethra alnifolia, Collinsonia canadensis, Cornus rugosa, Heliopsis helianthoides, Ilex laevigata, Lilium canadense* ssp. *canadense, Lonicera sempervirens, Lycopodium dendroideum, Matteuccia struthiopteris, Phegopteris connectilis, Populus heterophylla, Rhododendron viscosum, Rosa carolina* var. *carolina, Salix discolor,* and *Symplocarpus foetidus.* In the woodlands, tree species diversity was high. Ten native oak species were identified in the Park, including *Quercus alba, Q. coccinea,* and *Q. stellata.* In drier areas of the uplands, native wildflowers included *Aquilegia canadensis, Chamaecrista nictitans, Desmodium canadense, Hypericum gentianoides, Opuntia humifusa, Silene caroliniana* var. *pensylvanica,* and *Silene stellata.*

19th century rare or significant native species. According to current criteria developed by the Natural Heritage Program in NYS (see Young and Weldy 2006), 21 species present in Central Park in the 19th century have special status designations in the state today. These are: *Acalypha virginica* var. *virginica, Agrimonia parviflora, Betula nigra, Botrychium lunaria, Celastrus scandens, Crotalaria sagittalis, Diospyros virginiana, Galactia volubilis, Hypericum prolificum, Juglans cinerea, Lespedeza violacea, Mimulus alatus, Silene caroliniana* var. *pensylvanica, Polygonum careyi, Polygonum tenue, Populus heterophylla, Ptelea trifoliata, Pycnanthemum clinopodioides, Rubus cuneifolius,* and *Salvia lyrata.* The historical status of four species in

Central Park recorded on the 19th century lists is questionable. *Tilia americana* var. *herterophylla* has not been found in other parts of NYC, and herbarium records come from central NYS (see Young and Weldy 2006). *Rhododendron arborescens* is listed as reported from NYS; however, no herbarium specimen is currently known from NYS (Mitchell 2000). Finally, there are two species, *Aletris aurea* and *Fuirena squarrosa,* that are not known in NYS either by voucher specimens or other types of reports. These may represent errors in identification by Pilat and Rawolle (1857). However, there are two closely related species (*F. pumila* and *A. farinose*), once collected in NYC, for which voucher specimens exist. For these four species, we have indicated the current uncertainty of their historical status in the metropolitan area in the Appendix.

Central Park 2006. Ongoing restoration efforts since ca. 1995 have increased native plant species diversity of the Park. Current management policy seeks to re-establish extirpated habitats such as wildflower meadows, and significantly increase the diversity and number of native herbaceous plants in riparian areas and upland woods. In the forests, *Acer platanoides* is the most difficult alien species to control. In the understory, removal of non-native *Alliaria petiolata, Polygonum cuspidatum, Ranunculus ficaria* var. *bulbifera,* and *Wisteria sinensis* require many hours of removal effort each year. *Polygonum perfoliatum* has been a recent arrival (since ca. 1997) but has been contained. In the woodlands, restoration efforts have concentrated on widespread planting of native trees, especially *Liriodendron tulipifera, Quercus alba,* and *Q. velutina* as well as other tree species typical of NYC.

There are three habitats typical of Central Park today: upland woods, riparian areas including ponds and a man-made reservoir, and ruderal areas with a diverse, primarily non-native flora.

In the woodlands, native species that thrive in dry, rocky, acidic soils are common. These include *Celtis occidentalis, Prunus serotina, Q. rubra,* and *Ulmus* spp. In richer soils two species predominate: *Liquidambar styraciflua* and *Liriodendron tulipifera.* Common forbs of the understory include *Alliaria petiolata, Allium vineale, Aster divaricatus, Circaea lutetiana* ssp. *canadensis, Eupatorium rugosum, Polygonum virginianum,* and *Viola sororia.* Invasive woody species such as *Acer platanoides, Acer pseudoplatanus, Phellodendron amurense, Quercus cerris,* and *Robinia pseudoacacia* are widespread and reproduce rapidly. In areas where *Q. cerris* is common along the southern edge of the reservoir, *Epipactis helleborine* (Figure 6.2) thrives in large colonies of 100-200 individuals in the shade of these oaks. In the last decade, native trees such as *Fraxinus* spp. and *Ulmus americana* have declined in number due to summer drought, the urban heat-island effect, non-native tree diseases, and non-native insects. In the canopy gaps, *Prunus serotina* is common, and it is the most abundant woody species in the Park (see also Loeb 1993).

Figure 6.1 *Epipactis helleborine*, the only Orchidaceae in the Park

In the wetlands of the Park such as riparian areas along the margin of the Harlem Meer, the Lake and Turtle Pond, restoration efforts have been negatively affected by large numbers of overwintering waterfowl, particularly Canada geese (*Branta canadensis*) and mallards (*Anas platyrhynchos*). These birds graze on tubers and emergent vegetation along the water's edge creating erosion problems and reducing habitat quality for other species. However, certain plant species can tolerate high levels of herbivory and have persisted in the Park. These include *Bidens frondosa, Cephalanthus occidentalis, Eclipta prostrata, Eupatorium perfoliatum, Hibiscus moscheutos, Impatiens capensis, Iris psedacorus, Saururus cernuus, Scirpus americanus, Typha latifolia,* and *Vernonia noveboracensis*. Along the protected rocky, sloping margin of the man-made reservoir, several herbaceous plant species are common: *Apocynum cannabinum* var. *cannabinum, Artemisia vulgaris, Asclepias syriaca, Chenopodium album* var. *album, Cirsium arvense, Conyza canadensis* var. *canadensis, Erechtites hieracifolia* var. *hieracifolia, Erigeron annuus, Eupatoirum serotinum, Hieracium subaudum, Lactuca canadensis* var. *canadensis, Lapsana communis, Linaria vulgaris, Parthenocissus quinequefolia, Polygonum lapthaifolium, Saponaira officinalis, Senecio vulgaris, Solidago canadensis* var. *scabra,* and *Verbascum thapsus*.

Central Park has a great diversity of ruderal species, including several non-native species of these families: Asteraceae, Brassicaceae, Chenopodiaceae-Amaranthaceae, and Polygonacaeae. Common weed species of the Park that thrives where full-sun conditions prevail include: *Amaranthus blitum, Cerastium fontanum, Chenopodium ambrosioides, Chenopodium pumilio, Matricaria discoidea, Mazus pumilus, Portulaca oleracea, Sagina* spp., *Senecio vulgaris, Sonchus oleraceus, Stellaria media,* and *Veronica persica.* In open areas once dominated by ruderals where restorations have begun, herbaceous meadow species are now thriving. Native

herbaceous species recently planted in Central Park that have done well and have spread to other areas include *Andropogon gerardii, Aster cordifolium, Aster novae-angliae, Aster novae-belgi* var. *novae-belgii, Erythronium americanum, Eupatorium perfoliatum, Eupatorium purpurea, Panicum* spp., S*chizachyrium scoparium* ssp. *scoparium, Silphium perfoliatum,* and *Solidago caesia.*

Central Park presents a unique opportunity to restore native meadows, woodlands, and riparian habitats in the center of a great metropolis. The restoration will depend upon coordinating the efforts of Park workers, volunteers and students from nearby schools. We recommend utilizing the extirpated plants listed in the Appendix whenever possible to return unique native species to Central Park. From a broader perspective, educational efforts should strive to make NYC residents aware of the significant diversity of plants and animals that have been found here. This biological diversity mirrors the complex cultural diversity of the people who compose NYC. Given the interest of many New Yorkers in the global environment, emphasis must also be placed upon the role local parks play in preserving regional biodiversity. The key to protecting the Park's remaining biodiversity will be to make people, at the grassroots level, aware of species that can still be seen in the natural areas of the Park and also aware of the rich flora and fauna that were extirpated.

Conclusions. The environmental history of Central Park shows that plant species diversity has significantly changed through time. Approximately 70% of the 248 native plant species identified in the park in the 19th and early 20th centuries have been extirpated. These extirpations disproportionately affected native herbaceous plants, including wildflowers and ferns growing in riparian areas such as swamps, moist meadows, and mesic woods. Non-native plants now

dominate the flora of Central Park, accounting for 60% of the species found in the Park from 1985 to 2007. Most of these alien species are widespread throughout New York City. The substantial change in Central Park's plant species diversity mirrors the loss of native plant species on Manhattan Island since the 19th century. Two strategies can halt and possibly even reverse this marked decline of New York City's biological heritage: education and restoration.

Full floral species list is Appendix 4.

Post 2006 update

The compiling of a complete flora of an area is an ongoing project, especially in a managed park. Species may have been overlooked; errors may have occured in printing; environmental conditions may have changed; areas have been restored; and new plants and seed sources have been brought in. What follows are some observations made since this paper was published.

One error in the full plant list is that *Acer saccharum* was omitted. As we have seen from my research, this species is not only present in the Park, but is regenerating (See Table 5.1). *Acer negundo* is also not listed; however, I found a small stand of it in the North Woods. My survey captured 7 stems of sizes 1.5 cm to 7.5 cm (see Table 4.2). This area should continue to be monitored to determine if this represents a self-sustaining population.

A species that we listed as extirpated was *Monotropa uniflora* L., Ericaceae. At the time the paper was published, we had in fact not seen that plant for the years indicated. However, one small stand made an appearance in 2009 (Figure 6.1). It has not been seen since. We are monitoring the site to see if it appears again.


Figure 6.2 *Monotropa uniflora* photographed in 2009

Quercus species that we listed as extant and regenerating on their own were *Q. palustris, Q. cerris and Q. rubra.* Other *Quercus* species can be found throughout the Park and it will be worthwhile to monitor restored areas to see if they begin regenerating. As indicated earlier in this text, this genus does not regenerate well in disturbed areas but once an area is restored and the soil is uncompacted, young red and pin oaks appear.

Prunus virginiana L., Rosaceae is listed only in historical records. My survey captured two small specimens, 8.5 cm and 9.5 cm. These were found in the North Woods and are listed in Table 4.2. However, this may not represent a self-sustaining population. The area should be resurveyed.

Diospera virginiana L. Ebenaceae is listed as only in historical records. There are several specimens in the Ramble that were planted by the Conservancy in the 1980s. In the past ten years, this site was revisited and additional work was done in this area to reduce compaction. Young persimmon saplings were planted, but others have come up on their own. Some are root

suckers, but there are some that appear to be regenerating from seed. This area should be monitored for further regeneration of this species.

In 2006 *Humulus japonicus* is listed as extirpated. However, since the restoration of the Great Hill area, this species has appeared in great numbers. This is a new population probably brought in with horticultural plant material used in the restoration of the area (See Chapter 7). It has since spread to other areas surrounding the Great Hill and is being managed by the Conservancy as an invasive species.

Platanus occidentalis is also listed as solely historical. However, following the restoration of the Ramble area North of Bow Bridge, *P. occidentalis* seedlings began appearing in the restored soil in areas around a large specimen. So far many of the seedlings die back because of shade. However, this area and surrounding restored areas should be monitored to determine if this becomes a self-sustaining population.

Photinia villosa is listed, and my survey found 16 stems in the North Woods (1 to 24.5 cm DBH). I also found one stem of *Photinia glabra*, 7.5 cm DBH, also in the North Woods. This species is not listed in the flora. The area should be resurveyed to determine if there are other stems and if it is a self-sustaining population.

Aquilegia canadensis is listed as historic and also listed as planted in 1995-2005. This species is recently showing signs of regenerating from seed in restored areas.

Eupatorium serotinum is listed as non-native. According to the USDA Plant Database, Clemants and Gracie (2006), and Peterson (1968), this species is native to the northeast United States. It is also listed as NYS S2, which means "Imperiled in New York State because of rarity (6-20 sites

or few remaining individuals) or highly vulnerable to extirpation from New York State due to biological or human factors." (Young 2010). However, in Central Park, this species regenerates at a rapid pace, quickly covering the areas in which it is found.

Eupatorium perfoliatum is listed as historic. Recently the Conservancy has been planting this species, which regenerates from seeds in restored areas. This species should be monitored to determine if a self-sustaining population is established.

Lilium superbum L., Liliaceae is not listed. Recently the Conservancy has been planting this species. It has shown signs of slowly self-seeding in restored areas. It remains to be seen if it establishes reproductive populations.

Matteuccia struthiopteris is listed as historic. Recently the Conservancy has been planting this species. In restored areas it spreads easily through rhizomes. This species should be monitored to determine if wild populations form.

One stem of *Vaccinium corymbosum* (1 cm DBH) was found in the Ramble. This species is listed as historic. However, this stem is most likely from a planting done by the Conservancy.

Other species to monitor that are listed historically or not listed and have recently been planted are *Rosa virginiana*, *Rosa carolina* L., *Rubus occidentalis* L., Rosaceae; *Vaccinium angustifolium* Ait., Ericaceae; *Cornus florida* L Cornaceae; *Rhus glabra* L. *Rhus typhina,* Anacardiaceae; *Verbena hastata* L., Verbenaceae; *Pycnanthemum muticum,* Lamiaceae; *Lobelia cardinalis* L. and *Lobelia siphilitica,* Campanulaceae; *Lonicera sempervirens* L., Caprifoliaceae; *Goodyera pubescens* (Willd.) R. Br., Orchidaceae; *Opuntia humifusa* L., Cactaceae.

Tradescantia virginiana L., Commelinaceae is listed as non-native. According to the USDA Plant Database, Clemants and Gracie (2006), and Peterson (1968), this species is native to the northeast United States.

At the time this paper was written, there was a significant problem with Canada geese and mallards along the wetland edges of the ponds and lakes. However, since that time, the Conservancy has implemented the use of border collies to reduce the population of geese in the park. This is a non-harmful method since the dogs are similar enough to geese predators in the wild that they frighten the geese away. This program is in its third year and seems to be making a difference for the wetland plantings. Future studies should focus on these wetland species.

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6.4 Other Biodiversity Surveys

Introduction

This section is a review of other biodiversity surveys. I assisted or led some of these surveys and other surveys were led and completed by other scientists. The objective of this section is to pull together as much information about the biodiversity of the park as is available and to have it in one place where everyone can access it and add to it.

Fungi

Gary Lincoff is a former president of the North American Mycological Society and the author of the National Audubon Society Field Guide to North American Mushrooms (1981). He has been conducting a survey of the fungi of Central Park since 2006. The full list of fungi as of December 2011 is found in Appendix 5. He has documented these species with photographs which can be found on his website, garylincoff.com.

Invertebrates

The list of invertebrates, totalling 389 species, was gathered from several places. The 2006 and 2008 BioBlitz events tallied significant numbers of invertebrates. Marie Winn, a member of the Central Park Conervancy's Woodland Advisory Board shared her list of night moths for this study. She and several other Park patrons, spent many hours identifying and photographing night flying moths. Other species on the list were identified by me and other Conservancy staff members. This list is far from complete but is a first attempt at gathering all invertebrate species

of Central Park in one database. To my knowledge this is the first attempt to consolidate this information in one place. A follow-up to compiling this list is to get photographic confirmation or voucher specimens of each species. The list of invertebrates is Appendix 7.

The Central Park Centipede

Elizabeth Johnson of the American Museum of Natural History's Center for Biodiversity conducted a survey during 1997-98 in the woodlands of Central Park, focusing on leaf litter invertebrates. The collection was sorted and sent to experts for identification. One species of centipede, collected from leaf litter in the North Woods, posed a problem in identification and was sent to experts in Italy (Elizabeth Johnson, personal communication). Foddai et al. (2003) identified it as a new species in the family Arrupinae and named it *Nannarrup hoffmani*. The Central Park specimen is the type specimen for this species as it was the first to be discovered. At 10.3 mm in length, this is the smallest member of the family and the only species in the genus. The population in the North Woods is the only known population and it is considered to have been introduced, perhaps from Asia, likely via soil with plant material.

Summer 1997 the Center for Biodiversity and Conservation at AMNH and the Central Park Conservancy initiated a survey of the leaf litter of the woodlands of CP. The purpose was to develop a species list of the leaf litter invertebrates to provide a baseline data set and to educate the public on the importance of soil organisms and their diversity in urban areas.

Representatives of the major invertebrate taxa were found but species diversity of some groups was low compared with non-urban forests such as Black Rock Forest. The low numbers are

probably due to unfavorable environmental conditions, higher pollution levels and heavy use by park visitors leading to soil compaction and dryness.

Also, the grazing activity of high densities of non-native earthworms also appears to be significantly reducing the amount of litter available for other species. In addition, the leaf litter provided by the overstory of the non-native tree species in the park may not provide the resources required by many leaf litter dwellers.

The report goes on to say that the major functional groups of invertebrates are well-represented, so with continued resotation the litter and soil conditions should improve, leading to increased litter species diversity.

Birds

Of all species in Central Park, birds are the most observed and cataloged. As noted in the introduction, Central Park is one of the top ten birding locations in the country. A recently updated checklist of the birds of Central Park is found in Appendix 7. This list was provided to me by Marie Winn. She and the following reviewers worked on this list: Tom Fiore, Dick Gershon, Jack Meyer, Roger Pasquier, Peter Post, Steve Quinn, David Speiser, Lloyd Spitalnik and Bruce Yolton.

Mammals

There are far fewer mammals than birds, fungi or invertebrates. However, there are more than most people are aware of (Table 6.2). Two species on the list are feral domestic dogs and cats. People historically have used Central Park as a dumping ground for unwanted animals. Efforts are made to keep up with capturing these animals.

Bats are common in the park, although most species except the big brown bat and little brown bat are migratory.

Eastern cottontail rabbits used to be found in the park, but have not been seen in the past 5-10 years. The proliferation of raccoons may be the cause.

Norway rats have historically been a problem in Central Park (as well as the rest of New York City). However, great strides have been made by the Conservancy to control the population. The main effort is in sanitation, keeping the food source low for rats has helped tremendously and is now the main method used for control. Although they were used in the past, the Conservancy has discontinued the use of rodenticides.

With the decrease in the population of the Norway rat, there has been an increase in the population of Eastern chipmunk. It will be worth monitoring this species in the future to see if a sustaining population develops.

White-footed mice were discovered in the pellets of owls wintering in Central Park in 1996 (Marie Winn, personal communication). But recently, a population genetics study done by Dr. Jason Munshi-South of Baruch College (2012) gave definite proof of populations of white-footed mice in the North Woods and the Ramble. None were found in Hallett.

There have been reports of oppossums, but no confirmed sightings.

There was one unconfirmed sighting of a flying squirrel at the Great Hill during the clean up of the storm of August 2008.

Species	Common Name
Canis familiaris	Domestic dog
Eptesicus fuscus	Big brown bat
Homo sapiens	Human
Lasiurus borealis	Eastern red bat
Marmota monax	Woodchuck
Peromyscus sp.	Deer mouse
Procyon lotor	Raccoon
Rattus norvegicus	Norway rat
Sciurus carolinensis	Gray squirrel
Peromyscus leucopus	White footed mouse
Myotis lucifugis	Little brown bat
Lasiurus cinereus	Hoary bat
Sylvilagus floridanus	Eastern cottontail rabbit
Canis latrans	Coyote
Tamias striatus	Chipmunk
Felis domesticus	Feral cat
Mus musculus	House mouse
Glaucomys sabrinus	Northern flying squirrel

Table 6.2 Mammals

Fish

The list of fish species comes from several "fish-rescues" during the renovation of the various water bodies in the park, and from a survey done by the Conservancy in 1995 of the Harlem Meer Fish. The fish rescues involved capturing and moving fish from a water body that was undergoing renovation and putting them in another water body. During that process, the species were identified by me and other Conservancy staff.

Species	Common name	Family
Lepomis gibbosus	Pumpkinseed	Centrarchidae
Lepomis macrochirus	Bluegill	Centrarchidae
Micropterus dolomieu	Smallmouth Bass	Centrarchidae
Micropterus salmoides	Largemouth bass	Centrarchidae
Pomoxis annularis	White crappie	Centrarchidae
Pomoxis nigromaculatus	Black crappie	Centrarchidae
Carasius auratus	Goldfish	Cyprinidae
Ctenopharyngodon idella	Grass carp	Cyprinidae
Cyprinus carpio	Common carp	Cyprinidae
Notemigonus crysoleucas	Golden shiner	Cyprinidae
Pimephales cf. notatus	Bluntnose minnow	Cyprinidae
Pimephales promelas	Fathead minnow	Cyprinidae
Esox niger	Chain pickerels	Esocidae
Fundulus diaphanous	Banded killifish	Fundulidae
Ameiurus melas	Black Bullhead	Ictaluridae
Ameiurus natalis	Yellow bullhead catfish	Ictaluridae
Ameiurus nebulosus	Brown bullhead catfish	Ictaluridae
Ictalurus punctatus	Channel catfish	Ictaluridae
Perca flavescens	Yellow perch	Percidae
Gambusia affinis	Mosquitofish	Poeciliidae

Table 6.3 Fish species of Central Park

Herptiles

Some species of turtles and frogs are seen throughout the Park on a regular basis. Others have been identified during various fish rescues and during the two BioBlitz events. Several non-native species have been seen only once and may represent species that have been abandoned in the Park by Park patrons. These include the African helmeted turtle, Florida cooter and musk turtle. Several native species have been seen few times and further studies should be made to determine if these are self sustaining populations. These include box turtle, yellowbelly slider, spring peeper, green frog and wood frog.

Turtles	
Snapping turtle	Chelydra serpentine
Wood turtle	Chlemmys insculpta
Western painted turtle	Chrysemys picta bellii
Eastern painted turtle	Chrysemys picta picta
African helmeted turtle	Pelomedusa subrufa
Florida cooter	Pseudemys floridana floridana
Musk turtle	Sternotherus odoratus
Box turtle	Terrapene carolina carolina
Red-eared slider	Trachemys scripta elegans
Yellowbelly slider	Trachemys scripta scripta
Frogs	
Spring peeper	Pseudacris crucifer
Bullfrog	Rana catesbeiana
Green frog	Rana clamitans melanota
Wood frog	Rana sylvatica

Table 6.4 Herpetiles of Central Park

Figure 6.3 Wood turtle found in the Shakespeare Garden

Figure 6.4 Yellowbellied slider

Mollusks

Pyganadon cataracta was discovered by me and my staff in the Lake during the 2007 fish rescue that preceded the restoration of the Lake. Although this is a common species throughout our area, this was the first sighting of this species in Central Park. We found approximately 100 individuals.

Other mollusks found during the two BioBlitz' are included in table 6.5. Future surveys should be conducted to complete this list.

Oxychilius	*cellarius*	Mollusk
Zonitoides	*arboreus*	Tree zonite snail
Lehmannia	*poirieri*	
Arion	*hortensis*	Slug
Physella	*heterostropha*	
Deroceras		Slug
Limax	*maximus*	
Physella	*heterostropha*	

Table 6.5 List of Mollusks from 2006 BioBlitz

Algae and Other Aquatic Organisms

A survey of aquatic organisms has not been done. This is planned for a future project. Table 6.6 shows a sample of aquatic organisms identified by Conservancy staff and during the 2006 BioBlitz.

Rhizoclonium sp
Microspora sp
Characium sp
Rhizoclonum
Euglenoids
Daphne water fleas
Chaetonotus
Midge larvae
Chironomus
Aquatic earthworms
Aelosoma
helodrilus
Halteria
Strobilidium
Arcella
Eudorina
Phacus
Ankistrodesmus
Synedra
Nitzschia linearis
Navicula
Staurosirell pinnata
Pinnularia
Cymbella

Table 6.6 Sample of aquatic organisms

Bibliography Chapter 6

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Chapter 7: Invasive Species

7.1 Introduction

There are several definitions of invasive plants. Cronk and Fuller (2001) define them as "alien plants spreading naturally in natural or seminatural habitats, to produce a significant change in terms of composition, structure or ecosystem processes." Richardson et al. (2000) define naturalized plants as "Alien plants that reproduce consistently and sustain populations over many life cycles without direct intervention by humans (or in spite of human intervention); they often recruit offspring freely, usually close to adult plants, and do not necessarily invade natural, seminatural or human-made ecosystems." They then define invasive plants as "Naturalized plants that produce reproductive offspring, often in very large numbers, at considerable distances from parent plants, and thus have the potential to spread over a considerable area." Sarver et al. (2008) define an invasive as "an alien plant species that is capable of rapid spread into relatively undisturbed natural communities and that, once established, causes adverse ecological impacts within the invaded community."

Most non-native plants in the United States were introduced for food, fiber and ornamental purposes and an estimated 5,000 species are established (Pimentel et al. 2004), about 675 of which are thought to be highly invasive (Weston et al. 2005). An estimated 138 non-native tree and shrub species have invaded U.S. forest ecosystems (Pimentel et al. 2004). Cost estimates for dealing with the problem of invasives exceed $138 billion annually, with plants accounting for over $34.7 billion of that total (Weston et al. 2005). There is often a sequence of events that transforms a native plant into an invasive species. First, a species is moved from its native range to a new location. This happens either deliberately or accidentally. Depending on the mode of

transport, many species die in transit. These plant species then interact with their new environment. Approximately 10% of species released establish self-sustaining populations. A yet smaller percentage goes on to become widespread enough to be considered invasive (Kolar and Lodge 2001). In the United States, approximately 400 of the 958 species listed as threatened or endangered under the Endangered Species Act are there because of threats from non-native species (Pimentel et al. 2004). Other factors that make a plant invasive may include lack of natural enemies (the "escape from enemies hypothesis"), development of new associations, disturbed habitats that provide favorable ecosystems or species simply being highly adaptable (Pimentel et al. 2004). Some species alter nearby soil chemistry by secreting chemicals that inhibit the germination of seeds or growth of other plants (allelopathy) (Sarver et al. 2008). The problem of invasive species differs from other environmental problems in that it is persistent. If a problem such as pollution stops, the habitat can usually recover. However, if one stops bringing invasive plants to a habitat, the site does not recover because those plants that are already there continue to spread and cause destruction (Cronk and Fuller 2001). Being able to predict which species will become invasive is critical for managers.

Invasive plants affect wildlife in several different ways. Robins nesting in invasive shrubs such as *Lonicera maackii* and *Rhamnus carthartica* experience higher predation than robins nesting in comparable native shrubs (Richardson 2011). Some change the soil chemistry around them and thus the soil microbes are affected. Some are unpalatable to native invertebrates, thus there is reduced forage for insect-eating birds.

Despite their negative impacts, some invasives do provide some food and cover for native wildlife and in areas that are already highly disturbed, their contributions to wildlife can be important (Sarver et al. 2008). In some areas, invasive species are seen as good nurse plants for

the restoration of severely degraded areas (Richardson 2011). A case in point: On Easter Island, where the environment had become severely degraded from loss of all trees, many native plant species became extinct. During my work there on an ecological restoration project in 2007, I observed how "invasive" plants, brought in for such ecological projects as well as food for human consumption and forage for livestock, can serve as habitat to wildlife in such a degraded environment (Alvarez and Sperling 2010).

There are six species of invasive plants in the woodlands of Central Park that for some time now have presented the most problems for the managers. *Polygonum cuspidatum* Siebold & Zucc. Polygonaceae (Japanese knotweed) and *Acer platanoides* (Norway maple) are two of the more prominent invasives. The other major invasives are *Wisteria sinensis*, Fabaceae (Chinese wisteria); *Ranunculus ficaria* L. Ranunculaceae (Lesser celandine); *Alliaria petiolata* (M. Bieb.) Cavara & Grande, Brassicaceae (Garlic mustard); and *Artimesia vulgaris* L., Asteraceae (Mugwort or Common wormwood). There are others that are newly introduced, such as *Polygonum perfoliatum*, Polygonaceae (Mile-a-minute vine or Asiatic tearthumb) and *Humulus japonicus*, Cannabaceae (Japanese hops). And as my results indicate, others such as *Styphnolobium japonicum* (Japanese scholartree) and *Aralia elata* (Japanese angelica tree) still have the potential to become invasive.

7.2 Invasive Tree and Shrub Species

It has been only in the past few decades that any tall woody plants have been considered invasive species (Richardson 2011). Many species and families contribute to the list of invasive woody plants world-wide, but it is interesting to note that there are several families that have not yet contributed any or at least very few invasives: Anacardiaceae, Betulaceae, Ericaceae, and

Magnoliaceae, to name a few. It is unknown why these families contribute so few invasive species, but it may have to do with how recently they have been transported around the globe; given more time, there may be more invasives from these families (Richardson 2011). An exception may be the families in the Pinopsida. These species have life history traits (e.g., small seeds and short juvenile periods) such that they are not likely to become invasive (Richardson 2011).

Acer platanoides has been shown to be a problematic tree, capable of dominating some forest stands (Martin 1999). It was introduced in 1756 to Philadelphia by the botanist John Bartram (Sarver et al. 2008). In Central Park it was planted as an ornamental and this species has been used extensively in the horticultural field, often as street trees. It has robust growth, high seed production and a high tolerance for shade. It occupies a similar habitat to *Acer saccharum,* the native American sugar maple. However, its phenology is such that it leafs out earlier in the spring and holds its leaves longer in the fall than the native species, by at least two weeks in both directions. It displaces the native flora by casting deep shade. During my tenure in the Park I observed how areas liberated of dense stands of young Norway maples quickly recover an herbaceous layer, especially ephemerals such as trout lily (*Erythronium americanum* Ker Gawl.) (Figure 7.1). A study done by Patrick Martin (1999) showed that, regardless of the size of the canopy of a Norway maple stand, species richness in the understory was adversely affected. He suggests that this is a result of greater competition for resources due to Norway maple's rapid growth rate.

Figure 7.1 *Erythronium americanum* thriving in a woodland freed of young Norway maple saplings

The ecological dominance rankings for the total data set (Table 2.1) show many native species in the top ten: *Prunus serotina, Quercus rubra, Q. palustris, Ulmus americana, Fraxinus americana, Celtis occidentalis, Viburnum dentatum* var. *lucidum*. However, *A. platanoides* is third in ecological dominance despite years of removal by the Park managers. Furthermore, if one looks at the ecological dominance of the lower quartile DBH stems (Table 2.3), *A. platanoides* is first. The sizes of stems in this lower quartile class are precisely the sizes that are regularly removed as part of the maintenance of the woodlands. Despite such regular, this species still shows ecological dominance here. Similarly, *A. pseudoplatanus* which ranks ninth, is almost as aggressive as *A. platanoides* and is similarly managed. One main difference is that it is susceptible to drought, whereas Norway maple is not.

The rankings for ecological dominance are different if one looks at the individual woodlands (Tables 2.5, 3.1, and 4.1). The North Woods, the largest woodland, has a ranking that is similar to the total data. However, *A. pseudoplatanus* is higher on this list, ranking fourth rather than

ninth. The higher ranking is probably due to the presence of a large stream (The Loch) flowing through the southern end of the North Woods. Much of the soil there is moist and fewer sycamore maples were lost to drought in this area than in other areas. In the Ramble data set, *Phellodendron amurense, Styphnolobium japonicum, Ailanthus altissima,* and *Morus alba* show up in the top ten. As noted in the introduction to this study, the Ramble was a much more open landscape when it was first created than it is today. It has far more pathways than the North Woods or Hallett (Hallett has no pathways). In essence, it is a more disturbed environment. This could partially explain the higher number of non-natives and invasives found in the top ten in ecological dominance for the Ramble as compared with the North Woods. Another reason is that the Ramble was much more landscaped than the North Woods. The topography was drastically changed and thousands of plants were installed, many of which were likely to have been non-native species. There are several large *Phellodendron amurense* (Figure 3.2), the oldest specimens in the park, and they are probably the seed source of all the young saplings. There seems to be little literature on *Styphnolobium japonicum* as an invasive species in the northeastern United States. However, it not only shows up sixth in ecological dominance in the Ramble data set but also shows up 15th in ecological dominance of the lower quartile DBHs of the total data set, a rank higher than *Phellodendron amurense*, a species known to be invasive in our area.

Aralia spinosa and *Aralia elata* are species that can be very difficult to tell apart in the field (Sarver et al. 2008). For our floral survey, we consulted several botanists and named the species *A. spinosa*; however, we are fairly certain now that the species is *A. elata.* Brooklyn Botanic Garden Metro Flora Project only lists *A. elata* in the boroughs of New York (although neither *A. elata* nor *A. spinosa* are found in Brooklyn).

In the Hallett Nature Sanctuary, *Frangula alnus* is listed as fifth in IV dominance. This is another species that has been shown to be invasive (Frappier et al. 2004) but has not yet been a focus of management in Central Park.

Robinia pseudoacacia shows at number three. This species is native as far north as Pennsylvania, but out of our range, and it is considered not native to our area.

7.3 Invasive Vines and Herbaceous Species

Vines and lianas are a group of plants that are unable to climb to heights on their own to gather sunlight and instead use other plants as support. They use several forms and methods for climbing, depending on the species. Some use tendrils to attach themselves to other plants, others use aerial roots. Some simply twine themselves around the stems of other plants (Simberloff 2011). Whatever the method, the end result is often that the supporting plant is shaded from sunlight, becomes weak and eventually falls under the weight of the smothering vine. Twiners can grow so tightly that they interfere in the translocation of nutrients in the phloem (Simberloff 2011). In a forest, vines usually occupy edge areas and canopy gaps. Once these gaps are filled in, these species usually are not shade-tolerant enough to survive. In Central Park, these species present a serious problem since the Park is fundamentally all edge.

Polygonum cuspidatum (syn. *Fallopia japonica* and *Reynoutria japonica*) is not listed in the historical records for Central Park, yet has become a significant pest throughout the woodlands as well as other areas of the Park (Figure 7.2). This species originated in Asia and it is unclear when it arrived in Central Park. It is usually assumed that Olmsted introduced this species during the creation of the Park; however, there seems to be no hard evidence to support this (Townsend 1997). *Polygonum cuspidatum* has bamboo-like stems that can exceed five meters in

height and individuals can form dense stands. The rhizomes can extend more than two meters in depth and 15-20 cm in length, and it is through these rhizomes as well as stem fragments that the plant reproduces throughout its introduced range (Weston et al. 2005). Invasion of this species causes loss of wildlife habitat, decreased species diversity and reduction in the available water supply (Weston et al. 2005).

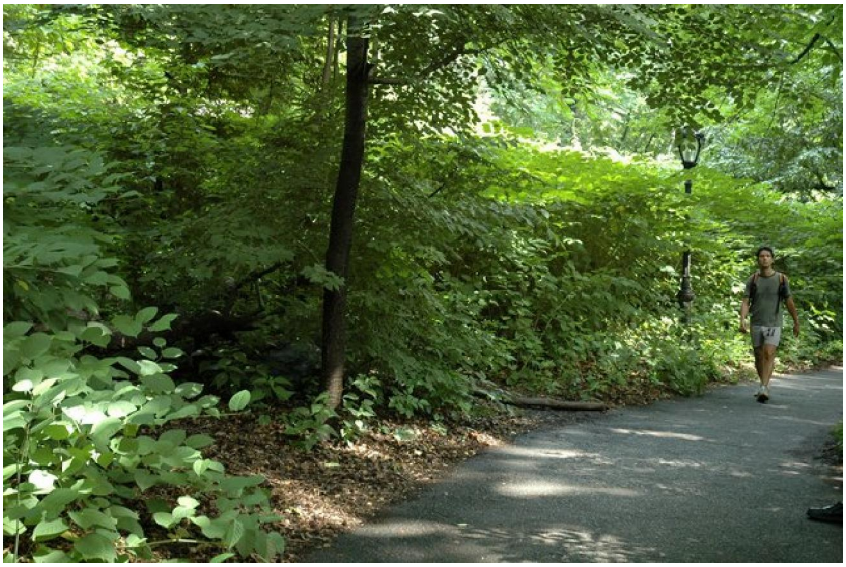

Figure 7.2 Stand of *Polygonum cuspidatum* in the Ramble

Wisteria sinensis is a popular ornamental vine. It is a woody vine in the Fabaceae, deciduous compound leaves with showy fragrant pendant lilac-colored flowers. USDA Plant Database shows it to be invasive New York, Kings, Nassau, Suffolk, Rockland, Orange, Sullivan and Ulster counties. This database also states that it was brought to the United States for horticultural purposes in 1816. It is not known how long this plant has been naturalized in the United States, but estimates based on the size of escaped plants point toward more than 50 years

(Trusty et al., 2008). Figure 7.3 shows the extent of the invasion in the northeast section of the Hallett Nature Sanctuary.

Although this species grows well from seed, its vegetative growth is most vigorous and it has the ability to sprout from damaged roots, stumps or root fragments.

Figure 7.3 Northeast section of the Hallett Nature Sanctuary showing infestation of *Wisteria sinensis*

Polygonum perfoliatum (Figure 7.4) appeared in the park some time in 1997-1998. It is possible that it was accidentally brought in with plant material used to plant the island in Turtle Pond during the restoration of the Great Lawn/Turtle Pond areas. The infestation began at Turtle Pond; subsequently a small stand was found in the adjoining Shakespeare Garden. The following year it appeared in the Ramble, approximately two city blocks south of the original

infestation, and more recently has been found at the Great Hill in the northwest section of the Park. The berries are eaten by birds and thus dispersed throughout the Park. So far Park managers have kept this species somewhat under control, but since it is such a fast grower, keeping it under control is not an easy task.

Figure 7.4 *Polygonum perfoliatum*

Humulus japonicus (Figure 7.5) began appearing in the Great Hill area (northwest of the North Woods) soon after planting was completed during the 2005 restoration.

Figure 7.5 *Humulus japonicus* at the Great Hill

7.4 Other Invasives

Most plant and vertebrate animal introductions have been intentional, whereas most invertebrate animal and microbe introductions have been accidental (Pimentel et al. 2004) More than 2,000 species of non-native arthropods have been introduced into the continental U.S, including about 360 non-native insect species that have become established in U.S. forests, approximately 30% of these insect species are serious pests. The figure for plant pathogens invading the U.S. is approximately 20,000 species (Pimentel et al. 2004). Two of those pathogens are *Cryphonectria parasitica* (Murrill) Barr (chestnut blight fungus) and *Ophiostoma ulmi* (Buisman) Melin & Nannf. (Dutch elm disease). Before the introduction of the chestnut blight, approximately 25% of eastern U.S. forest consisted of *Castanea dentata* (American chestnut trees) (Pimentel et al. 2004).

Dutch Elm Disease (DED) arrived from the Netherlands by way of the Bronx in 1930 (Kinkead 1990). This disease is caused by a species of fungi, *Ophiostoma ulmi.* The spores of this fungus are carried from tree to tree by three species of elm bark beetle; the native *Hylurgopinus rufipes*, and two non-native species, *Scolytus multistriatus* and *Scolytus schevyrewi.* Although more than half the nation's American elms have perished, the toll being especially heavy in the east, Central Park's losses have been reduced to an average of 10-15 per year (Neil Calvanese, personal communication) because of management practices by the Central Park Conservancy, preserving what is one of the largest remaining stands of American elms in the country. All American and English elms are inspected weekly by Conservancy staff for signs of trouble. Infected branches are cut back to 6 feet of sound (uninfected) wood; fungicide is used if deemed necessary; and terminally sick trees, including roots, are removed.

Anoplophora glabripennis, the Asian Longhorned Beetle (ALB), is a non-native insect that arrived in the United States on packing crates in a shipment arriving in New York City's Brooklyn waterways. It was discovered in 1996 in the Greenpoint section of Brooklyn where many trees were severely damaged. ALB is a large beetle, approximately 2.5-4 cm in length, which lays its eggs in the bark of many tree species, *Acer saccharum* being the favorite. The larvae take one to two years to mature, all that while living inside the tree and feeding on the wood. Each female lays up to 40 eggs at once on a tree, leading to large populations. This causes considerable structural damage to the tree. The U.S. Department of Agriculture (USDA) has been working to keep this infestation contained. In 2001 a small infestation was found on two *Acer saccharum* in Central Park in the Hallett Nature Sanctuary. These trees, along with nine *A. platanoides* surrounding the two sugar maples, were removed by the USDA. In 2007, a second small infestion was found on an American elm tree on Fifth Avenue on Park property. This infestation was much smaller and consisted only of one larva.

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Chapter 8

Conclusions

The aim of this study was to quantify the community ecology of the woodlands of Central Park, focusing closely on the woody species. As part of a fully human-made park under continuous management, these woodlands contain a high number of non-native and horticultural species. As the largest green space in Manhattan, and located under the Atlantic Flyway, Central Park is an important site for wildlife. A large number of species reside in or migrate through this park. The Park managers work continually to maintain and improve this habitat. Knowing the community ecology allows for better management decsions. Additionally, a scientific study following protocols that can be replicated allows for future studies to continue monitoring the ecology of the Park and to determine the success of management decisions.

Prunus serotina (black cherry) has been shown repeatedly by this and other surveys to be the most dominant tree in the Park. It is a native pioneer species, producing large quantities of seeds that are easily dispersed by birds. This species is member of the Rosaceae, which is the dominant family in these woodlands. *Prunus serotina* was found in 188 of 318 total points surveyed. In seven of those points, all four stems were *P. serotina.* In 22 points, *P. serotina* was 3 of the 4 stems. This indicates that this species' distribution is widespread rather than clumped. Although *P. serotina* is a native and a good wildlife species, the fact that it is a pioneer species, coupled with the fact that Central Park is essentially an all "disturbed" environment, allows this species to reach an ecological dominance over other species and this warrents management concern. At present, the management policy is to control this species only enough to give other

native species the space and resources to flourish. I would recommend continuing and perhaps expanding this policy. A future study could examine the distribution and determine the influence of *P. serotina* on the distribution and abundance of other taxa.

Two other dominant species are *Acer platanoides* and *A. pseudoplatanus.* These are non-native invasive species that continually rank in the top ten in dominance despite ongoing removal of these species by the Park's managers. Although these two *Acer* species are so agressive, Aceraceae is third in relative dominance (basal area). Fagaceae is second in relative dominance due to the large size of *Quercus* species. *Quercus rubra* shows high dominance in Importance Value (IV) due to the large size of many specimens; however, it shows little regeneration. Based on my experience, *Quercus* species regenerate well in restored areas. Future studies may show this species as stronger in IV and will also indicate if management of the two *Acer* species is successful.

In the Ramble data set, *Celtis occidentalis* shows higher dominance than in the total data set. There is a large stand of this species in the Ramble and despite disturbance and compacted soil, this species regenerates well. *Phellodendron amurense* has been shown in other studies to be an invasive species and in this study is fifth in ecological dominance in the Ramble data set. There are several large specimens of this species in the Ramble from which the species is regenerating. Park managers should consider treating this species as an invasive. *Styphnolobium japonicum* is not generally classified as an invasive. It is ranked sixth in ecological dominance in the Ramble data set, and my experience with this species is that it tends to be aggressive. I recommend that this species be monitored for possible invasive potential.

The North Woods is the only one of the three subsets of data set that shows any species with a higher relative dominance than *Prunus serotina.* In this data set, *Quercus rubra* has the highest relative dominance, which is a result of the presence of several very large specimens. The North Woods is one of the only areas in the Park that did not undergo drastic changes in its landscape during construction of the Park. That circumstance may have contributed to the large sizes of *Quercus* that we see. However, since *Quercus* species do not regenerate well on disturbed soils, *P. serotina* and *A. platanoides* have higher absolute densities. Importance Value analysis of the lower quartile DBH trees for the North Woods shows this and also reveals that *Aralia elata* is a species of concern.

Unlike in the other two woodlands, *Fraxinus americana* ranks second in ecological dominance in the Hallett Nature Sanctuary. This is despite large losses of this species throughout the Park during several years of drought and blight. Third in ecological dominance is *Robinia pseudoacacia*. Also different in the Hallett data set is that *Quercus plaustris* is the most dominant oak, not *Quercus rubra. Acer saccharum* shows strong ecological dominance because of many stems in the lower DBH quartile. *Frangula alnus* is the invasive species of concern in this woodland. It ranks fifth in ecological dominance in this data subset. Although this species is classified as an invasive, it is showing invasive tendencies only in the Hallett woodland, not in the Ramble or the North Woods.

Central Park's woodlands contain several species that are considered to be invasive. *Acer platanoides* and *A. pseudoplatanus* are two examples. Invasive vines such as *Wisteria sinensis* are a problem in the woodlands; however, due to aggressive management, no stems of *Wisteria* appeared in this survey. Recently new invasive species such as *Humulus japonicus* and *Polygonum perfoliatum* have been introduced through horticultural plantings. Management

practices have kept some of these species under control while others are still problems that need monitoring. Several species that are not treated as invasives have been shown by this survey to have the potential to become invasive and should be monitored by management. *Phellodendron amurense* and *Styphnolobium japonicum* are two such species.

This study shows the importance of including smaller stem diameters in ecological inventories. Analysis of the lower DBH quartiles revealed the potential of species to be invasive. It indicated that some species, such as the oaks, although they have high basal area, they have low absolute density, due to low regeneration. The lower DBH quartile also revealed a species, *Acer saccharum*, which did not show up in the 2008 survery (with the 15 cm cutoff), but was eighth in dominance in Hallett in my survey with the 1 cm cutoff, and is tied with *Robinia pseudoacacia* for fifth place in absolute density.

A survey Central Park flora compared extant plants with the historic record. Many of the original species were extirpated through changes in the topography of the Park and through human use and disturbance. However, this study shows that restoration efforts by the Central Park Conservancy are resulting in significant improvements to disturbed areas, and native plants are now able to establish self-sustaining populations.

The biodiversity of Central Park as documented in this work shows that the Park is an important natural area in an increasingly urban world. Quantitative ecological plant inventories such as those in this study should be performed every decade in the Central Park woodlands to track dominance changes so that management expectations for the preservation of native biodiversity may be realized.

Appendix 1

Full species list

Family	Species	Common name
Aceraceae	*Acer negundo* L.	Boxelder
Aceraceae	*Acer platanoides* L.	Norway maple
Aceraceae	*Acer pseudoplatanus* L.	Sycamore maple
Aceraceae	*Acer rubrum* L.	Red maple
Aceraceae	*Acer saccharum* Marsh.	Sugar maple
Anacardiaceae	*Rhus glabra* L.	Smooth sumac
Anacardiaceae	*Rhus typhina* L.	Staghorn sumac
Aquifoliaceae	*Ilex opaca* Aiton	American holly
Araliaceae	*Aralia elata* (Miq.) Seem.	Japanese angelica tree
Betulaceae	*Betula lenta* L.	Sweet birch
Betulaceae	*Carpinus caroliniana* Walter	American hornbeam
Caprifoliaceae	*Sambucus nigra* L. ssp. c*anadensis* (L.) R. Bolli	American black elderberry
Caprifoliaceae	*Viburnum dentatum* L. var. *lucidum* Aiton	Arrowwood
Caprifoliaceae	*Viburnum opulus* L.	European cranberrybush
Caprifoliaceae	*Viburnum plicatum* Thunb.	Japanese snowball
Caprifoliaceae	*Viburnum prunifolium* L.	Blackhaw
Caprifoliaceae	*Viburnum setigerum* Hance.	Tea viburnum
Celastraceae	*Euonymus alatus* (Thunb.) Siebold.	Burning bush
Celastraceae	*Euonymus europaeus* L.	European spindletree
Cornaceae	*Cornus kousa* Hance	Kousa dogwood
Cornaceae	*Cornus mas* L.	Cornelian cherry
Cornaceae	*Cornus racemosa* Lam.	Gray dogwood
Ericaceae	*Rhododendron sp.* L.	Azalea species
Ericaceae	*Vaccinium corymbosum* L.	Highbush blueberry
Fabaceae	*Cercis canadensis* L.	Eastern redbud
Fabaceae	*Gleditsia triacanthos* L.	Honey-locust
Fabaceae	*Gleditsia triacanthos L.* var. *inermis* (L.) C.K. Schneid.	Thornless honeylocust

Fabaceae	*Gymnocladus dioicus* (L.) K. Koch	Kentucky coffeetree
Fabaceae	*Robinia pseudoacacia L.*	Black locust
Fabaceae	*Styphnolobium japonicum* (L.) Schott	Japanese pagoda tree
Fagaceae	*Castanea dentata* (Marshall) Borkh.	American chestnut
Fagaceae	*Fagus grandifolia* Ehrh.	American beech
Fagaceae	*Quercus alba* L.	White oak
Fagaceae	*Quercus laevis* Walter	Turkey oak
Fagaceae	*Quercus macrocarpa* Michx.	Bur oak
Fagaceae	*Quercus palustris* Münchh.	Pin oak
Fagaceae	*Quercus phellos* L.	Willow oak
Fagaceae	*Quercus prinus* L.	Chestnut oak
Fagaceae	*Quercus rubra* L.	Northern red oak
Ginkgoaceae	*Ginkgo biloba* L.	Maidenhair tree
Hamamelidaceae	*Hamamelis vernalis* Sarg.	Ozark witchhazel
Hamamelidaceae	*Hamamelis virginiana* L.	American witchhazel
Hamamelidaceae	*Liquidambar styraciflua* L.	Sweetgum
Hippocastanaceae	*Aesculus hippocastanum* L.	Horse chestnut
Hydrangeaceae	*Philadelphus coronarius* L.	Sweet mock orange
Juglandaceae	*Carya alba* (L.) Nutt.	Mockernut hickory
Juglandaceae	*Carya cordiformis* (Wangenh) K. Koch.	Bitternut hickory
Lauraceae	*Lindera benzoin* (L.) Blume.	Northern spicebush
Lauraceae	*Sassafras albidum* (Nutt.) Nees.	Sassafras
Magnoliaceae	*Liriodendron tulipifera* L.	Tuliptree
Moraceae	*Morus alba* L.	White mulberry
Oleaceae	*Fraxinus americana* L.	White ash
Oleaceae	*Ligustrum vulgare* L.	European privet
Pinaceae	*Pinus nigra* Arnold	Austrian pine
Pinaceae	*Pinus strobus* L.	Eastern white pine
Platanaceae	*Platanus hybrida* Brot.	London Plane
Platanaceae	*Platanus occidentalis* L.	American sycamore

Rhamnaceae	*Frangula alnus* Mill.	Glossy buckthorn
Rosaceae	*Amelanchier canadensis* (L.) Medik.	Canadian serviceberry
Rosaceae	*Crataegus phaenopyrum* (L.f.) Medik.	Washington hawthorn
Rosaceae	*Crataegus* sp. L.	Hawthorn species
Rosaceae	*Crataegus viridis* L.	Green hawthorn
Rosaceae	*Cratageus x lavallei* Herincq.	Lavalle hawthorn
Rosaceae	*Malus sylvestris* (L.) Mill.	European crab apple
Rosaceae	*Photinia glabra* (Thunb.) Maxim.	Japanese photinia
Rosaceae	*Photinia villosa* (Thunb.) DC.	Oriental photinia
Rosaceae	*Prunus serotina* Ehrh.	Black cherry
Rosaceae	*Prunus* sp. L.	Cherry species
Rosaceae	*Prunus virginiana* L.	Chokecherry
Rosaceae	*Rhodotypos scandens* (Thunb.) Makino	Jetbead
Rosaceae	*Rosa multiflora* Thunb.	Multiflora rose
Rutaceae	*Evodia daniellii (Benn.) Hemsl.*	Korean Evodia
Rutaceae	*Phellodendron amurense* Rupr.	Amur corktree
Sapindaceae	*Koelreuteria paniculata* Laxm.	Goldenrain tree
Simaroubaceae	*Ailanthus altissima* (Mill.) Swingle	Tree of heaven
Tiliaceae	*Tilia americana* L.	American basswood
Tiliaceae	*Tilia cordata* Mill.	Littleleaf linden
Ulmaceae	*Celtis occidentalis* L.	Common hackberry
Ulmaceae	*Ulmus americana* L.	American elm
Ulmaceae	*Ulmus procera* Salisb.	English elm
Ulmaceae	*Ulmus* sp. L.	Elm species
Vitaceae	*Parthenocissus tricuspidata* (Siebold & Zucc.) Planch.	Boston ivy

Appendix 2

PCQ program in R

```
# Name of this file:  PCQ 2.R                 A program in R  (www.r-project.org)

# ================================================================================

#                                                    Author: Professor Dwight Kincaid

#      IMPORTANCE VALUES in quantitative                    dkincaid49@yahoo.com

#      ecological plant inventory

#                                                                  Department of
Biological Sciences

#       version 19 March 2011                Lehman College, City University of New
York

#                                                                  Bronx, New York
10468 USA

#                                            718.960.8235/.8651

# ================================================================================

# REQUIRES: base R only

# NOTE: Reads a csv file: col names and order of cols MUST BE -- PCQ, sp.ID, DBH

# NOTE: Enter raw data in the 3 vectors below. Comment-out the 3 below and add your
own.

# NOTE: To preserve output text in R Console, copy/paste it out.


#my.frame <- read.csv("/Users/Regina/Desktop/DissFinalDocs/PCQ in R/Hallett PCQ.csv");
attach(my.frame); summary(my.frame)

#my.frame <- read.csv("/Users/Regina/Desktop/DissFinalDocs/PCQ in R/Ramble PCQ.csv");
attach(my.frame); summary(my.frame)

#my.frame <- read.csv("/Users/Regina/Desktop/DissFinalDocs/PCQ in R/North Woods
PCQ.csv"); attach(my.frame); summary(my.frame)
```

```
my.frame <- read.csv("/Users/Regina/Desktop/DissFinalDocs/PCQ in R/Total data set PCQ.csv"); attach(my.frame); summary(my.frame)

#my.frame <- read.csv("/Users/Regina/Desktop/DissFinalDocs/PCQ in R/Lower quartile total data PCQ.csv"); attach(my.frame); summary(my.frame)

#my.frame <- read.csv("/Users/Regina/Desktop/DissFinalDocs/PCQ in R/Genera total data PCQ.csv"); attach(my.frame); summary(my.frame)

#my.frame <- read.csv("/Users/Regina/Desktop/DissFinalDocs/PCQ in R/PCQ Families total data set.csv"); attach(my.frame); summary(my.frame)


s <- length(unique(sp.ID))       # N of species - a scalar

n <- length(DBH)                        # N of trees or plants - a scalar

pts <- length(unique(PCQ))       # N of PCQ points or quadrats - a scalar

basal <- pi * (DBH/2)^2                 # DBH converted to basal area - a vector


my.frame <- data.frame(PCQ,sp.ID,DBH,basal)  # add basal area column to obs data

# ---------------------------------------

# RELATIVE DENSITY in %

den <- tapply(DBH,sp.ID,length)         # density

rel.d <- (den/n)*100                    # rel.density

# ---------------------------------------

# RELATIVE FREQUENCY in %,  the vector 'freq' is absolute freq

my.fun1 <- function(PCQ) length(unique(PCQ))

freq <- tapply(PCQ,sp.ID,my.fun1); rel.freq <- (freq/sum(freq))*100

# ---------------------------------------

# RELATIVE DOMINANCE in % of total basal area

basal.by.species <- tapply(basal,sp.ID,sum)

rel.dom <- (basal.by.species/sum(basal))*100
```

```
mean.DBH <- tapply(DBH,sp.ID,mean)  # get vector of mean DBH per taxon

# ---------------------------------------

# IMPORTANCE VALUE as rel.den. + rel.freq. + rel.dom.

IV <- rel.d + rel.freq + rel.dom

aa <- order(IV,decreasing=TRUE)


# sort vectors by order of IV value

rel.d <- rel.d[aa]; rel.freq <- rel.freq[aa]; rel.dom <- rel.dom[aa]


den <- den[aa]; freq <- freq[aa]; mean.DBH <- mean.DBH[aa]


IV <- rel.d + rel.freq + rel.dom  # get IV again, using sorted vectors

# ---------------------------------------

# CUMULATIVE values

c.IV <- cumsum(IV); c.d <- cumsum(rel.d); c.freq <- cumsum(rel.freq); c.dom <-
cumsum(rel.dom);

# ---------------------------------------

# construct the data frame of results

spacer <- "---"

IV.frame <-
data.frame(den,freq,mean.DBH,spacer,rel.d,c.d,rel.freq,c.freq,rel.dom,c.dom,IV,c.IV)

# ---------------------------------------

# print results to R Console


options(digits=4)

lf <- function() print("",quote=FALSE);lf();lf()
```

```
d.line <- function(){
print("================================================================================",qu
ote=F)}


d.line();lf();print("  Output from 'PCQ 2.R' by Professor Dwight Kincaid,
dkincaid49@yahoo.com",quote=F)

lf();d.line();lf(); note1 <- paste("This run: ",date()); print(note1,quote=F); lf()


print(paste("NUMBER of SPECIES:",s),quote=F);lf()

print(paste("NUMBER of TREES:",n),quote=F);lf()

print(paste("NUMBER of SAMPLING UNITS:",pts),quote=F);lf()


print("The raw data is listed. PCQ stands for sampling unit: quadrat, PCQ quadrant,
etc.",quote=F);lf()

print(my.frame);lf()


print("Absolute density, absolute frequence per sampling unit, mean DBH followed by --
-",quote=F);

print("rel. density, rel. frequency, rel. dominance(basal), Importance Value",quote=F)

print("and cumulative values for rel.den, rel.freq, rel.dom and IV.",quote=F);lf()

print(IV.frame);lf()

print("The first column above is species ID integer.");lf()

# ---------------------------------------

# construct graphs


x.str <- "Species by IV Rank"; cl <- "wheat"; b.label <- rownames(IV.frame)

g1 <- "ECOLOGICAL DOMINANCE"; g2 <- "Abundance"; g3 <- "Distribution"; g4 <- "Size"
```

```
par(mfrow=c(2,2))

  barplot(IV,col=cl,ylab="Importance Value (0-
300)",ylim=c(0,max(IV)+.15*max(IV)),xlab=x.str,main=g1,names.arg=b.label)

  barplot(rel.d,col=cl,ylab="Relative
Density",ylim=c(0,max(rel.d)+.15*max(rel.d)),xlab=x.str,main=g2,names.arg=b.label)

  barplot(rel.freq,col=cl,ylab="Relative
Frequency",ylim=c(0,max(rel.freq)+.15*max(rel.freq)),xlab=x.str,main=g3,names.arg=b.la
bel)

  barplot(rel.dom,col=cl,ylab="Relative Dominance (Basal
Area)",ylim=c(0,max(rel.dom)+.15*max(rel.dom)),xlab=x.str,main=g4,names.arg=b.label)

par(mfrow=c(1,1))



print("end   PCQ 2.R",quote=F);d.line()

# ----------------------------------------

# NOTES

# need to add bootstrap to get 95% CI of everything

# need to add if() decision for PCQ to get absolute density overall and per taxon, if
sampling unit is PCQ

# need to add option for reading raw data from a matrix-type file



# end   PCQ 2.R
```

Diversity indices Program in R

```
# diversity 2.R    ver. 23 Nov. 2011   by   Dwight Kincaid


# USER enters frequencies with the lowest frequency as 1. Zeros not permitted.

# Comment-in, comment-out one data set for the run.

# File may be submitted as Source Code at R Console or copy/pasted as blocks.

# Don't forget to initialize NS as desired.

# Only base R is used.


rm(list=ls())              # delete all objects in RAM at R Console, comment-out as
desired


NS <- 1e4           # number of bootstrap samples; change as desired, begin low

# ------------------------------------------------------------------

# data of Hough(1936) on abundance of large trees in a PA forest,

# as analyzed on p. 364 of Krebs(1989) Ecological Methology

# ------------------------------------------------------------------

# abundances for hemlock,beech,yellow birch,sugar maple,black birch,red maple,

# black cherry,white ash,basswood,yellow poplar,magnolia


Hough <- c(1940,1207,171,134,97,93,34,22,15,7,4)

# ----------------------------------------

# Central Park tree data of Regina Alvarez

# ----------------------------------------

Hallett.freq.1982 <- c(12,1,2,1,3,6,2,1,4,3,22,1,7,1,2,157,1,11,1,58,3,2)

Hallett.freq.2002 <- c(13,1,65,1,20,2,2,1,11,3,1,1,2,16,1,4,2,1,241,11,1,59,2,1,3)
```

```
Hallett.freq.2008 <- c(3,4,54,1,15,2,3,16,3,1,1,3,11,3,3,2,221,11,2,1,54,1,2,7)

Hallett.freq.full.2002 <-
c(13,1,1,20,2,1,59,11,1,3,2,14,11,4,2,1,1,2,241,1,1,65,2,2,1,3)

Hallett.freq.PCQ <- c(6,2,7,3,5,1,1,1,11,1,3,1,1,3,4,4,2,63,2,1,13,6,6,7,1,3,10)

Ramble.freq.PCQ <-
c(95,10,43,54,18,11,28,1,1,7,2,4,2,5,9,12,3,5,11,10,10,3,2,2,3,1,2,4,19,2,12,2,3,5,6,6
,1,6,1,2,1,1,7,2,1,1,1,1,4,2)

NorthWoods.freq.PCQ <-
c(158,9,9,61,6,2,11,44,28,38,11,36,25,11,4,3,10,19,6,25,2,4,1,1,10,8,2,22,1,2,15,1,4,1
,1,7,1,2,3,3,1,16,7,2,2,11,1,1,2,1,1,2,1,1,1,1,2)

TotalData.freq.PCQ <-
c(316,29,56,121,22,15,41,3,1,46,8,11,2,50,23,37,4,5,18,10,10,13,6,2,12,1,14,4,22,5,50,
19,4,14,6,7,1,32,1,3,2,1,29,32,4,1,9,6,2,38,10,1,1,2,1,2,14,4,1,7,1,2,3,1,16,2,1,2,11,
1,2,1,1,7,2,1,1,1,1,1,2,1)

# ---------------------------

# some simple, testing data

# ---------------------------

tester1 <- c(5,5,5,5,5)

tester2 <- c(100,1,1,1,1,1,1,1)

tester3 <- c(5,5,5,5,5)

stilling.p.434 <- c(50,30,10,9,1)

stilling.p.433 <- c(100,50,30,20,1)

# ------------------------------------------------------------

# decide which data set to run while commenting-out all others

# ------------------------------------------------------------

#y <- Hough

#y <- Hallett.freq.1982

#y <- Hallett.freq.2002

#y <- Hallett.freq.2008
```

```
#y <- Hallett.freq.full.2002

#y <- tester1

#y <- tester2

#y <- tester3

#y <- stilling.p.434

#y <- stilling.p.433

#y <- Hallett.freq.PCQ

#y <- Ramble.freq.PCQ

#y <- NorthWoods.freq.PCQ

y <- TotalData.freq.PCQ

# ----------------------------

# observed diversity indices

# ----------------------------

S <- length(y); N <- sum(y)                    # species richness and total N


rel <- y/N                                     # vector of relative abundances

Shannon <- abs(sum(rel*log(rel)))   # Shannon diversity

J <- Shannon/log(S)                            # Shannon evenness, J


Margalef <- (S-1)/log(N)                # Margalef diversity


Simpson.D <- sum((y/N)^2)               # Simpson's D       CHECKS w/ Krebs

one.minus.Simpson <- 1-Simpson.D  # 1-D                     CHECKS w/ Krebs

one.over.Simpson <- 1/Simpson.D         # 1/D                       CHECKS w/ Krebs

# ----------------------------

# begin print out to R Console
```

```
# ----------------------------

dots <-
"..........................................................................
.."


cat("\n","\n","\n")        # linefeeds

cat(dots,"\n","\n")

cat("    "," OUTPUT from: "," diversity 2.R   ver. Nov. 23, 2011   by   Dwight
Kincaid","\n","\n")

cat(dots,"\n","\n")

cat("           ","           ","THIS RUN: ",date(),"\n","\n")


cat("OBSERVED data: ",y,"\n")

cat("(Abundance per taxon. Zeros not allowed here.)","\n","\n")

cat("OBSERVED INDICES","\n","\n")

cat("     ","Species Richness   ",S,"\n")

cat("     ","Total N            ",N,"\n","\n")

cat("     ","Shannon diversity  ",Shannon,"\n")

cat("     ","Shannon evenness   ",J,"\n")

cat("     ","Margalef diversity ",Margalef,"\n")

cat("     ","Simpson D          ",Simpson.D,"\n")

cat("     ","1-D                ",one.minus.Simpson,"\n")

cat("     ","1/D                ",one.over.Simpson,"\n","\n",dots,"\n","\n")

cat("Bootstrap underway. Abundances are used to reconstitute the raw data which are
resampled.","\n")

cat("NS =",NS,"bootstrap samples. Change NS as desired. Begin low then
increase.","\n")

cat("PATIENCE, this is slow if NS is high and data set is large.","\n","\n")
```

```
# ---------------------------------

# kincaid's bootstrap of 6 indices

# ---------------------------------

# before bootstrapping, reconstitute raw data from frequency vector y


yy <- 1:N   # initialize vector to hold reconstituted, raw data multiplied out from
the frequencies

counter <- 0; for(i in 1:S){for(j in 1:y[i]) {counter <- counter+1; yy[counter] <- i}}


resample.trees <- function(x){          # x local var and is raw data passed from the
call

      xx <- sample(x,replace=TRUE)      # bootstrap sample of raw data

      taxa <- unique(xx)                      # vector of taxa in boot sample

      S <- length(taxa)                       # species richness in boot sample

      N <- length(xx)                               # number of individuals


      freq <- rep(0,S)                        # vector to hold boot frequencies

      for(i in 1:S){ for(j in 1:N){ if(xx[j] == taxa[i]) freq[i] <- freq[i]+1}    }
# recover frequencies

      rel <- freq/N                           # vector of relative frequencies -
abundance


      Shannon <- abs(sum(rel*log(rel))) # Shannon diversity

      J <- Shannon/log(S)                           # Shannon evenness, J

      Margalef <- (S-1)/log(N)                # Margalef diversity

      Simpson.D <- sum((freq/N)^2)            # Simpson's D

      one.minus.Simpson <- 1-Simpson.D  # Simpson: 1-D
```

```
      one.over.Simpson <- 1/Simpson.D         # Simpson: 1/D

      out <- cbind(Shannon,J,Margalef,Simpson.D,one.minus.Simpson,one.over.Simpson)
# array 'out' is returned

}

# first we need a TIME ESTIMATE for user in case NS needs to be changed


t1 <- proc.time()   # begin bootstrap timer

boot.index <- replicate(10,resample.trees(yy))   # send the raw data; boot.indices
collects Shannon

elapsed <- proc.time()-t1

cat("Elapsed minutes for a trial run of 10 bootstrap
samples:",round(elapsed[1]/60,3),"\n")

est.1 <- 10*elapsed[1]/60  ; est.1 <- round(est.1,3)  # for NS=100

est.2 <- 100*elapsed[1]/60 ; est.2 <- round(est.2,3)  # for NS=1000

est.3 <- 1e3*elapsed[1]/60 ; est.3 <- round(est.3,2)  # for NS=10,000

est.4 <- 1e4*elapsed[1]/60 ; est.4 <- round(est.4,2)  # for NS=100,000

cat("So, it will take about --","\n")

cat("            ","            ",est.1,"minutes for NS = 100 bootstrap samples","\n")

cat("            ","            ",est.2,"minutes for NS = 1,000","\n")

cat("            ","            ",est.3,"minutes for NS = 10,000","\n")

cat("            ","            ",est.4,"minutes for NS = 100,000","\n","\n")

cat("Hit ESCAPE to end the run, if you want to change NS in the code, otherwise be
patient.")

# ------------------------------------------------------------------------

# the full bootstrap run, by calling the above function: 'resample.trees()'

# ------------------------------------------------------------------------

t1 <- proc.time()   # begin bootstrap timer
```

```
boot.index <- replicate(NS,resample.trees(yy))   # send the raw data; boot.indices
collects Shannon

# boot.index[,1,] is Shannon; [,2,] is J; [,3,] is Margalef; [,4,] is D; [,5,] is 1-D;
[,6,] is 1/D)


elapsed <- proc.time()-t1   ; cat("\n")

cat("Elapsed minutes for the bootstrap:",round(elapsed[1]/60,3),"\n","\n")


Shannon.LB <- quantile(boot.index[,1,],.025); Shannon.UB <-
quantile(boot.index[,1,],.975)

J.LB <- quantile(boot.index[,2,],.025); J.UB <- quantile(boot.index[,2,],.975)

M.LB <- quantile(boot.index[,3,],.025); M.UB <- quantile(boot.index[,3,],.975)

S1.LB <- quantile(boot.index[,4,],.025); S1.UB <- quantile(boot.index[,4,],.975)

S2.LB <- quantile(boot.index[,5,],.025); S2.UB <- quantile(boot.index[,5,],.975)

S3.LB <- quantile(boot.index[,6,],.025); S3.UB <- quantile(boot.index[,6,],.975)


cat("Bootstrap 95% confidence intervals using the percentile method and achieved after
NS =",NS,"\n","\n")

cat("                    Lower","   Upper","\n","\n")

cat("Shannon diversity  ",round(Shannon.LB,4),",",round(Shannon.UB,4),"\n")

cat("Shannon evenness   ",round(J.LB,4),",",round(J.UB,4),"\n")

cat("Margalef diversity ",round(M.LB,4),",",round(M.UB,4),"\n")

cat("Simpson D          ",round(S1.LB,4),",",round(S1.UB,4),"\n")

cat("1-D                ",round(S2.LB,4),",",round(S2.UB,4),"\n")

cat("1/D                ",round(S3.LB,4),",",round(S3.UB,4),"\n","\n")
```

```
cat("End.","\n")

# end    diversity 2.R
```

Collector's curve program in R

```
# collector curve multiple.R      ver. 14 September 2011      A program in R

# ============================================================================

#

# Professor Dwight Kincaid         dkincaid49@yahoo.com

#

# C O L L E C T O R'S  C U R V E S  by  approximate randomization

#

# Department of Biological Sciences, Lehman College, City University of New York

# Bronx, New York 10468 USA             718.960.8235/.8651

#

# ============================================================================

# Differs from 'collector curve 1.R' as multiple inventories are processed

# and the mean curves graphed on same axis. Program requires only base R.

# A call to sample(x) returns a permutation of the elements of x; x is shuffled --
randomized.

# USER sets NS at desired level -- the number of desired randomizations; start small
(NS=100) then scale up.

# READS csv files with species ID integer in SECOND COLUMN.

# It only uses this column with column names of your choice as long as R compliant.

# SUBMIT as Source Code.

#

rm(list=ls())  # delete all objects in RAM at R Console

begin.time <- Sys.time()


process.file <- function(d.frame){      # get discrete frequency distribution
```

```
     species <- hist(d.frame[,2],breaks=seq(1,max(d.frame[,2]),1),plot=FALSE)

     species$counts   # the discrete counts of individuals per taxon

}


lf <- function() print("",quote=FALSE);lf();lf();lf()

d.line <- function(){


print("================================================================================
======",quote=FALSE)


print("================================================================================
======",quote=FALSE)}

d.line();lf();print("  Output from 'collector curve multiple.R'    A program in the R
language",quote=FALSE);lf()

print("  by Professor Dwight Kincaid,
dkincaid49@yahoo.com",quote=FALSE);lf();d.line();lf()

note1 <- paste("Time stamp: ",date()); print(note1,quote=FALSE); lf()


shuffle <- function(sp,N,NS,y,freq) {  lf();d.line();lf()


   data.name <- paste("CURRENT DATA SET:  ",as.character(file.name))

   print(data.name,quote=FALSE); lf()

   a1 <- paste("N of categories =",sp); a2 <- paste(a1,"   N of individuals (cases)
=",N)

   a3 <- paste("N of randomizations, NS =",NS,"   Change NS as desired; start low then
increase.")

   print(a2,quote=FALSE);lf();print("THE DATA as a sorted, discrete frequency
distribution.",quote=FALSE);print(freq);lf()

   print(a3,quote=FALSE);lf()
```

```
   print("Program setting up. PROGRESS REPORT scrolls.",quote=FALSE);lf()

   print("PATIENCE...",quote=FALSE);lf()


   # prepare for shuffle loop by initializing vectors

   i <- j <- 0            # nested loop counters

   combo <- 0; total <- 1:NS ; rnd.mean <- 1:N

   p1 <- "Processing:"; p2 <- paste("out of",N); p3 <- "  Shuffles:" ; p4 <- "
Mean:";

   jump = 100; if(N <= 500) jump=5; if(N > 1000) jump=200


   for(i in 2:N) {  combo <- i ;


          for(j in 1:NS) { y <- sample(y); total[j] <- length(unique(y[1:combo])) };


          rnd.mean[i] <- mean(total);

          time.post <- paste("   Time:",Sys.time());


          if (i == 2)
print(paste(p1,combo,p2,p3,NS,p4,signif(rnd.mean[i],4),time.post),quote=FALSE)

          if (i/jump == floor(i/jump)) {


print(paste(p1,combo,p2,p3,NS,p4,signif(rnd.mean[i],4),time.post),quote=FALSE)

          }

   }


   assign("rnd.mean",rnd.mean,envir=.GlobalEnv)

   lf();note2 <- paste("Time stamp: ",date());print(note2,quote=FALSE)
```

```
}

# ------------------------------------------------------------------

# code to read csv files. species ID integer must be in column #2

# ------------------------------------------------------------------

# NOTE: Use as the first file to read, the data set with the most species and the most individuals

# so the graph will accomodate it. Trial-and-error will also work in terms of data file sequence.

# One-off coding in 'plot()' will also work.


# FIRST file

# -------------------

NS1 <- 1e4                                    # NUMBER of SHUFFLES; change as needed

my.frame1 <- read.csv("C:/Users/Regina/Desktop/DissFinalDocs/Collector's Curve in R/Ramble CC.csv")

file.name <- "'Ramble PCQ.csv'"


freq1 <- process.file(my.frame1); freq1 <- sort(freq1,decreasing=TRUE)

species1 <- length(freq1)  # number of species           # species1 <- unique(my.frame1[,2])  # alternative

N1 <- sum(freq1)                  # number of individuals       # N1 <- length(my.frame1[,2])        # alternative

Y1 <- my.frame1[,2]          # raw data to be shuffled


shuffle(species1,N1,NS1,Y1,freq1)  # vector 'rnd.mean' is returned

mean1 <- rnd.mean


# SECOND file
```

```
# --------------------

NS2 <- 1e4                                    # NUMBER of SHUFFLES; change as needed

my.frame2 <- read.csv("C:/Users/Regina/Desktop/DissFinalDocs/Collector's Curve in
R/NorthWoods CC.csv")  # if a mac

#file.name <- "'NorthWoods PCQ.csv'"


freq2 <- process.file(my.frame2); freq2 <- sort(freq2,decreasing=TRUE)

species2 <- length(freq2)  # number of species

N2 <- sum(freq2)                 # number of individuals

Y2 <- my.frame2[,2]          # raw data to be shuffled

shuffle(species2,N2,NS2,Y2,freq2)  # vector 'rnd.mean' is returned

mean2 <- rnd.mean

# THIRD file

# --------------------

NS3 <- 1e4                                    # NUMBER of SHUFFLES; change as needed

my.frame3 <- read.csv("C:/Users/Regina/Desktop/DissFinalDocs/Collector's Curve in
R/Hallett CC.csv")    # if a mac

#file.name <- "'Hallett PCQ.csv'"


freq3 <- process.file(my.frame3); freq3 <- sort(freq3,decreasing=TRUE)

species3 <- length(freq3)  # number of species

N3 <- sum(freq3)                 # number of individuals

Y3 <- my.frame3[,2]          # raw data to be shuffled

shuffle(species3,N3,NS3,Y3,freq3)  # vector 'rnd.mean' is returned

mean3 <- rnd.mean


# FOURTH file           # insert code following templates above, as needed
```

```
# --------------------

NS4 <- 1e4                                    # NUMBER of SHUFFLES; change as needed

my.frame4 <- read.csv("C:/Users/Regina/Desktop/DissFinalDocs/Collector's Curve in
R/Total data set CC.csv")    # if a mac

#file.name <- "'Total data set PCQ.csv'"


freq4 <- process.file(my.frame4); freq4 <- sort(freq4,decreasing=TRUE)

species4 <- length(freq4)  # number of species

N4 <- sum(freq4)                 # number of individuals

Y4 <- my.frame4[,2]         # raw data to be shuffled

shuffle(species4,N4,NS4,Y4,freq4)  # vector 'rnd.mean' is returned

mean4 <- rnd.mean


lf(); print("--------------- Randomization finished for all files ---------------
",quote=FALSE);lf()


end.time <- Sys.time(); total.time <- end.time - begin.time; lf()

time.summary <- paste("TIME for the entire run: ",signif(total.time,4))

print(time.summary,quote=FALSE)

# -----------------

# graph the result

# -----------------

x.string <- paste("N of Individuals ( 1 to",as.character(N1),")")  # change string as
desired

main.string <- paste("Collector's Curves by Randomization, 10,000 randomizations")
```

```
plot(1:N1,mean1,type="l",lwd=2,ylab="Mean Species
Accumulation",xlab=x.string,main=main.string)

text(200,45,"Ramble",col="black",pos=4)  # comment-out or customize for your
particular graph


lines(1:N2, mean2,type="l",lwd=2,col="black")

text(200,37,"North Woods",col="black",pos=4)  # comment-out or customize for your
particular graph


lines(1:N3, mean3,type="l",lwd=2,col="black")

 text(173,27,"Hallett",col="black",pos=4)     # comment-out or customize for your
particular graph


lines(1:N4, mean4,type="l",lwd=2,col="black")

 text(82,44,"Total Data",col="black",pos=4)     # comment-out or customize for your
particular graph


# optional code to add faint grid lines

#abline(h=seq(0,80,10),lty=3,col="gray"); abline(v=seq(0,1300,100),lty=3,col="gray")

# ------------------------------------------------------------

# make data frame with vectors of means and save as csv file

# ------------------------------------------------------------

mean.sp.accum <- c(mean1,mean2,mean3)  # vector of mean species accumulations

data.set.name <-
c(rep("A",length(mean1)),rep("B",length(mean2)),rep("C",length(mean3)) )

data.set.name <- factor(data.set.name)

cases <- c(1:N1,1:N2,1:N3)

out.frame <- data.frame(data.set.name,mean.sp.accum,cases)
```

```
my.file.name <- "three.csv"; write.csv(out.frame,file=my.file.name,row.names=FALSE)


lf(); print("end 'collector curve multiple.R'  by  Professor Dwight Kincaid,
dkincaid49@yahoo.com",quote=FALSE);lf();d.line()


# end
```

Absolute density program in R

```
# Name of this file:  PCQ abs density.R      ver. 5 May 2011
# ============================================================================
#
#  Author: Professor Dwight Kincaid     dkincaid49@yahoo.com
#
#  Estimates of absolute density in quantitative ecological plant inventory
#  using the point centered-quarter transect method
#
#  Department of Biological Sciences
#  Lehman College, City University of New York
#  Bronx, New York 10468 USA          718.960.8235/.8651
#
# ============================================================================
#
# REQUIRES: base R only


# NOTE: Enter raw data in the 3 vectors below. Comment-out the 3 below and add your
own.
# NOTE: To preserve output text in R Console, copy/paste it out.


#PCQ <- c(1,1,1,1,2,2,2,2,3,3,3,3,4,4,4,4,5,5,5,5)       # PCQ quadrants
#sp.ID <- c(2,1,3,4,2,2,2,2,1,2,3,3,1,2,2,1,1,1,2,3)     # integers as species ID
numbers
#d <- c(.7,1.6,3.5,2,1.1,.8,1.9,1.8,1.3,.7,1.5,2,3.1,1.7,1.1,1.9,2.5,2.2,1.4,2.8) #
distance in meters
```

```
#my.frame <- read.csv("/Users/Regina/Desktop/DissFinalDocs/Abs Density in R/Abs
Density Hallett.csv"); attach(my.frame); summary(my.frame)

#my.frame <- read.csv("/Users/Regina/Desktop/DissFinalDocs/Abs Density in R/Abs
Density Ramble.csv"); attach(my.frame); summary(my.frame)

#my.frame <- read.csv("/Users/Regina/Desktop/DissFinalDocs/Abs Density in R/Abs
Density North Woods.csv"); attach(my.frame); summary(my.frame)

#my.frame <- read.csv("/Users/Regina/Desktop/DissFinalDocs/Abs Density in R/Abs
Density Total data set 2012.csv"); attach(my.frame); summary(my.frame)

my.frame <- read.csv("/Users/Regina/Desktop/DissFinalDocs/Abs Density in R/Abs density
Genera total data.csv"); attach(my.frame); summary(my.frame)


s <- length(unique(sp.ID))   # N of species - a scalar

n <- length(PCQ)                  # N of trees or plants - a scalar

pts <- length(unique(PCQ))   # N of PCQ points or quadrats - a scalar


my.frame <- data.frame(PCQ,sp.ID,d)

# ---------------------------------------

# RELATIVE DENSITY

den <- tapply(PCQ,sp.ID,length)         # density

rel.d <- (den/n)                        # rel.density 0 to 1.0

# ---------------------------------------

# Absolute density in trees per hectare (10,000 sq. m)


mean.d <- mean(d)

abs.den.total <- 1e4 / mean.d^2

abs.den <- rel.d * abs.den.total

# ---------------------------------------
```

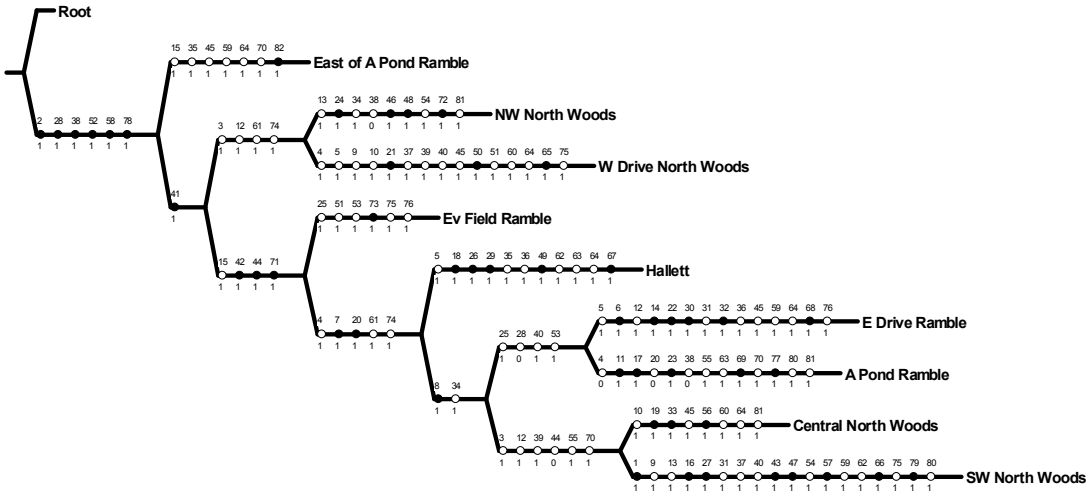
```
# print header to Console before boot loop


options(digits=6)  # increase/decrease as desired

sp="  ";lf <- function() print("",quote=FALSE);lf();lf()

d.line <- function(){
print("=========================================================",quote=F)}

d.line();lf()


cat(sp,sp,"Output from 'PCQ abs density.R'","\n","\n")

cat(sp,sp,"by Professor Dwight Kincaid, dkincaid49@yahoo.com","\n","\n");d.line();lf()

cat(sp,sp,"This run: ",date(),"\n"); lf()

cat(sp,sp,sp,"NOTE: Distance from PCQ to tree is in meters.","\n","\n")

cat(sp,sp,sp,sp,"P A T I E N C E . . .   BOOTSTRAP in progress.","\n","\n")


# bootstrap the trees for 95% CI for absolute density,

# overall and per taxon


NS <- 1e4   # number of bootstrap samples

d1 <- d; abs.den.total1 <- 1:NS; elapsed1 <- proc.time()

for(i in 1:NS){

       indx <- sample(1:n,replace=TRUE); d1 <- d[indx]

       mean.d1 <- mean(d1); abs.den.total1[i] <- 1e4/mean.d1^2

       }


elapsed1 <- proc.time() - elapsed1 # seconds
```

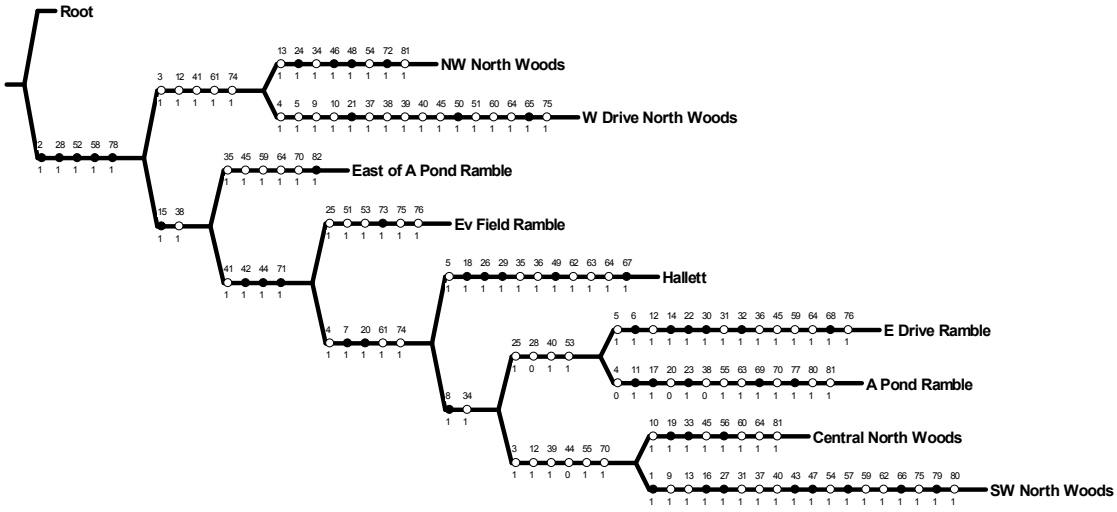
```
# 95% CI for total, absolute density in trees per hectare

LB.abs <- quantile(abs.den.total1,.025)

UB.abs <- quantile(abs.den.total1,.975)


# 95% CI for absolute density for each taxon

LB.95 <- rel.d * LB.abs

UB.95 <- rel.d * UB.abs


den.matrix <- cbind(abs.den,LB.95,UB.95)


# print final results to R Console


cat(sp,sp,"N of SPECIES:",s,"\n")

cat(sp,sp,sp,"N of TREES:",n,"\n")

cat(sp,sp,sp,sp,"N of SAMPLING UNITS:",pts,"\n");lf();lf()

cat(sp,sp,"ABSOLUTE DENSITY of trees:",abs.den.total,"per hectare","\n","\n")

cat(sp,sp,"Bootstrap 95% CI for absolute density:",LB.abs,"to",UB.abs,"\n")

cat(sp,sp,"NS = ",NS,"bootstrap samples with trees as sampling unit.","\n");lf();lf()

cat(sp,sp,"ABSOLUTE DENSITY per hectare per taxon:","\n");lf()

print(abs.den); lf();lf()

cat(sp,sp,"Bootstrap 95% CI for absolute density per taxon:","\n");lf()

print(den.matrix); lf()


cat(sp,"Time in seconds for bootstrap loop: ",signif(elapsed1[1],4),"\n")

d.line();lf()
```

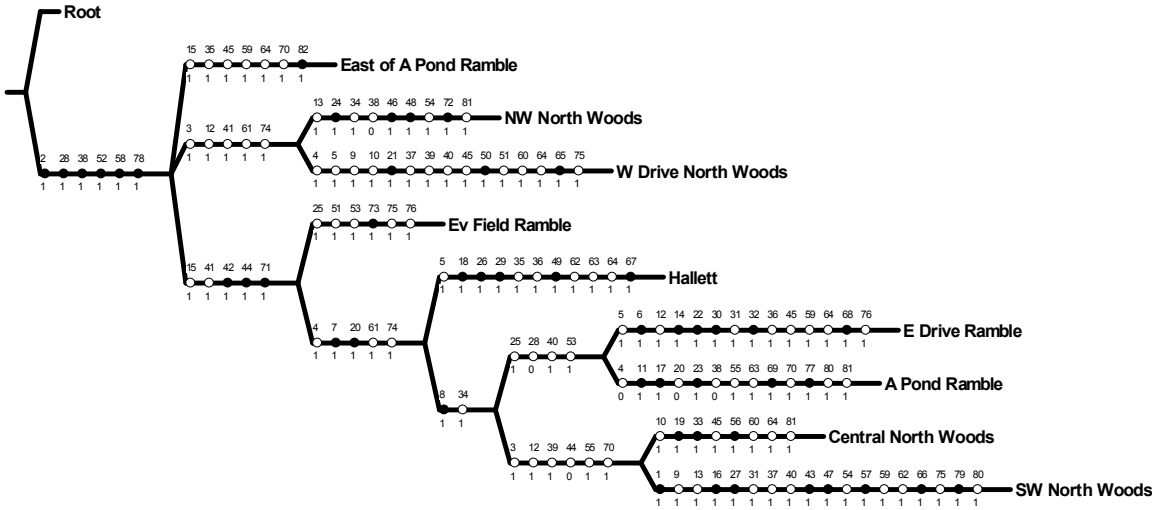
```
cat(sp,"The raw data:","\n");lf()

print(my.frame);lf()

# graph each taxon's estimated absolute density with bootstrap 95% CI


x <- 1:s    # x-coordinate for graphing

stripchart(abs.den~x,
pch=20,vertical=T,xlab="Taxon",ylab="Trees/hectare",xlim=c(.5,s+.5),ylim=c(min(LB.95[]
),max(UB.95[])),col="red",lwd=1, cex.axis=1,cex.lab=1, main="Total Data, Absolute
Density with bootstrap 95% CI")

arrows(1:s,UB.95,1:s,LB.95,angle=90,code=3,length=0,lwd=1,col="red")  # try length=.1

text(1.2,310,"Prunus serotina",pos=4,cex=1) #Total data

text(3.2,120,"Acer platanoides",pos=4,cex=1)#Total data

text(2.2,70,"Quercus rubra",pos=4,cex=1)#Total data

text(4.2,55,"Quercus palustris, Ulmus americana",pos=4,cex=1)#Total data

#text(6,60,"Acer pseudoplatanus, Ulmus americana",pos=4,cex=1)#North woods data

#text(1.2,260,"Prunus serotina",pos=4,cex=1)#North Woods data

#text(3.2,100,"Acer platanoides",pos=4,cex=1)#North Woods data

#text(2.2,70,"Quercus rubra",pos=4,cex=1)#North Woods data

#text(1.2,550,"Prunus serotina",pos=4,cex=1) #Hallett data

#text(2.1,100,"Fraxinus",pos=4,cex=1) #Hallett data

#text(5.2,118,"Rhamnus frangula",pos=4,cex=1) #Hallett data

#text(3.1,66,"Robinia",pos=4,cex=1) #Hallett data

#text(6.2,93,"Viburnum dentatum",pos=4,cex=1) #Hallett data

#text(1.2,335,"Prunus serotina",pos=4,cex=1) #Rambledata

#text(2.2,190,"Acer platanoides",pos=4,cex=1) #Rambledata

#text(3.2,100,"Quercus palustris",pos=4,cex=1) #Rambledata

#text(4.2,150,"Celtis occidentalis",pos=4,cex=1) #Rambledata
```

```
#text(5.2,55,"Phellodendron amurense",pos=4,cex=1) #Rambledata

#text(6.2,70,"Sophora japonica",pos=4,cex=1) #Rambledata

print("end   PCQ abs density.R",quote=F);d.line()

# ---------------------------------------

# end   PCQ abs density.R
```

Appendix 3


Root
East of A Pond Ramble
NW North Woods
W Drive North Woods
Ev Field Ramble
Hallett
E Drive Ramble
A Pond Ramble
Central North Woods
SW North Woods


Root
NW North Woods
W Drive North Woods
East of A Pond Ramble
Ev Field Ramble
Hallett
E Drive Ramble
A Pond Ramble
Central North Woods
SW North Woods


Root
East of A Pond Ramble
NW North Woods
W Drive North Woods
Ev Field Ramble
Hallett
E Drive Ramble
A Pond Ramble
Central North Woods
SW North Woods

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Site 1	0	1	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
Site 2	0	1	1	1	0	0	1	1	0	1	0	1	0	0	1	0	0	0	1	1
Site 3	0	1	1	1	1	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0
Site 4	1	1	1	1	0	0	1	1	1	0	0	1	1	0	1	1	0	0	0	1
Site 5	0	1	0	1	1	1	1	1	0	0	0	1	0	1	1	0	0	0	0	1
Site 6	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Site 7	0	1	0	0	0	0	1	1	0	0	1	0	0	0	1	0	1	0	0	0
Site 8	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Site 9	0	1	0	1	1	0	1	0	0	0	0	0	0	0	1	0	0	1	0	1

	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
Site 1	0	0	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	1
Site 2	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	1	1	0	1
Site 3	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	1	1	1
Site 4	0	0	0	0	0	1	1	0	0	1	0	0	1	0	0	1	1	1	1	1
Site 5	1	0	0	1	0	0	0	0	1	1	1	0	1	0	1	0	1	0	1	1
Site 6	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0	0	0
Site 7	0	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1
Site 8	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1
Site 9	0	0	0	0	1	0	1	1	0	0	0	0	0	1	1	0	1	0	0	1

	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62
Site 1	0	0	0	1	0	1	0	0	0	1	0	1	0	0	0	1	0	0	1	0
Site 2	0	0	1	0	0	0	0	0	0	1	0	0	1	1	0	1	0	1	1	0
Site 3	0	0	1	0	0	0	0	1	1	1	0	0	0	0	0	1	0	1	1	0
Site 4	1	0	0	0	1	0	0	0	0	1	0	1	1	0	1	1	1	0	1	1
Site 5	0	1	1	0	0	0	0	0	0	1	1	0	0	0	0	1	1	0	1	0
Site 6	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0
Site 7	0	1	0	0	0	0	0	0	0	1	1	0	1	0	0	1	0	0	1	0
Site 8	0	1	0	0	0	0	0	0	1	1	1	0	0	0	0	1	0	0	0	0
Site 9	0	1	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	0	1	1

	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82
Site 1	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	1	0	0	1	0
Site 2	0	1	0	0	0	0	0	1	1	0	0	1	0	0	0	1	0	0	1	0
Site 3	0	1	1	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	0	0
Site 4	0	0	0	1	0	0	0	1	1	0	0	1	1	0	0	1	1	1	0	0
Site 5	0	1	0	0	0	1	0	0	1	0	0	1	0	1	0	1	0	0	0	0
Site 6	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1
Site 7	1	0	0	0	0	0	1	1	1	0	0	1	0	0	1	1	0	1	1	0
Site 8	0	0	0	0	0	0	0	0	1	0	1	0	1	1	0	1	0	0	0	0
Site 9	1	1	0	0	1	0	0	0	1	0	0	1	0	0	0	1	0	0	0	0

Data matrix for 9 sites analyzed by Winclada for Parsimony Analysis

Acer negundo L.	1
Acer platanoides L.	2
Acer pseudoplatanus L.	3
Acer rubrum L.	4
Acer saccharum Marshall.	5
Aesculus hippocastanum L.	6
Ailanthus altissima (Miller) Swingle.	7
Amelanchier canadensis (L.) Medikus	8
Aralia spinosa L.	9
Betula lenta L.	10
Carpinus caroliniana Walter.	11
Carya cordiformis (Wangenh) K. Koch	12
Carya tomentosa (Poiret) Nutt.	13
Castanea dentata (Marshall) Borkh. (hybrid)	14
Celtis occidentalis L.	15
Cercis canadensis L.	16
Cornus kousa Hance.	17
Cornus mas L.	18
Cornus racemosa Lam.	19
Crataegus sp. L.	20
Crataegus viridis	21
Cratageus phaenopyrum (L.f.) Medikus.	22
Cratageus x lavallei (grignonensis) Herincq.	23
Euonymus alatus (Thunb.) Siebold.	24
Euonymus europaeus L.	25
Evodia davidii	26
Fagus grandifolia Ehrh.	27
Fraxinus americana L.	28
Gingko biloba L.	29
Gleditsia triacanthos L.	30
Gleditsia triacanthos var. inermis Willd.	31
Gymnocladus dioica (L.) K. Koch.	32
Hamamelis vernalis Sarg.	33
Hamamelis virginiana L.	34
Ilex opaca Aiton.	35
Koelreuteria paniculata Laxm.	36
Ligustrum vulgare L.	37
Lindera benzion (L.) Blume.	38
Liquidambar styraciflua L.	39
Liriodendron tulipifera L.	40
Malus sp. L.	41
Morus alba L.	42
Parthenocissus tricuspidata (Siebold & Zucc.) Planchon.	43
Phellodendron amurense Rupr.	44
Philadelphus coronarius L.	45
Photinia glabra Maxim.	46
Photinia villosa (Thunb.) DC.	47
Pinus nigra Arnold.	48
Pinus strobus L.	49
Platanus occidentalis L.	50

Platanus x hybrida Brot.	51
Prunus serotina Ehrh.	52
Prunus sp. L.	53
Prunus virginiana L.	54
Quercus alba L.	55
Quercus laevis Walter.	56
Quercus macrocarpa Michx.	57
Quercus palustris Muenchh.	58
Quercus phellos L.	59
Quercus prinus L.	60
Quercus rubra L.	61
Rhamnus frangula L.	62
Rhododendron sp. L.	63
Rhodotypos scandens Makino.	64
Rhus glabra L	65
Rhus typhina L.	66
Robinia psuedoacacia L.	67
Rosa multiflora Thunb.	68
Sambucus canadensis L.	69
Sassafras albidum (Nutt.) Nees.	70
Sophora japonica L.	71
Tilia americana L.	72
Tilia cordata Miller.	73
Ulmus americana L.	74
Ulmus procera Salisb.	75
Ulmus sp. L.	76
Vaccinium corymbosum L.	77
Viburnum dentatum var. lucidum Ait.	78
Viburnum opulus var. opulus L.	79
Viburnum plicatum Thunb.	80
Viburnum prunifolium L.	81
Viburnum setigerum Hance.	82

Species identification numbers for Winclada analysis

Appendix 4

The Vascular Flora of Central Park, 2006

(This list preserves the original nomenclature of DeCandido et al. 2007)

Species	Family	Historical only	References and comments
Acer platanoides L.	Aceraceae		non-native
Acer pseudoplatanus L.	Aceraceae		non-native
Acer rubrum var. *rubrum*L.	Aceraceae		1857a
Acer saccharinum L.	Aceraceae	x	1857a
Acer saccharum L.	Aceraceae		
Alisma subcordatum Raf.	Alismataceae	x	1857a
Amaranthus blitum L.	Amaranthaceae		non-native
Amaranthus caudatus L.	Amaranthaceae	x	non-native; 1880
Amaranthus crispus (Lesp. & Thev.) Terrace	Amaranthaceae		non-native
Amaranthus hybridus L.	Amaranthaceae		non-native
Amaranthus retroflexus L.	Amaranthaceae		non-native; 1857a, 1880
Rhus aromatica Ait.	Anacardiaceae		planted 1995-2005
Rhus copallinum L.	Anacardiaceae		1857a
Rhus glabra L.	Anacardiaceae	x	1857a; 1880
Rhus hirta (L.) Sudworth	Anacardiaceae		1857a
Toxicodendron radicans ssp. *radicans* (L.) Kuntze	Anacardiaceae		1857a; 1880
Toxicodendron vernix (L.) Kuntze	Anacardiaceae	x	1857a
Cryptotaenia canadensis (L.) DC.	Apiaceae		planted 1995-2005
Daucus carota L.	Apiaceae		non-native; 1857a; 1880
Osmorhiza longistylis (Torrey) DC	Apiaceae		Rare
Sanicula canadensis L.	Apiaceae		Rare
Apocynum cannabinum var. *cannabinum* L.	Apocynaceae		
Vinca minor L.	Apocynaceae		non-native
Arisaema triphyllium ssp. *triphyllum* (L.) Schott ex Schott & Endll.	Araceae	x	1857a
Symplocarpus foetidus (L.) Salisb. ex Nutt.	Araceae		1857a; planted 1995-2005
Acanthopanax sieboldianus L.	Araliaceae		non-native
Aralia spinosa L.	Araliaceae		1857a
Aralia racemosa L.	Araliaceae	x	1857a
Hedera helix L.	Araliaceae		non-native
Asclepias incarnata var. *incarnata* L.	Asclepiadaceae		1857a; planted 1995-2005
Asclepias syriaca L.	Asclepiadaceae		1880
Asclepias tuberosa var. *interior* L.	Asclepiadaceae		1857a; planted 1995-2005
Cynanchum louiseae Kartesz & Gandhi	Asclepiadaceae		non-native

Asplenium platyneuron L.	Aspleniaceae		BSP - 1857a
Asplenium trichomanes L.	Aspleniaceae	x	1857a
Athyrium filix-femina var. *asplenioides* (Michx.) Farw.	Aspleniaceae	x	1857a; recently planted but no sustaining groups
Ambrosia artemisiifolia L.	Asteraceae		1880
Ambrosia trifida L.	Asteraceae		
Anaphalis margaritacea (L.) Benth. & Hooker f. ex Clarke	Asteraceae	x	1880
Anthemis arvensis L.	Asteraceae		non-native, uncommon
Anthemis cotula L.	Asteraceae	x	non-native, uncommon
Arctium lappa L.	Asteraceae	x	1857a
Arctium minus (Hill) Bernh.	Asteraceae		non-native; 1880
Artemisia annua L.	Asteraceae		non-native
Artemisia vulgaris L.	Asteraceae		non-native
Aster acuminatus Michx.	Asteraceae	x	1880
Aster cordifolius L.	Asteraceae		planted 1995-2005
Aster divaricatus L.	Asteraceae		
Aster ericoides L.	Asteraceae		1857a; 1880
Aster laevis var. *laevis* L.	Asteraceae		planted 1995-2005
Aster lanceolatus var. *simplex* (Willd.) A. Jones	Asteraceae		1880; planted 1995-2005
Aster lateriflorus var. *lateriflorus* (L.) Britt.	Asteraceae		rare; 1880
Aster novae-angliae L.	Asteraceae		1880; planted 1995-2005
Aster novi-belgii var. *novi-belgii* L.	Asteraceae		planted 1995-2005
Aster paternus Cronq.	Asteraceae	x	1857a
Aster pilosus var. *pilosus* Willd.	Asteraceae		
Bidens cernua L.	Asteraceae	x	1880
Bidens frondosa L.	Asteraceae		1880
Centaurea jacea L.	Asteraceae		non-native
Centaurea nigra L.	Asteraceae		non-native
Cichorium intybus L.	Asteraceae		non-native; 1857a; 1880
Cirsium arvense (L.) Scop.	Asteraceae		non-native; 1880
Cirsium vulgare (Savi) Tenore	Asteraceae		non-native; 1880
Conyza canadensis var. *canadensis* (L.) Cronq.	Asteraceae		non-native; 1880
Coreopsis lanceolata L.	Asteraceae		non-native
Eclipta prostrata (L.) L.	Asteraceae		NYS S1
Erechitites hieracifolia var. *hieracifolia* (L.) Raf ex DC.	Asteraceae		1857a
Erigeron annuus (L.) Pers.	Asteraceae		
Erigeron philadelphicus (L.)	Asteraceae	x	1857a
Eupatorium perfoliatum (L.)	Asteraceae	x	1857a; 1880
Eupatorium purpureum L.	Asteraceae	x	1857a
Eupatorium rugosum Houtt.	Asteraceae		
Eupatorium serotinum Michx.	Asteraceae		NYS S2
Euthamia graminifolia (L.) Nutt. Ex Cass.	Asteraceae		
Euthamia tenuifolia (Pursh) Nutt.	Asteraceae	x	non-native; 1880
Galinsoga parviflora Cav.	Asteraceae	x	non-native; 1880
Galinsoga quadriradiata Ruiz & Pavón	Asteraceae		non-native
*Gnaphalium uliginosum*L.	Asteraceae	x	non-native; 1857a
Gnaphalium macounii Greene	Asteraceae	x	1880
Helianthus annuus L.	Asteraceae		non-native ;1880;

			uncommon
Helianthus strumosus L.	Asteraceae		Planted 1995-2005
Helianthus tuberosus L.	Asteraceae		non-native
Heliopsis helianthoides (L.) Sweet	Asteraceae	x	1857a
Hieracium floribundum Wimm. & Gräbn.	Asteraceae		non-native
Hieracium piloselloides Vill.	Asteraceae		non-native
Hieracium subaudum L.	Asteraceae		non-native
Hieracium scabrum Michx.	Asteraceae	x	1857a
Hypochaeris radiacata L.	Asteraceae		non-native
Inula helenium L.	Asteraceae	x	1857a
Lactuca canadensis var. *canadensis* L.	Asteraceae		1857a; 1880
Lactuca biennis (Moench) Fern.	Asteraceae		Rare
Lactuca sativa L.	Asteraceae	x	1880
Lactuca serriola L.	Asteraceae		non-native; 1880
Lapsana communis L.	Asteraceae		non-native
Leucanthemum vulgare Lam.	Asteraceae		non-native; 1880
Matricaria discoidea DC.	Asteraceae		non-native
Mikania scandens (L.) Willd.	Asteraceae	x	1857a
Prenanthes altissima L.	Asteraceae	x	1857a
Rudbeckia hirta var. *pulcherrima* Farw.	Asteraceae		non-native
Rudbeckia laciniata L.	Asteraceae		Planted 1995-2005
Senicio vulgaris L.	Asteraceae		non-native
Silphium perfoliatum L.	Asteraceae		non-native
Solidago bicolor L.	Asteraceae	x	1857a
Solidago caesia L.	Asteraceae		Planted 1995-2005
Solidago canadensis var. *scabra* (Muhl.) Torrey & A. Gray	Asteraceae		
Solidago juncea Ait.	Asteraceae		
Solidago nemoralis Ait.	Asteraceae	x	1880
Solidago rigida L.	Asteraceae	x	1857a
Solidago rugosa ssp. *rugosa* var. *rugosa* Mill.	Asteraceae		
Solidago sempervirens var. *sempervirens* L.	Asteraceae		Planted 1995-2005
Sonchus asper (L.) Hill	Asteraceae		non-native; uncommon
Sonchus oleraceus L.	Asteraceae		non-native
Tanaceteum parthenium (L.) Schultz	Asteraceae	x	non-native; 1857a
Taraxacum officinale Weber ex Wiggers	Asteraceae		non-native; 1880
Vernonia noveboracensis (L.) Michx.	Asteraceae		non-native; 1880; planted 1995-2005
Xanthium strumarium var. *strumarium* L.	Asteraceae		non-native; 1880; 1857a
Impatiens capensis Meerb.	Balsaminaceae		1857a; 1880
Berberis vulgaris L.	Berberidaceae	x	1857a; non-native
Podophyllum peltatum L.	Berberidaceae		planted 1995-2005
Alnus serrulata (Dryand ex. Ait.) Willd.	Betulaceae	x	1857a
Betula allegheniensis Britt.	Betulaceae	x	1857a
Betula lenta L.	Betulaceae		1857a
Betula nigra L.	Betulaceae	x	1857a; NYS S3
Betula populifolia Marsh.	Betulaceae		1857a
Carpinus caroliniana ssp. *virginiana* (Marsh.) Furlow	Betulaceae		1857a

Corylus americana Walt.	Betulaceae	x	1857a
Corylus cornuta Marsh.	Betulaceae	x	1857a
Ostra virginiana (Mill.) Koch	Betulaceae		
Campsis radicans (L.) Seem. ex Bureau	Bignoniaceae		non-native
Catalpa bignonoides Walt.	Bignoniaceae	x	non-native; planted 1985-2005; 1857a; 1880
Catalpa speciosa (Warder ex Barney) Engelm	Bignoniaceae		non-native
Paulownia tomentosa (Thunb.) Sieb. & Zucc. ex Steud.	Bignoniaceae		non-native
Mertensia virginica (L.) Pers. Ex. Link	Boraginaceae		planted 1995-2005
Alliaria petiolata (Bieb.) Cav. & Grande	Brassicaceae		non-native
Arabidopsis thaliana (L.) Heynh.	Brassicaceae		non-native
Barbarea vulgaris R. Br. ex. Ait.	Brassicaceae		non-native, uncommon
Brassica rapa L.	Brassicaceae		non-native; 1880
Capsella bursa-pastoris (L.) Medik.	Brassicaceae		non-native; 1880
Cardamine hirsuta L.	Brassicaceae		non-native
Cardamine pensylvanica Muhl. ex. Willd.	Brassicaceae		
Coronopus didymus (L.) Sm.	Brassicaceae		non-native, uncommon
Erysimum cheiranthoides L.	Brassicaceae		non-native, uncommon
Hesperis matronalis L.	Brassicaceae		non-native, uncommon
Lepidium virginicum L.	Brassicaceae		non-native, uncommon; 1880
Raphanus raphanistrum L.	Brassicaceae		non-native
Rorippa palustris ssp. *palustris* (L.) Besser	Brassicaceae		non-native
Sinapis alba L.	Brassicaceae		non-native
Sinapis arvensis L.	Brassicaceae		non-native
Sisymbrium officinale (L.) Scop.	Brassicaceae		non-native; 1880
Thlaspi arvense L.	Brassicaceae		non-native
Opuntia humifusa (Raf.) Raf.	Cactaceae	x	1857a
Campanula rapunculoides L.	Campanulaceae	x	non-native; 1880
Lobelia cardinalis L.	Campanulaceae	x	1857a
Lobelia inflata L.	Campanulaceae		Rare
Lobelia spicata Lam.	Campanulaceae	x	1857a
Triodanis perfoliata var. perfoliata (L.) Nieuwl.	Campanulaceae		Rare
Cannabis sativa L.	Cannabaceae	x	1880
Humulus japonicus L.	Cannabaceae		non-native; extirpated 2006
Humulus lupulus L.	Cannabaceae		1857a; non-native; no specimen collected
Diervilla lonicera Mill.	Caprifoliaceae	x	1857a
Lonicera japonica Thunb.	Caprifoliaceae		non-native
Lonicera maackii (Rupr.) Maxim.	Caprifoliaceae		non-native
Lonicera sempervirens L.	Caprifoliaceae	x	1857a
Sambucus canadensis L.	Caprifoliaceae		1857a; 1880
Viburnum acerifolium L.	Caprifoliaceae	x	1857a

Viburnum dentatum var. *lucidum* Ait.	Caprifoliaceae		1857a
Viburnum opulus var. *opulus* L.	Caprifoliaceae		non-native
Viburnum plicatum Thunb.	Caprifoliaceae		non-native
Viburnum prunifolium L.	Caprifoliaceae		1857a
Viburnum rhytidophyllum Helms.	Caprifoliaceae	x	
Achillea millefolium var. *millefolium* L.	Caprifoliaceae	x	non-native; 1880
Cerastium fontanum Baumg.*emend*Jalas	Caryophyllaceae		non-native
Dianthus armeria L.	Caryophyllaceae		non-native; rare
Sagina japonica (Sw.) Ohwi	Caryophyllaceae		non-native
Sagina procumbens L.	Caryophyllaceae		non-native
Saponaria officinalis L.	Caryophyllaceae		non-native; 1857a
Silene caroliniana var. *pensylvanica* (Michx.) Fern	Caryophyllaceae	x	1857a; NYS S3
Silene latifolia Poir.	Caryophyllaceae		non-native
Silene noctiflora L.	Caryophyllaceae	x	non-native; 1880
Silene stellata (L.) Ait. F.	Caryophyllaceae	x	1857a
Silene vulgaris (Moench) Garcke	Caryophyllaceae		non-native, rare; 1880
Spergularia rubra (L.) J. & C. Presl.	Caryophyllaceae		non-native
Stellaria graminea L.	Caryophyllaceae		non-native; Rare
Stellaria media (L.) Vill.	Caryophyllaceae		non-native; 1880
Celastrus orbiculata Thunb.	Celastraceae		non-native
Celastrus scandens L.	Celastraceae	x	1857a; NYS S3
Ilex laevigata (Pursh) A. Gray	Celastraceae	x	1857a
Ilex montana Torrey & A. Gray ex A. Gray	Celastraceae	x	1857a
Atriplex patula L.	Chenopodiaceae	x	1880
Chenopodium album var. *album* L.	Chenopodiaceae		non-native; 1857a, 1880
Chenopodium ambrosioides L.	Chenopodiaceae		non-native; 1880
Chenopodium botrys L.	Chenopodiaceae		non-native; 1880
Chenopodium pumilio R. Br.	Chenopodiaceae		non-native
Chenopodium simplex (Torrey) Raf.	Chenopodiaceae	x	1857a
Chenopodium urbicum L.	Chenopodiaceae	x	1880
Amaranthus albus L.	Chenopodiaceae	x	1880
*Clethra alnifolia*L.	Clethraceae		planted 1995-2005; 1857a
Hypericum ellipticum Hooker	Clusiaceae	x	1857a
Hypericum gentianoides (L.) BSP.	Clusiaceae	x	1857a
Hypericum perforatum L.	Clusiaceae		non-native; 1880
Hypericum prolificum L.	Clusiaceae	x	1857a; NYS S2
Commelina communis var. *ludens* (Miq.) Pennell	Commelinaceae		non-native
Tradescantia virginiana L.	Commelinaceae		
Calystegia sepium ssp. s*epium* (L.) R. Br.	Convolvulaceae		non-native
Convolvulus arvensis L.	Convolvulaceae		non-native; 1880
Ipomoea purpurea (L.) Roth	Convolvulaceae	x	non-native; 1880
Cornus alternifloia L.	Cornaceae		

Cornus amomum ssp. *amomum* Mill.	Cornaceae	x	1857a
Cornus florida L.	Cornaceae	x	1857a
Cornus foemina ssp. *racemosa* (Lam.) J. Wilson	Cornaceae		1857a
Cornus rugosa Lam.	Cornaceae	x	1857a
Cornus sericea L.	Cornaceae	x	1857a
Penthorum sedoides L.	Crassulaceae	x	1857a; 1880
Sedum acre L.	Crassulaceae		non-native; 1857a
Juniperus virginiana L.	Cupressaceae	x	1857a
Curcurbita pepo L.	Curcurbitaceae		non-native
Sicyos angulatus L.	Curcurbitaceae	x	1857a
Cuscuta gronovii Willd ex Schultz	Cuscutaceae		1857a
Carex annectens (Bickn.) Bickn.	Cyperaceae		
Carex blanda Dewey	Cyperaceae		
Carex radiata (Wahl.) Small	Cyperaceae		
Carex vulpinoidea Michx.	Cyperaceae		
Cyperus esculentus var. *leptostachyus* Boeck.	Cyperaceae		non-native
Cyperus strigosus L.	Cyperaceae	x	1857a; 1880
Fuirena squarrosa Michx.	Cyperaceae		1857a ?
Scirpus hattorianus Pers.	Cyperaceae		Planted 1995-2005
Dennstaedtia punctiloba (Michx.) Moore	Dennstaedtiaceae		uncommon; planted regularly, does well, some regeneration
*Pteridium aquilinum*var. *Latiusculum* (Desv.) Underw. Ex Heller	Dennstaedtiaceae	x	1857a; One patch that has sustained itself for >20 years
Dioscorea villosa L.	Dioscoreaceae	x	1857a
Cystopteris fragilis (L.) Bernh.	Dryopteridaceae		Rare
Onoclea sensibilis L.	Dryopteridaceae		1857a; 1880; rare planted, spreads
Deparia acrostichoides (Sw.) Kato	Dryopteridaceae	x	1857a
Dryopteris carthusiana (Vill.) Fuchs	Dryopteridaceae	x	1857a
Dryopteris intermedia (Muhl. Ex. Willd.) A. Gray	Dryopteridaceae	x	1880
Matteuccia struthiopteris (L.) Todaro	Dryopteridaceae	x	1857a; planted regularly, regenerates through rhizomes.
Woodsia obtusa (Spreng.) Torrey	Dryopteridaceae		Uncommon
*Polypodium virginianum*L.	Dryopteridaceae	x	1857a
Diospyros virginiana L.	Ebenaceae	x	1857B; NYS S2
Equisetum arvense L.	Equisetaceae		rare, no specimen collected
Andromeda glaucophylla Link	Ericaceae	x	1857b
Gaylussacia frondosa (L.) Torrey & A. Gray ex Torrey	Ericaceae	x	1857a

Leucothose racemosa (L.) A. Gray	Ericaceae	x	1857a
Lyonia ligustrina (L.) DC	Ericaceae	x	1857a
Monotropa uniflora L.	Ericaceae		extirpated 2006
Rhododendron arborescens (Pursh) Torrey	Ericaceae	x	1857a; ?; NYS Extirpated
Rhododendron viscosum (L.) Torrey	Ericaceae	x	1857a
Vaccinium angustifolium Ait.	Ericaceae	x	1857a
*Vaccinium corymbosum*L.	Ericaceae	x	1857a
Vaccinium pallidum Ait.	Ericaceae	x	1857a
Vaccinium stamineum L.	Ericaceae	x	1857a
Acalypha virginica var. *rhomboidea* (Raf.) Cooperrider	Euphorbiaceae		
Acalypha virginica var. virginica (L.)	Euphorbiaceae	x	1857a; 1880; NYS S2
Chamaesyce maculata (L.) Small	Euphorbiaceae		1880
Euphorbia cyparissias L.	Euphorbiaceae		non-native
Albizia julibrissin Durazz.	Fabaceae		non-native
Apios americana Medik.	Fabaceae	x	1857a; 1880
Cercis canadensis L.	Fabaceae		uncommon
Chamaecrista nictitans (L.) Moench	Fabaceae	x	1857a
Coronilla varia L.	Fabaceae		non-native
Crotolaria sagittalis L.	Fabaceae	x	1857a; NYS S1
Desmodium canadense (L.) DC.	Fabaceae	x	1857a
Desmodium paniculatum (L.) DC	Fabaceae	x	1857a
Galactia volubilis (L.) Britt.	Fabaceae	x	1857a; NYS Extirpated
Gleditsia triacanthos L.	Fabaceae		uncommon; 1894
Gymnocladus dioica (L.) Koch	Fabaceae		uncommon
Lespdeza capitata Michx.	Fabaceae	x	1857a
Lespedeza procumbens Michx.	Fabaceae	x	1857a
Lespedeza violacea (L.) Pers.	Fabaceae	x	1857a; NYS S3
Lotus corniculata L.	Fabaceae		non-native
Medicago lupulina L.	Fabaceae		non-native
Melilotus alba Desr. ex Lam	Fabaceae		non-native; 1880
Robinia pseudoacacia L.	Fabaceae		non-native; 1857a
Robinia hispida L.	Fabaceae	x	1889
Trifolium arvense L.	Fabaceae		non-native
Trifolium pratense L.	Fabaceae		non-native; 1880
Trifolium aureum Pollich	Fabaceae	x	1880
Trifolium repens L.	Fabaceae		non-native; 1880
Vicia sativa ssp. *nigra* (L.) Ehrh.	Fabaceae		non-native
Vicia tetrasperma (L.) Schreb.	Fabaceae		non-native
Vicia villosa ssp. *villosa* Roth	Fabaceae		non-native
Wisteria sinensis (Sims) Sweet	Fabaceae		non-native
Castanea dentata (Marsh.) Borkh.	Fagaceae	x	1857a
Fagus grandifolia Ehrh.	Fagaceae	x	1857a
Quercus alba L.	Fagaceae	x	1857a
Quercus cerris L.	Fagaceae		non-native
Quercus coccinea Muenchh.	Fagaceae	x	1857a
Quercus marilandica Muenchh.	Fagaceae	x	1857a

Quercus montana Willd.	Fagaceae	x	1857a
Quercus muhlenbergeii Engelm.	Fagaceae	x	1857a
Quercus rubra L.	Fagaceae		1857a
Quercus palustris Muenchh.	Fagaceae		1857a
Quercus prinoides Willd.	Fagaceae	x	1857a
Quercus stellata Wang.	Fagaceae	x	1857a
Quercus velutina Lam.	Fagaceae	x	1857a
Gentiana andrewsii Griesb.	Gentianaceae	x	1857a
Erodium cicutarium (L.) L'Her. ex Ait.	Geraniaceae		non-native; rare
Geranium carolinianum var. *carolinianum* L.	Geraniaceae		
Geranium maculatum L.	Geraniaceae		planted 1995-2005
Geranium pusillum Burm. f.	Geraniaceae		non-native; rare
Ginkgo biloba L.	Ginkgoaceae		non-native
Hamamelis virginiana L.	Hamamelidaceae		1857a
Liquidambar styraciflua L.	Hamamelidaceae		1857a
Aesculus hippocastanum L.	Hippocastanaceae		non-native; 1857a; planted 1995-2005
Philadelphus coronarius L.	Hydrangeaceae		non-native
Iris pseudoacorus L.	Iridaceae		non-native
Iris versicolor L.	Iridaceae		Planted 1995-2005
Sisyrinchiumangustifolium Mill.	Iridaceae		
Carya cordiformis (Wang.) Koch	Juglandaceae		1857a
Carya glabra (Mill.) Sweet	Juglandaceae		
Carya ovalis (Wang.) Sarg.	Juglandaceae	x	1857a
Carya ovata (Mill.) Koch	Juglandaceae	x	1857a
Carya tomentosa (Poir. Ex Lam.) Nutt.	Juglandaceae		1857a
Juglans cinerea L.	Juglandaceae	x	1857a; NYS S4
Juglans nigra L.	Juglandaceae	x	1857a
Juncus effusus Var. *pylaei* (LaHarpe) Fern. & Wieg.	Juncaceae		
Ajuga reptans L.	Lamiaceae		non-native
Collinsonia canadensis L.	Lamiaceae	x	1880
Glechoma hederacea L.	Lamiaceae		non-native; 1880
Lamiastrum galeobdolan (L.) Ehren. & Polatschek	Lamiaceae		non-native
Lamium amplexicaule L.	Lamiaceae		non-native
Lamium purpureum var. *purpureum* L.	Lamiaceae		non-native
Leonurus cardiaca L.	Lamiaceae	x	non-native; 1857a; 1880
Lycopus europaeus L.	Lamiaceae	x	non-native; 1880
Mentha canadensis L.	Lamiaceae	x	non-native; 1857a
Nepeta cataria L.	Lamiaceae	x	
Origanum vulgare L.	Lamiaceae	x	1857a

Pysostegia virginiana (L.) Benth.	Lamiaceae	x	non-native; 1857a
Prunella vulgaris L.	Lamiaceae		non-native; 1857a
Pycnanthemum clinopodioides Torrey & A. Gray	Lamiaceae	x	1857a; NYS S1
Salvia lyrata L.	Lamiaceae	x	1880; NYS extirpated
Scutellaria galericulata L.	Lamiaceae	x	1857a
Scutellaria lateriflora L.	Lamiaceae	x	1880
Teucrium canadense var. *canadense* L.	Lamiaceae		Rare
Lindera benzoin (L.) Blume	Lauraceae		1857a
Sassafras albidum (Nutt.) Nees	Lauraceae		1857a
Lemna minor L.	Lemnaceae		1857a
Wolffia columbiana Karst.	Lemnaceae		
Aletris aurea Walt.	Liliaceae	x	1857a ?
Allium tricoccum Ait.	Liliaceae		Planted 1995-2005
Allium vineale L.	Liliaceae		non-native
Asparagus officinalis L.	Liliaceae	x	non-native; 1857a
Erythronium americanum Ker.	Liliaceae		Planted 1995-2005
Hemerocallis fulva (L.) L.	Liliaceae		non-native
Hosta ventricosa (Salisb.) Stearn.	Liliaceae		non-native
Hyacinthoides nonscripta (L.) Chouard ex Rothm.	Liliaceae		non-native
Lilium canadense ssp. *canadense* L.	Liliaceae	x	1857a
Ornithogalum umbellatum L.	Liliaceae		non-native
Polygonum biflorum (Walt.) Ell.	Liliaceae	x	1857a
Linum usitatissimum L.	Linaceae		non-native; uncommon
Linum virginianum L.	Linaceae	x	1857a
Huperzia lucidula (Michx.) Trev.	Lycopodiaceae	x	1857a
Lycopodium dendroideum	Lycopodiaceae	x	1857a
Lythrum salicaria L.	Lythraceae		non-native
Liriodendron tulipifera L.	Magnoliaceae		1857a
Abutilon theophrasti Medik.	Malvaceae		uncommon; 1857a, 1880
Hybiscus syriacus L.	Malvaceae	x	1857a; planted 1995-2005
Malva neglecta Wallr.	Malvaceae		non-native; 1857a; 1880
Menispermum canadense L.	Menispermaceae	x	1857a
Mollugo verticillata L.	Molluginaceae		non-native; 1880
Broussonetia papyrifera (L.) L'Hér. ex Vent.	Moraceae		1857a; non-native
Maclura pomifera (Raf. ex Sarg.)	Moraceae		non-native
Morus alba L.	Moraceae	x	1857a; non-native
Myrica pensylvanica Loisel. Ex. Duhamel	Myricaceae	x	1857a

Nyssa sylvatica Marsh	Nyssaceae		
Fraxinus americana L.	Oleaceae		1857a
Fraxinus nigra Marsh.	Oleaceae	x	1857a
Fraxinus pennsylvanica Marsh.	Oleaceae		1857a
Ligustrum vulare L.	Oleaceae	x	non-native; 1857a; planted 1995-2005
Syringa vulgaris L.	Oleaceae	x	non-native; 1857a; planted 1995-2005
Agalinis tenuifolia var. *tenuifolia* (Vahl) Raf.	Oleaceae	x	1857a
Chelone glabra L.	Oleaceae	x	1857a
Circaea lutetiana ssp. *canadensis* (L.) Aschers. & Magnus	Onagraceae		
Epilobium ciliatum ssp. *ciliatum* Raf.	Onagraceae		Rare
Epilobium coloratum Biehl.	Onagraceae	x	1857a
Ludwigia alternifolia L.	Onagraceae	x	1857a
Oenothera biennis L.	Onagraceae		1857a; 1880
Oenothera glazioviana L.	Onagraceae		non-native
Botrychium dissectum Spreng.	Ophioglossaceae	x	1857a
Botrychium lunaria (L.) Sw.	Ophioglossaceae	x	1857a; NYS S1
Epipactis helleborine (L.) Crantz	Orchidaceae		non-native
Goodyera pubescens (Willd.) R. Br.	Orchidaceae	x	1857a
Spiranthes lacera var. *gracilis* (Biegl.) Luer	Orchidaceae	x	1857a
Osmunda regalis var. *spectabilis* (Willd.) A. Gray.	Osmundaceae	x	1857a; Planted regularly, does well but no regeneration
Oxalis corniculata L.	Oxalidaceae		non-native, rare
Oxalis stricta L.	Oxalidaceae		1857a; 1880
Chelidonium majus L.	Papaveraceae		non-native
Phytolacca americana L.	Phytolaccaceae		1857a, 1880
Pinus strobus L.	Pinaceae	x	1857a; planted in 19th century
Tsuga canadensis (L.) Carr.	Pinaceae	x	1857a; planted in 19th century
Plantago major L.	Plantaginaceae		non-native; 1857a; 1880
Plantago lanceolata L.	Plantaginaceae		non-native; 1857a
Platanus occidentalis L.	Platanaceae	x	1857a
Platanus x hybrida Brot.	Platanaceae		non-native
Agrostis gigantea Roth.	Poaceae		non-native
Anthoxanthum odoratum L.	Poaceae		non-native
Bromus sterilis L.	Poaceae		non-native

Bromus tectorum L.	Poaceae		non-native
Dactylis glomerata L	Poaceae		non-native
Danthonia compressa Austin	Poaceae		planted 1995-2005
Echinochloa crusgalli ssp. *crusgalli* (L.) Beauv.	Poaceae		non-native
Digitaria sanguinalis (L.) Scop.	Poaceae		non-native
Eleusine indica (L.) Gaertn.	Poaceae		non-native
Elymus hystrix var. *hystrix* L.	Poaceae		planted 1995-2005
Holcus lanatus L.	Poaceae		non-native
Leersia virginica Willd.	Poaceae		1857a
Lolium perenne var. *perenne* L.	Poaceae		non-native
Microstegium vimineum (Trin.) Camus	Poaceae		non-native
Muhlenbergia schreberi Gmel.	Poaceae		
Panicum capillare L.	Poaceae	x	1857a
Panicum clandestinum L.	Poaceae		
Panicum milaceum L.	Poaceae		non-native; rare
Phleum pratense ssp. *pratense* L.	Poaceae		non-native
Phragmites australis (Cav.) Trin. Ex Steud.	Poaceae		non-native
Poa annua L.	Poaceae		non-native
Poa compressa L.	Poaceae		non-native
Poa pratense L.	Poaceae		non-native
Schizachyrium scoparium ssp. *scoparium* L.	Poaceae		uncommon
Setaria faberi Herrm.	Poaceae		non-native
Setaria pumila (Poir.) Schultes	Poaceae		non-native
Sporobolus asper (Michx.) Kunth	Poaceae	x	1857a
Polygala verticillata var. *verticillata* L.	Polygalaceae	x	1857a
Fagopyrum esculentum Moench.	Polygonaceae		non-native, rare
Polygonum amphibium var. *stipulaceum* Colem.	Polygonaceae	x	1857a
Polygonum arenastrum Jord. ex Bor.	Polygonaceae		non-native
Polygonum aubertii Henry	Polygonaceae		non-native
Polygonum aviculare L.	Polygonaceae	x	1857a
Polygonum careyi Olney	Polygonaceae	x	1857a; NYS S1-S2
Polygonum cespitosum var.*longisetum* (DeBruyn) Stewart	Polygonaceae		non-native
Polygonum convolvulus L.	Polygonaceae		non-native; 1857a
Polygonum cuspidatum Sieb. & Zucc.	Polygonaceae		non-native
Polygonum erectum L.	Polygonaceae	x	1880; NYS extirpated
Polygonum hydropiper L.	Polygonaceae	x	1880
Polygonum lapathifolium L.	Polygonaceae		non-native
Polygonum orientale L.	Polygonaceae	x	1880
Polygonum pensylvanicum L.	Polygonaceae	x	1857a 1880
Polygonum perfoliatum L.	Polygonaceae		non-native
Polygonum persicaria L.	Polygonaceae		non-native; 1880
Polygonum punctatum var. *punctatum* Ell.	Polygonaceae	x	1880
Polygonum scandens var. *dumetorum* (L.) Gleason	Polygonaceae		non-native; 1880
Polygonum setaceum Bald. ex. Ell.	Polygonaceae		
Polygonum tenue Michx.	Polygonaceae	x	1857a; NYS S3
Polygonum virginianum L.	Polygonaceae		
Rumex acetosella L.	Polygonaceae		non-native; 1880

Rumex crispus L.	Polygonaceae		non-native; 1880
Rumex obtusifolius L.	Polygonaceae		non-native
Rumex orbiculatus A. Gray	Polygonaceae	x	1857a
Claytonia virginica L.	Portulacaceae	x	1888
Portulaca oleracea L.	Portulacaceae		non-native; 1857a, 1880
Anagallis arvensis L.	Primulaceae		non-native, rare
Lysimachia quadrifolia L.	Primulaceae		
*Lysimachia terrestris (*L.) BSP.	Primulaceae	x	1857a
Adiantum pedatum L.	Pteridaceae	x	1857a; Planted but does not do so well.
Actaea spicata ssp. *Rubra* (Ait.) Hulten	Ranunculaceae	x	1857a
Anemone virginiana var.*virginiana* L.	Ranunculaceae		Rare
Aquilegia canadensis L.	Ranunculaceae	x	1857a; planted 1995-2005, regeneration?
Clematis terniflora DC	Ranunculaceae		non-native
Clematis virginiana L.	Ranunculaceae	x	1857a
Hepatica nobilis var. obtusa *L.*	Ranunculaceae	x	1857a
Ranunculus arbortivus var. arborvitus (Pursh) Steyerm.	Ranunculaceae		
Ranunculus acris L.	Ranunculaceae		1880; non-native
Ranunculus ambigens S. Wats.	Ranunculaceae	x	1857a
Ranunculus bulbosus L.	Ranunculaceae		non-native
Ranunculus ficaria var. *bulbifera* Mardens-Jones	Ranunculaceae		non-native
Ranunculus repens L.	Ranunculaceae		non-native
Ranunculus sceleratus L.	Ranunculaceae		non-native
Thalictrum pubescens Pursh.	Ranunculaceae	x	1857a
Xanthorhiza simplicissima Marsh.	Ranunculaceae		non-native, planted 1995-2005
Ceanothus americanus L.	Rhamnaceae	x	1857a
Rhamnus frangula L.	Rhamnaceae		non-native
Agrimonia parviflora Soland ex Ait.	Rosaceae	x	1897a; NYS S3
Amelanchier arborea (Michx. f.) Fern	Rosaceae		Rare
Amelanchier canadensis (L.) Medik.	Rosaceae		1888
Aronia arbutifolia (L.) Pers.	Rosaceae	x	1857a
Crataegus calpodendron (Ehrh.) Medik.	Rosaceae	x	1857a
Crataegus crusgalli L.	Rosaceae	x	1892
Crataegus monogyna Jacq.	Rosaceae		non-native
Duchesnea indica (Andr.) Focke	Rosaceae		non-native
Fragaria vesca ssp. *vesca* L.	Rosaceae	x	1857a; 1880
Fragaria virginiana Dene.	Rosaceae		
Geum canadense Jacq.	Rosaceae		1857a
Malus baccata (L.) Borkh.	Rosaceae		non-native
Malus hupehensis (Pamp.) Rehder	Rosaceae		non-native
Photinia villosa (Thunb.) DC.	Rosaceae		non-native
Potentilla argentea L.	Rosaceae		non-native; 1857a; 1880

Potentilla canadensis L.	Rosaceae	x	1880
Potentilla norvegica ssp. *norvegica* L.	Rosaceae		non-native
Potentilla recta L.	Rosaceae		non-native
Potentilla simplex Michx.	Rosaceae		
Prunus maritima Marsh.	Rosaceae	x	1857a
Prunus persica (L.) Batsch	Rosaceae		non-native
Prunus serotina Ehrh.	Rosaceae		1857a
Prunus virginiana L.	Rosaceae	x	1857b
Prunus x *yedoensis* Matsum	Rosaceae		non-native
Rhodotypos scandens (Thunb.) Makino	Rosaceae		non-native
Rosa carolina var.*carolina* L.	Rosaceae	x	1857a
Rosa eglanteria L.	Rosaceae	x	non-native; 1857a
Rosa multiflora Thunb. Ex Murr.	Rosaceae		non-native
Rosa virginiana Mill.	Rosaceae	x	1857a
Rubus allegheniensis Porter ex Bailey	Rosaceae		
Rubus argutus Link	Rosaceae	x	1857a; 1880
Rubus canadensis L.	Rosaceae	x	1880
Rubus cuneifolius Pursch	Rosaceae	x	1857a; NYS Extirpated
Rubus flagellaris Willd.	Rosaceae		
Rubus hispidus L.	Rosaceae	x	1857a
Rubus laciniatus Willd.	Rosaceae		non-native
Rubus occidentalis L.	Rosaceae	x	1857a
Rubus phoenicolasius Maxim.	Rosaceae		non-native
Spirea tomentosa var. *tomentosa* L.	Rosaceae	x	1857a
Galium aparine L.	Rubiaceae		
Gallium mollugo L.	Rubiaceae		non-native
Mitchella repens L.	Rubiaceae	x	1857a
Phellodendron amurense Maxim.	Rutaceae		non-native
Ptelea trifoliata L.	Rutaceae		rare; NYS S1-S2
Tetradium danielli (Benn.) T.G. Hartley	Rutaceae		non-native
Populus alba L.	Salicaceae		non-native
Populus balsamifera L.	Salicaceae	x	1857b
Populus deltoides Bartr. ex Marsh	Salicaceae		1857a
Populus grandidentata Michx.	Salicaceae	x	1857a
Populus heterophylla L.	Salicaceae	x	1857a, NYS S1
Populus nigra L.	Salicaceae	x	planted 1995-2005
Populus tremuloides Michx. A. & D. Love	Salicaceae	x	1857a
Salix alba L.	Salicaceae	x	1857a
Salix babylonica L.	Salicaceae	x	1857a
Salix discolor Muhl.	Salicaceae		
Salix eriocephala Michx.	Salicaceae	x	1857a
Salix fragilis L.	Salicaceae	x	1857a, non-native
Salix humilis var. *tristis* (Ait.) Griggs	Salicaceae	x	1857a
Salix lucida Muhl.	Salicaceae	x	1857a
Salix nigra Marsh.	Salicaceae		
Salix sericea Marsh.	Salicaceae	x	1857a

Koelreuteria paniculata Laxm.	Sapindaceae		non-native
Saururus cernuus L.	Saururaceae		1857a; planted 1995-2005
Saxifraga virginiensis Michx.	Saxifragaceae	x	
Tiarella cordifolia L.	Saxifragaceae		planted 1995-2005
Linaria canadensis (L.) Dumort	Scrophulariaceae		Rare
Linaria vulgaris Mill.	Scrophulariaceae		non-native; 1857a
Lindernia dubia var. *dubia* (L.) Penell	Scrophulariaceae	x	1857a; extirpated 2006
Mazus pumilus (Burm.f.) Steenis	Scrophulariaceae		non-native
Mimulus alatus Ait.	Scrophulariaceae	x	1847a; NYS S3
Mimulus ringens L.	Scrophulariaceae	x	1880
Penstemon hirsutus (L.) Willd.	Scrophulariaceae		Planted 1985-2005
Verbascum blatteria L.	Scrophulariaceae		non-native, uncommon; 1880
Verbascum thapsus L.	Scrophulariaceae		non-native; 1857a; 1880
Veronica arvensis L.	Scrophulariaceae		non-native
Veronica peregrina ssp. *peregrina* L.	Scrophulariaceae		
Veronica persica Poir.	Scrophulariaceae		non-native
Veronica serpyllifolia ssp. *serpyllifolia* L.	Scrophulariaceae		non-native
Selaginella rupestris (L.) Spring.	Selaginaceae	x	1857a
Ailanthus altissima (Mill.) Swingle	Simaroubaceae		non-native; 1857a; 1880
Smilax glauca Walt.	Smilacaceae	x	1857a
Smilax herbacea L.	Smilacaceae	x	1857a
Smilax rotundifolia L.	Smilacaceae		1857a; 1880
Datura stramonium L.	Solanaceae	x	1880; extirpated 2006
Lycium barbarum L.	Solanaceae		non-native
Lycopersicon esculentum Mill.	Solanaceae		non-native
Physalis heterophylla	Solanaceae	x	1857a
Solanum carolinense L.	Solanaceae		
Solanum dulcamara L.	Solanaceae		non-native; 1857a
Solanum nigrum L.	Solanaceae		1880
Solanum ptycanthum Dunal.	Solanaceae		non-native
Solanum rostratum Dunal.	Solanaceae		non-native
Solanum tuberosum L.	Solanaceae		non-native
Phegopteris connectilis (Michx.) Watt.	Thelypteridaceae	x	1857a
Tilia americana var. *americana* L.	Tiliaceae		uncommon; 1857a
Tilia americana var. *heterophylla* (Vent.) Loud	Tiliaceae	x	?; 1857a; NYS Extirpated
Typha latifolia L.	Typhaceae		Planted 1995-2005; 1857a
Celtis occidentalis L.	Ulmaceae		1857a
Ulmus americana L.	Ulmaceae		1857a
Ulmus glabra Huds.	Ulmaceae		

Ulmus minor Mill.	Ulmaceae		non-native
Ulmus pumila L.	Ulmaceae		non-native
Ulmus rubra Muhl.	Ulmaceae	x	1857a
Boehmeria cylindrica (L.) Sw.	Urticaceae		1857a; rare
Parietaria pensylvanica Muhl. Willd	Urticaceae	x	1857a
Pilea pumila (L.) A. Gray	Urticaceae		1857a
Urtica dioica ssp. g*racilis* (Ait.) Selander	Urticaceae		Rare
Verbena hastata L.	Verbenaceae	x	1880
Verbena stricta Vent.	Verbenaceae	x	1857a
Verbena urticifolia var. *urticifolia* L.	Verbenaceae		1857a; 1880
Viola palmata L.	Violaceae	x	
Viola sororia Willd.	Violaceae		
Ampelopsis brevipedunculata var. *brevipedunculata* (Maxim.) Trautv.	Vitaceae		non-native
Parthenocissus quinquifolia (L.) Planch. ex DC	Vitaceae		1857a; 1880
Parthenocissus tricuspidata (Sieb. & Zucc.) Planch. ex DC	Vitaceae		non-native
Vitis aestivalis Michx.	Vitaceae	x	1857a
Vitis labrusca L.	Vitaceae	x	1857a; 1857b

Appendix 5

Central Park Mushrooms, as of December 2011

ASCOMYCETES

Apiosporina morbosa

Ascocoryne sarcoides (Jacq. Ex S.F.G.) Groves & Wilson

Biscogniauxia atropunctata

Bisporella citrina (Batsch ex Fr.) Korf & Carp.

Daldinia concentrica (Bolt. Ex Fr.) Ces. & DeNot.

Diatrype stigma

Erysiphaceae

Hypomyces aurantius

Hypomyces chrysospermus

Hypomyces hyalinus

H. onstereum

Hypoxylon rubiginosum

Hypoxylon sp.

Morchella esculenta ?

Nectria cinnabarina

Netria complex (Amphilogia gyrosa)

Pachyella clypeata

Peziza badia

Phaeocalicium polyporaeum

Scutellinia scutellata

Sepedonium chrysospermum

Sphaeriaceae : gray-white w black perithecia

Powdery mildew on euonymus

Xylaria polymorpha (Pers. Ex Mér.) Grev.

JELLY FUNGI

Auricularia auricular

Exidia recisa

Tremella mesenterica

CHANTERELLES, CORAL and TOOTH FUNGI

Cantharellus lateritius

Clavaria vermicularis

Clavulina cristata

Climacodon septentrionale

Hericium erinaceus

Sparassis spathulata

Steccherinum ochraceum

PARCHMENT and CRUST FUNGI

Aleurodiscus oakesii ?

Botryobasidium sp.

Chondrostereum purpureum ?

Cystidiellum sp.

Hydnochaete oliveum

Hymenochaete rubiginosum

Laeticorticium bombycinum

Laeticorticium roseum

Laxitextum bicolor

Merulius tremellosus

Peniophora cf albobadia

Peniophora cf cinerea

Phanerochaete crassa

Phlebia tremellosa

Plicaturopsis crispa

Schizophyllum commune

Stereum complicatum

Stereum hirsutum

Stereum ostrea

Stereum sericium

Stereum cf ochraceoflavum ?

Tomentella sp.?

Xylobolus frustulatus

Pinkish tan resupinate

Crust yellowish and a bit pink, green…5' spread on willow log

Crust yellow green (small)…..with tiny white fringe at margin?

Crust pinkish tan……..long sheet…?

Crust red brown Stereum-like…..Peniophora cf albobadia

Crust white like paint….Peniophora cf cinerea

Crust with tiny, separated white teeth (not Irpex)

and many others not listed yet…..

POLYPORES

Abortiporus biennis

Antrodia sp.?

Bondarzewia berkeleyi

Ceriporia cf viridans

Ceriporia sp. (greenish tint)

Daedalea quercina

Daedaleopsis confragosa

Favolus alveolaris

Fistulina hepatica

Fomitopsis spraguei

Ganoderma applanatum

Ganoderma curtisii

Ganoderma lucidum

Grifola frondosa

Inonotus dryadeus

Inonotus hispidus

Irpex lacteus

Laetiporus Cincinnatus

Laetiporus sulphureus

Meripilus sumstinei

Oligoporus caesius

Oxyporus populinus

Phellinus gilvus

Phellinus pomaceus

Phellinus rimosus

Polyporus brumalis

Polyporus squamosus

Pycnoporus cinnabarinus

Schizopora paradoxa

Trametes cervina

Trametes conchifer

Trametes elegans (gibbosa)
Trametes hirsutum
Trametes pubescens
Trametes suaveolens
Trametes versicolor
Trichaptum biforme
Tyromyces chioneus
Resup. brown w white margin

BOLETES

Boletus bicolor
Boletus campestris
Boletus chrysenteron
Boletus pseudosensibilis
Boletus pulverulentus
Boletus subvelutipes
Gyrodon merulioides
Gyroporus castaneus
Phyloporus rhodoxanthus
Strobilomyces floccopus
Tylopilus badiceps
Tylopilus plumbeoviolaceus

GASTEROMYCETES

Calvatia cyathiformis
Calvatia gigantean
Crucibulum leave
Cyatus cf olla
Cyathus striatus
Geastrum saccatum
Lycoperdon coloratum
Lycoperdon curtisii
Lycoperdon perlatum
Lycoperdon pusillum
Lycoperdon pyriforme
Mutinus elegans
Phallus ravenelii

Phallus rubicundus
Pseudocolus fusiformis
Scleroderma cepa
Scleroderma citrinum
Scleroderma lycoperdoides
Scleroderma polyrhizon

GILLED MUSHROOMS

Agaricus abruptibulbus
Agaricus macrosporus
Agaricus subrufescens
Agaricus bitorquis
Agaricus campestris
Agaricus placomyces
Agrocybe acericola
Agrocybe dura
Agrocybe pediades
Amanita crenulata
Amanita flavoconia
Amanita flavorubescens
Amanita muscaria
Amanita praecox
Amanita rubescens
Amanita vaginata
Amanita volvata
Armillaria mellea
Armillaria tabescens
Bolbitius vitellinus
Cheimonophyllum?
Clitocybe nuda
Clitocybe odora
Clitocybe phaeophthalma
Clitoycbe sp. (small)
Conocybe lacteal
Conocybe cf tenera
Coprinus atramentarius
Coprinus comatus

Coprinus disseminates
Coprinus cf flocculosus
Coprinus micaceus
Coprinus plicatilis
Coprinus quadrifidus
Coprinus sp.
Crepidotus mollis
Entoloma sp. (72nd & CPW)
Flammulina velutipes
Galerina autumnalis
Galerina sp. (near G. hypnorum?)
Gymnopilus spectabilis
Gymnopilus sp. near G. sapineus
Gymnopus acervatus
Gymnopus dryophilus
Gymnopus cf earleae
Gymnopus luxurians
Gymnopus sp. near kauffmanii?
Hebeloma sp. (under linden)
Hohenbuehelia geogenia
Hypsizygus tessulatus
Hypsizygus ulmarius
Hypholoma aurantiacum [= Leratiomyces ceres]
Hypholoma fasciculare
Hypholoma sublateritium
Inocybe abundans
Inocybe albodisca
Inocybe caesariata
Inocybe fastigiata
Inocybe lacera
Inocybe rimosoides
Laccaria amethystine
Laccaria laccata
Laccaria ohiensis
Lactarius sp. (near griseus?)
Lentinellus ursinus
Lepiota americana

Lepiota cepaestipes
Lepiota cristata
Lepiota "naucina"
Lyophyllum decastes
Marasmius graminum
Marasmius nigrodiscus
Marasmius oreades
Marasmius rotula
Marasmius scorodonius
Marasmius sp. (smaller than dime)
Melanoleuca albiflavid?
Mycena corticola
Mycena inclinata
Omphalotus illudens
Oudemansiella "radicata"
Panaeolina foenisecii
Panellus stipticus
Panus rudis (Lentinus strigosus)
Pholiota aurivella
Phyloporus nidulans
Pleurotus ostreatus
Pluteus cervinus var alba
Pluteus cervinus
Pluteus sp. (cellulodermi)
Psathyrella candolleana
Psathyrella conopilea
Psathyrella cf hydrophila
Psathyrella velutina
Psathyrella sp. (fleshy, base of tree)
Resupinatus alboniger?
Rickenella fibula
Russula aeruginea
Russula albonigra
Russula crustosa complex
Russula cyanoxantha
Russula foetentula
Russula mariae

Russula mutabilis
Russula ornaticeps
Russula parvovirescens
Russula pectinatoides
Russula cf pulchra
Russula variata
Stropharia rugosoannulata
Tubaria furfuracea
Volvariella bombycina

RUST FUNGI

Gymnosporangium clavipes (on hawthorn fruit)
Rust fungi are ubiquitous on plants in Central Park, just not listed here.

ZYGOMYCETES

Syzygites megalosporus

MYXOMYCETES

Arcyria denudate
Brefeldia maxima
Ceratiomyxa fruticulosa
Dictydium cancellatum
Enteridium lycoperdon
Fuligo septica
Lycogala epidendrum
Physarum globiferum
Physarum polycephalum
Stemonitis splendens
Stemonitis sp.

Appendix 6

The Birds of Central Park: An Annotated Checklist

YEAR-ROUND/ MORE COMMON

YEAR-ROUND/ LESS COMMON

Annual Migrant /More Common

Annual Migrant /Less Common

Infrequent [italics]

Water fowl	
Snow Goose	*flyover*
Brant	*flyover*
CANADA GOOSE	*nests*
MUTE SWAN	*has nested*
Wood Duck	
Gadwall	
American Wigeon	
American Black Duck	
MALLARD	*nests*
Blue-winged Teal	
Northern Shoveler	
Northern Pintail	
Green-winged Teal	
Canvasback	
Ring-necked Duck	
Lesser Scaup	
Greater Scaup	
Bufflehead	
Hooded Merganser	
Common Merganser	
Red-breasted Merganser	
Ruddy Duck	

Pheasants

Ring-necked Pheasant	*has nested*
Loons, Grebes, Cormorants	
Red-throated Loon	*mainly flyover*
Common Loon	*mainly flyover*
Pied-billed Grebe	
Double-crested Cormorant	
Wading Birds	
American Bittern	
Great Blue Heron	
Great Egret	
Snowy Egret	*mainly flyover*
Green Heron	*has nested*
Black-crowned Night-Heron	
Yellow-crowned Night Heron	
Birds of Prey	
Black Vulture	*flyover*
Turkey Vulture	*flyover*
Osprey	*flyover*
Bald Eagle	*flyover*
Northern Harrier	*flyover*
Sharp-shinned Hawk	*occ. winters*
Cooper's Hawk	*occ. winters*
Northern Goshawk	*mainly flyover*
Red-shouldered Hawk	*flyover*
Broad-winged Hawk	*flyover*
RED-TAILED HAWK	*has nested*
Rough-legged Hawk	*flyover*
Golden Eagle	*flyover*
AMERICAN KESTREL	*nests near park*
Merlin	*mainly flyover*
PEREGRINE FALCON	*mainly flyover*
Gallinules, Coots	
Common Moorhen	
American Coot	

Shorebirds	
Killdeer	*has nested*
Solitary Sandpiper	
Spotted Sandpiper	
Greater Yellowlegs	
Wilson's Snipe	
American Woodcock	
Gulls, Skimmers	
Laughing Gull	*summer visitor*
RING-BILLED GULL	
HERRING GULL	
Iceland gull	
Great Black-backed Gull	
Black Skimmer	*summer visitor, crepuscular*
Pigeons, Doves	
ROCK PIGEON	*nests*
MOURNING DOVE	*nests*
Cuckoos	
Black-billed Cuckoo	
Yellow-billed Cuckoo	
Owls	
Long-eared Owl	*occ. winters*
Northern Saw-whet Owl	*occ. winters*
EASTERN SCREECH-OWL	*re-introduced in 1999, 2000; nests*
Goatsuckers	
Common Nighthawk	
Chuck-will's-widow	
Whip-poor-will	
Swifts, Hummingbirds, Kingfishers	
Chimney Swift	
Ruby-throated Hummingbird	

Belted Kingfisher	
Woodpeckers	
Red-headed Woodpecker	*occ. winters*
RED-BELLIED WOODPECKER	*nests*
Yellow-bellied Sapsucker	*a few winter*
DOWNY WOODPECKER	*nests*
Hairy Woodpecker	*occ.winters*
Northern Flicker	*nests; a few winter*
Flycatchers	
Olive-sided Flycatcher	
Eastern Wood-Pewee	
Yellow-bellied Flycatcher	
Acadian Flycatcher	
Alder Flycatcher	
Willow Flycatcher	
Least Flycatcher	
Eastern Phoebe	
Great Crested Flycatcher	
Eastern Kingbird	*nests*
Swallows	
Purple Martin	
Tree Swallow	
Northern Rough-winged Swallow	
Bank Swallow	
Cliff Swallow	
Barn Swallow	*oft nests*
Jays, Crows	
BLUE JAY	*nests*
AMERICAN CROW	*nests*
Fish Crow	*has nested*
Chickadees, Titmice	
BLACK-CAPPED CHICKADEE	*has nested*
TUFTED TITMOUSE	*nests*

Nuthatches, Creepers	
Red-Breasted Nuthatch	*occ. winters*
White-breasted Nuthatch	*winters, occ. nests*
Brown Creeper	*a few winter*
Wrens	
Carolina Wren	*occ. winters, nests*
House Wren	*nests*
Winter Wren	
Marsh Wren	
Kinglets, Gnatcatchers	
Golden-crowned Kinglet	*occ. winters*
Ruby-crowned Kinglet	*occ. winters*
Blue-gray Gnatcatcher	
Thrushes	
Eastern Bluebird	
Veery	
Swainson's Thrush	
Gray-cheeked Thrush	
Bicknell's Thrush	
Hermit Thrush	*a few winter*
Wood Thrush	*nests*
AMERICAN ROBIN	*nests; a few winter*
Mimic Thrushes	
Gray Catbird	*nests; occ. winters*
NORTHERN MOCKINGBIRD	*has nested*
Brown Thrasher	*occ. nests; occ. winters*
Waxwings, Starlings, Pipits	
Cedar Waxwing	*oft. nests*
EUROPEAN STARLING	*nests*
American Pipit	*mainly flyover*
Vireos	
White-eyed Vireo	
Blue-headed Vireo	

Yellow-throated Vireo	*has nested*
Warbling Vireo	*nests*
Philadelphia Vireo	*mostly fall*
Red-eyed Vireo	*occ. nests*

Wood-Warblers	
Blue-winged Warbler	
Golden-winged Warbler	
Lawrence's Warbler (BW x GW hybrid)	
Brewster's Warbler (BW x GW hybrid)	
Tennessee Warbler	
Orange-crowned Warbler	
Nashville Warbler	
Northern Parula	
Yellow Warbler	
Chestnut-sided Warbler	
Magnolia Warbler	
Cape May Warbler	
Black-throated Blue Warbler	
Yellow-rumped Warbler	
Black-throated Green Warbler	
Blackburnian Warbler	
Yellow-throated Warbler	*mostly spring*
Pine Warbler	
Prairie Warbler	
Palm Warbler	
Bay-breasted Warbler	
Blackpoll Warbler	
Cerulean Warbler	*mostly spring*
Black-and-white Warbler	
American Redstart	
Prothonotary Warbler	*mostly spring*
Worm-eating Warbler	
Ovenbird	
Northern Waterthrush	
Louisiana Waterthrush	
Kentucky Warbler	*mostly spring*

Connecticut Warbler	*mostly fall*
Mourning Warbler	*mostly spring*
Common Yellowthroat	
Hooded Warbler	
Wilson's Warbler	
Canada Warbler	
Yellow-breasted Chat	
Tanagers	
Summer Tanager	*mostly spring*
Scarlet Tanager	
Grosbeaks, Buntings	
NORTHERN CARDINAL	*nests*
Rose-breasted Grosbeak	
Blue Grosbeak	
Indigo Bunting	
Sparrows	
Eastern Towhee	*occ. winters*
American Tree Sparrow	
Chipping Sparrow	
Clay-colored Sparrow	
Field Sparrow	
Vesper Sparrow	
Savannah Sparrow	
Fox Sparrow	*occ. winters*
SONG SPARROW	*nests*
Lincoln's Sparrow	
Swamp Sparrow	*occ. winters*
White-throated Sparrow	*winters in numbers*
White-crowned Sparrow	
Dark-eyed Junco	*occ. winters*
Blackbirds	
Bobolink	
Red-winged Blackbird	*nests; a few winter*
Eastern Meadowlark	

Rusty Blackbird	
Common Grackle	*nests; occ. winters*
Brown-headed Cowbird	*occ winters*
Orchard Oriole	*has nested*
Baltimore Oriole	*nests*

Finches, Old World Sparrows	
Purple Finch	
Common Redpoll	
Pine Siskin	
HOUSE FINCH	*nests*
American Goldfinch	*winters*
Evening Grosbeak	
HOUSE SPARROW	*nests*

Rare

Seen 1-5 times since 1970

Not seen since 1970

*Not seen since 1930

Horned Grebe	
Red-necked Grebe	
Great Cormorant	
Tundra Swan	
Anhinga	*flyover*
Least Bittern	
Little Blue Heron	
Tricolored Heron	
Cattle Egret	*flyover*
Glossy Ibis	
Eurasian Wideon	
Redhead	
Tufted Duck	
Common Eider	
Oldsquaw	
Surf Scoter	
White-winged Scoter	

Common Goldeneye	
Mississippi Kite	
Wild Turkey	
*Ruffed Grouse **	
*Northern Bobwhite**	
*Clapper Rail**	
Virginia Rail	
Sora	
*Purple Gallinule**	
Black-bellied Plover	
Semipalmated Plover	
Lesser Yellowlegs	
Upland Sandpiper	
Whimbrel	*flyover*
Semipalmated Sandpiper	
Western Sandpiper	
Least Sandpiper	
White-rumped Sandpiper	
Pectoral Sandpiper	
Red Phalarope	
Common Black-headed Gull	
Bonaparte's Gull	
Lesser Black-backed Gull	
Glaucous Gull	
Caspian Tern	
Common Tern	
Forster's Tern	
Monk Parakeet	
Barn Owl	
Short-eared Owl	
Great Horned Owl	
*Snowy Owl**	
Barred Owl	
Boreal Owl	
Rufous Hummingbird	
Black-backed Woodpecker	
Western Kingbird	

Horned Lark

Boreal Chickadee

*Bewick's Wren**

Sedge Wren

Northern Wheatear

Northern Shrike

Loggerhead Shrike

Black-throated Gray Warbler

Townsend's Warbler

Swainson's Warbler

Western Tanager

Painted Bunting

Dickcissel

Lark Sparrow

Grasshopper Sparrow

Henslow's Sparrow

Le Conte's Sparrow

Nelson's Sharp-tailed Sparrow

Saltmarsh Sharp-tailed Sparrow

Seaside Sparrow

Lapland Longspur

Snow Bunting

Brewer's Blackbird

Pine Grosbeak

*Red Crossbill**

White-winged Crossbill

Appendix 7

Invertebrate species of Central Park

Class	Order	Family	Genus	Species	Common Name
Arachnida	Araneae	Clubionidae	Clubiona	kiowa	Sac spider
Arachnida	Araneae	Dictynidae	Dictyna	sublata	Dictynid spider
Arachnida	Araneae	Linyphiidae	Bathyphantes	pallidus	Dwarf and Sheetweb weavers
Arachnida	Araneae	Oxyopidae	Oxyopes	salticus	Lynx spiders
Arachnida	Araneae	Philodromidae	Philodromus	dispar	Running crab spider
Arachnida	Araneae	Salticidae		sp.	Jumping spiders
Arachnida	Araneae	Salticidae	Habrocestum	pulex	Jumping spider
Arachnida	Araneae	Salticidae	Metaphidippus	sp.	Metaphid jumping spider
Arachnida	Araneae	Theridiidae	Enoplognatha	marmorata	Cobweb weaver
Arachnida	Araneae	Theridiidae	Euryopis	funebris	Cobweb weaver
Arachnida	Araneae	Theridiidae	Theridion	sp. 1	Cobweb weaver
Arachnida	Araneae	Theridiidae	Theridion	sp. 2	Cobweb weaver
Arachnida	Araneae	Uloboridae	Uloborus	glomosus	Hackled orbweaver, Featherlegged spider
Arachnida	Opliones	Sclerosomatidae	Leiobunum	sp.	Daddy-long-legs
Arachnida	Parasitiformes	Ixodidae	Ixodes	scapularis	Black-legged or deer tick
Arachnida	Trombidiformes	Trombidiidae	Trombidium	sp.	Velvet mite
Chilopoda	Geophilomorpha			sp.	Soil centipede
Clitellata	Lumbriculida	Lumbriculidae			Earthworm
Diplopoda					Millipedes
Entognatha	Collembola	Entomobryidae		sp.	Springtail
Eutardigrada	Apochela	Milnesiidae	Milnesium	tardigradum	Water bear
Eutardigrada	Parachela	Macrobiotidae	Macrobiotus	sp.	Water bear
Gastropoda	Stylommatophora				Slug
Insecta	Coleoptera	Cantharidae	Chauliognathus	pennsylvanicus	Soldier beetle
Insecta	Coleoptera	Cerambycidae			Long-horned beetle (not Asian)
Insecta	Coleoptera	Coccinellidae			Ladybird beetles
Insecta	Coleoptera	Coccinellidae	Hippodamia	convergens	Convergent lady beetle
Insecta	Coleoptera	Curculionidae			Charancons, Snout beetles, Weevils
Insecta	Coleoptera	Gyrinidae	Gyrinus	sp.	Whirligig beetles
Insecta	Coleoptera	Staphylinidae		sp.	Rove beetle
Insecta	Diptera	Asilidae	Machimus	sp.	Robber fly
Insecta	Diptera	Bombyliidae			Bee flies
Insecta	Diptera	Calliphoridae			Blow flies
Insecta	Diptera	Calliphoridae	Phaenicia	sericata	Green bottle fly
Insecta	Diptera	Cecidomyiidae			Gall gnats, gall midges, leaf miners
Insecta	Diptera	Ceratopoginidae			No-see-ums
Insecta	Diptera	Chironomidae			Midge fly

Insecta	Diptera	Dolichopodidae			Longlegged flies
Insecta	Diptera	Muscidae	Musca	domestica	house fly
Insecta	Diptera	Sarcophagidae			Flesh flies
Insecta	Diptera	Scatophagidae	Nanna	sp.	Dung fly
Insecta	Diptera	Syrphidae	Baccha	elongata	Syrphid fly
Insecta	Diptera	Syrphidae	Melanostoma	obscurum	Flower fly or Hover fly
Insecta	Diptera	Syrphidae	Metasyrphus	americanus	American hover fly
Insecta	Diptera	Syrphidae	Syrphus	sp.	Syrphid fly
Insecta	Diptera	Syrphidae	Toxomerus	geminatus	
Insecta	Diptera	Tachinidae	Trichopoda	subdivisa	Fringe-legged tachinid fly
Insecta	Ephemeroptera	Tachinidae			Mayflies
Insecta	Heteroptera	Corixidae			Water boatman
Insecta	Heteroptera	Gerridae			Water striders
Insecta	Heteroptera	Miridae	Adelphocoris	sp.	Plant bug
Insecta	Heteroptera	Notonectidae			Backswimmers
Insecta	Heteroptera	Rhopalidae	Leptocoris	trivittatus	Eastern box elder bug
Insecta	Heteroptera	Saldidae			Shore bugs
Insecta	Heteroptera	Veliidae			Broad-shouldered water striders, ripple bugs, small water striders
Insecta	Homoptera	Aphidae			aphids
Insecta	Homoptera	Aphididae			Aphid
Insecta	Homoptera	Cercopidae	Philaenus	spumarius	Meadow spittlebug
Insecta	Homoptera	Cicadellidae			Cicadellids, Jassids, Leafhoppers, Sharpshooters
Insecta	Homoptera	Psyllidae	Pachypsylla	sp.	Hackberry gall psyllid
Insecta	Hymenoptera	Andrenidae	Andrena	miserabilis	
Insecta	Hymenoptera	Andrenidae	Andrena	spp.	2 different species
Insecta	Hymenoptera	Andrenidae	Calliopsis	sp.	Andrenid bees
Insecta	Hymenoptera	Anthophoridae			Bee
Insecta	Hymenoptera	Anthophoridae	Xylocopa	virginica	Carpenter bee
Insecta	Hymenoptera	Apidae	Apis	mellifera	Honey bee
Insecta	Hymenoptera	Apidae	Bombus	bimaculatus	Bumble bee
Insecta	Hymenoptera	Apidae	Bombus	fervidus	Bumble bee
Insecta	Hymenoptera	Apidae	Bombus	griseocollis	
Insecta	Hymenoptera	Apidae	Bombus	impatiens	Bumble bee
Insecta	Hymenoptera	Apidae	Bombus	perplexus	Bumble bee
Insecta	Hymenoptera	Apidae	Ceratina	sp. 1	Bee
Insecta	Hymenoptera	Apidae	Ceratina	sp. 2	Bee
Insecta	Hymenoptera	Chrysididae	Chrysis		
Insecta	Hymenoptera	Colletidae	Hylaeus	sp.	Yellow-faced bee
Insecta	Hymenoptera	Formicidae	Acanthomyops	claviger	Smaller yellow ant
Insecta	Hymenoptera	Formicidae	Acanthomyops	sp.	Ant
Insecta	Hymenoptera	Formicidae	Camponotus	pennsylvanicus	Black carpenter ant
Insecta	Hymenoptera	Formicidae	Camponotus	sp. 2	Ant

Insecta	Hymenoptera	Formicidae	Crematogaster	lineolata	Ant
Insecta	Hymenoptera	Formicidae	Dolichoderus	sp.	Ant
Insecta	Hymenoptera	Formicidae	Formica	schaufussi	Ant
Insecta	Hymenoptera	Formicidae	Formica	sp. 1	Ant
Insecta	Hymenoptera	Formicidae	Formica	sp. 2	Ant
Insecta	Hymenoptera	Formicidae	Lasius	alienus	Cornfield ant
Insecta	Hymenoptera	Formicidae	Lasius	flavus	Ant
Insecta	Hymenoptera	Formicidae	Lasius	nearcticus	Ant
Insecta	Hymenoptera	Formicidae	Lasius	neoniger	Ant
Insecta	Hymenoptera	Formicidae	Lasius	umbratus	Field ant
Insecta	Hymenoptera	Formicidae	Leptothorax	sp.	Ant
Insecta	Hymenoptera	Formicidae	Monomorium	pharaonis	Pharaoh ant
Insecta	Hymenoptera	Formicidae	Myrmica	sp. 1	Ant
Insecta	Hymenoptera	Formicidae	Paratrechina	flavipes	Ant
Insecta	Hymenoptera	Formicidae	Pheidole	sp.	Ant
Insecta	Hymenoptera	Formicidae	Prenolepis	imparis	Ant
Insecta	Hymenoptera	Formicidae	Solenopsis	molesta	Thief ant
Insecta	Hymenoptera	Formicidae	Tetramorium	caespitum	Pavement ant
Insecta	Hymenoptera	Halictidae	Agapostemon	sericeus	Halictid bee
Insecta	Hymenoptera	Halictidae	Agapostemon	virescens	Halictid bee
Insecta	Hymenoptera	Halictidae	Halictus	sp.	Halictid bee, Sweat bee
Insecta	Hymenoptera	Halictidae	Lasioglossum	sp.	Halictid bee
Insecta	Hymenoptera	leafcutter bee	Osmia	pumila	
Insecta	Hymenoptera	Megachilidae	Anthidium	sp.	Leafcutter bee
Insecta	Hymenoptera	Megachilidae	Megachile	frigida	Leafcutter bee
Insecta	Hymenoptera	Megachilidae	Megachile	rotundata	Alfalfa leafcutter bee
Insecta	Hymenoptera	Megachilidae	Megachile	texana	Leafcutter bee
Insecta	Hymenoptera	Megachilidae	Osmia	sp.	Leafcutter bee
Insecta	Hymenoptera	Sphecidae			
Insecta	Hymenoptera	Sphecidae	Cerceris	sp.	Weevil wasp
Insecta	Hymenoptera	Sphecidae	Crossocerus	sp.	Wasp
Insecta	Hymenoptera	Sphecidae	Ectemnius	stirpicola	
Insecta	Hymenoptera	Sphecidae	Pemphredon	sp.	
Insecta	Hymenoptera	tadpole snail	Physella	heterostropha	
Insecta	Hymenoptera	Tenthredinidae	Profenusa	canadensis	Hawthorn leaf miner
Insecta	Hymenoptera	Vespidae			Hornet
Insecta	Hymenoptera	Vespidae	Ancistrocerus	adiabatus	Wasp
Insecta	Hymenoptera	Vespidae	Ancistrocerus	catskill	Potter wasp
Insecta	Hymenoptera	Vespidae	Ancistrocerus	unifasciatus	Wasp
Insecta	Hymenoptera	Vespidae	Dolichovespula	arenaria	Aerial yellowjacket
Insecta	Hymenoptera	Vespidae	Euodynerus	foraminatus	Wasp
Insecta	Hymenoptera	Vespidae	Euodynerus	hidalgo	Potter wasp
Insecta	Hymenoptera	Vespidae	Euodynerus	leucomelas	Potter wasp

Insecta	Hymenoptera	Vespidae	Monobia	quadridens	Potter wasp
Insecta	Hymenoptera	Vespidae	Parancistrocerus	pedestris	Potter wasp
Insecta	Hymenoptera	Vespidae	Polistes	dominulus	European paper wasp
Insecta	Hymenoptera		Alysson	trangulifer	
Insecta	Hymenoptera		Ammophila	pictipennis	
Insecta	Hymenoptera		Andrena	fragilis	
Insecta	Hymenoptera		Andrena	wilkella	
Insecta	Hymenoptera		Arion	hortensis	
Insecta	Hymenoptera		Calliopsis	andreniformis	
Insecta	Hymenoptera		Cerceris	fumipennis	Weevil wasp
Insecta	Hymenoptera		Deroceras	sp.	
Insecta	Hymenoptera		Halictus	ligatus	
Insecta	Hymenoptera		Hocopasites	callipsoides	
Insecta	Hymenoptera		Isodontia	elegans	
Insecta	Hymenoptera		Isodontia	mexicana	
Insecta	Hymenoptera		Isodontia	philadelphica	
Insecta	Hymenoptera		Lasioglossum	coeruleum	
Insecta	Hymenoptera		Lasioglossum	imitatum	
Insecta	Hymenoptera		Lehmannia	poireri	
Insecta	Hymenoptera		Megachile	campanulae	
Insecta	Hymenoptera		Megachile	centuncularis	
Insecta	Hymenoptera		Megachile	gemula	
Insecta	Hymenoptera		Megachile	pugnata	
Insecta	Hymenoptera		Megachile	relativa	
Insecta	Hymenoptera		Nomada	articulata	
Insecta	Hymenoptera		Sphex	ichneumon	Great golden digger wasp
Insecta	Lepidoptera	Arctiidae			
Insecta	Lepidoptera	Arctiidae	Euchaetias	egle	Milkweed moth
Insecta	Lepidoptera	Choristoneura			Moth
Insecta	Lepidoptera	Gelechiidae	Trichotaphe	flavocostella	Moth
Insecta	Lepidoptera	Geometridae			
Insecta	Lepidoptera	Geometridae	Chloroclystis	retangulata	Moth
Insecta	Lepidoptera	Geometridae	Itame	pustularia	Lesser maple spanworm
Insecta	Lepidoptera	Geometridae	Lomographa	vestaliata	Inchworm moth
Insecta	Lepidoptera	Geometridae	Orthonama	obstipata	Moth
Insecta	Lepidoptera	Geometridae	Scopula		
Insecta	Lepidoptera	Gracillariidae			
Insecta	Lepidoptera	Gracillariidae	Gracillariid	sp.	Gracillariid moth
Insecta	Lepidoptera	Hesperiidae	Ancyloxpha	numitor	Least skipper
Insecta	Lepidoptera	Hesperiidae	Atalopedes	campestris	Sachem Skipper
Insecta	Lepidoptera	Hesperiidae	Epargyreus	clarus	Silver-spotted skipper
Insecta	Lepidoptera	Hesperiidae	Erynnis	baptisiae	Wild indigo duskywing
Insecta	Lepidoptera	Hesperiidae	Erynnis	horatius	Horace's duskywing

Insecta	Lepidoptera	Hesperiidae	Erynnis	juvenalis	Juvenal's duskywing
Insecta	Lepidoptera	Hesperiidae	Euphyes	vestris	Dun skipper
Insecta	Lepidoptera	Hesperiidae	Hylephila	phyleus	Fiery skipper
Insecta	Lepidoptera	Hesperiidae	Lerema	accius	Clouded skipper
Insecta	Lepidoptera	Hesperiidae	Nastra	iherminier	Swarthy skipper
Insecta	Lepidoptera	Hesperiidae	Panoquina	ocola	Ocola skipper
Insecta	Lepidoptera	Hesperiidae	Pholisora	catullus	Common sootywing
Insecta	Lepidoptera	Hesperiidae	Poanes	hobomok	Hobomok skipper
Insecta	Lepidoptera	Hesperiidae	Poanes	viator	Broad-winged skipper
Insecta	Lepidoptera	Hesperiidae	Poanes	xabulon	Zabulon skipper
Insecta	Lepidoptera	Hesperiidae	Polites	pickius	Peck's skipper
Insecta	Lepidoptera	Hesperiidae	Polites	themistocles	Tawny-edged skipper
Insecta	Lepidoptera	Hesperiidae	Pompeius	verna	Little glassywing
Insecta	Lepidoptera	Hesperiidae	Pyrgus	communis	Common checkered skipper
Insecta	Lepidoptera	Hesperiidae	Thymelicus	lineola	European skipper
Insecta	Lepidoptera	Hesperiidae	Urbannis	proteus	Long Tailed Skipper
Insecta	Lepidoptera	Hesperiidae	Wallengrenia	egeremet	Northern broken dash
Insecta	Lepidoptera	Hummingbird clearwing moth	Hemaris	thysbe	
Insecta	Lepidoptera	Lasoicampidae	Malacosoma	americanum	Eastern tent caterpillar moth
Insecta	Lepidoptera	Lycaenidae	Calycopis	cecrops	Red-banded hairstreak
Insecta	Lepidoptera	Lycaenidae	Celastrina	argiolus	Spring azure
Insecta	Lepidoptera	Lycaenidae	Celastrina	neglecta	Summer azure
Insecta	Lepidoptera	Lycaenidae	Everes	comyntas	Eastern Tailed-Blue
Insecta	Lepidoptera	Lycaenidae	Feniseca	tarquinius	Harvester
Insecta	Lepidoptera	Lycaenidae	Parrhasius	m-album	White M hairstreak
Insecta	Lepidoptera	Lycaenidae	Satyrium	calanus	Banded hairstreak
Insecta	Lepidoptera	Lycaenidae	Strymon	melinus	Gray hairstreak
Insecta	Lepidoptera	Noctuidae	Maliattha	synochitis	Bird-dropping moth
Insecta	Lepidoptera	Noctuidae	Noctua	pronuba	Moth
Insecta	Lepidoptera	Noctuidae	Pseudaletia	unipuncta	Armyworm moth
Insecta	Lepidoptera	Noctuidae	Trichoplusia	ni	cabbage looper
Insecta	Lepidoptera	Noctuidae	Xestia	dolosa	Moth
Insecta	Lepidoptera	Notodontidae	Nadata	gibbosa	Prominent moth
Insecta	Lepidoptera	Nymphalidae	Asterocampa	celtis	Hackberry emperor
Insecta	Lepidoptera	Nymphalidae	Coenonympha	tullia	Common ringlet
Insecta	Lepidoptera	Nymphalidae	Danaus	gilippus	Queen*
Insecta	Lepidoptera	Nymphalidae	Danaus	plexippus	Monarch
Insecta	Lepidoptera	Nymphalidae	Dryas	iulia	Julia*
Insecta	Lepidoptera	Nymphalidae	Euptoieta	claudia	Variegated fritillary
Insecta	Lepidoptera	Nymphalidae	Heliconius	charithonius	Zebra Long Wing
Insecta	Lepidoptera	Nymphalidae	Junonia	coenia	Common buckeye
Insecta	Lepidoptera	Nymphalidae	Libytheana	carineneta	American snout
Insecta	Lepidoptera	Nymphalidae	Limenitis	archippus	Viceroy

Insecta	Lepidoptera	Nymphalidae	Limenitis	arthemis	Red Spotted Purple
Insecta	Lepidoptera	Nymphalidae	Megisto	cymela	Little wood satyr
Insecta	Lepidoptera	Nymphalidae	Nymphalis	antiopa	Mourning cloak
Insecta	Lepidoptera	Nymphalidae	Nymphalis	vaualbum	Compton tortoiseshell
Insecta	Lepidoptera	Nymphalidae	Phyciodes	tharos	Pearl Cresent
Insecta	Lepidoptera	Nymphalidae	Polygonia	comma	Eastern comma
Insecta	Lepidoptera	Nymphalidae	Polygonia	interrogationis	Question mark butterfly
Insecta	Lepidoptera	Nymphalidae	Speyeria	cybele	Great spangled fritillary
Insecta	Lepidoptera	Nymphalidae	Vanessa	atalanta	Red admiral
Insecta	Lepidoptera	Nymphalidae	Vanessa	cardui	Painted lady
Insecta	Lepidoptera	Nymphalidae	Vanessa	virginiensis	American lady
Insecta	Lepidoptera	Oecophoridae	Callima	argenticinctella	Micro moth
Insecta	Lepidoptera	Papilionidae	Battus	philenor	Pipevine swallowtail
Insecta	Lepidoptera	Papilionidae	Papilio	glaucus	Tiger swallowtail
Insecta	Lepidoptera	Papilionidae	Papilio	polyxenes	Black swallowtail
Insecta	Lepidoptera	Papilionidae	Papilio	cresphontes	Giant Swallowtail
Insecta	Lepidoptera	Papilionidae	Papilo	troilus	Spicebush swallowtail
Insecta	Lepidoptera	Pieridae	Colias	eurytheme	Orange sulphur
Insecta	Lepidoptera	Pieridae	Colias	philodice	Clouded sulphur
Insecta	Lepidoptera	Pieridae	Phoebis	sennae	Cloudless Sulphur
Insecta	Lepidoptera	Pieridae	Pieris	brassicae	Cabbage white
Insecta	Lepidoptera	Pieridae	Pieris	rapae	Cabbage butterfly
Insecta	Lepidoptera	Pieridae	Pontia	protodice	Checkered white
Insecta	Lepidoptera	Pterophoridae			Plume moths
Insecta	Lepidoptera	Pyralidae			Moth
Insecta	Lepidoptera	Pyralidae	Crambus	sp. 1	Grass moth
Insecta	Lepidoptera	Pyralidae	Crambus	sp. 2	Grass moth
Insecta	Lepidoptera	Pyralidae	Herculia	olinalis	Moth
Insecta	Lepidoptera	Pyralidae	Munroessa	sp. 1	Moth
Insecta	Lepidoptera	Pyralidae	Munroessa	sp. 2	Moth
Insecta	Lepidoptera	Pyralidae	Ostrinia	nubilalis	European corn borer
Insecta	Lepidoptera	Pyralidae	Parapoynx	obscuralis	Nymphaline moth
Insecta	Lepidoptera	Tortricidae	Archips	argyrospilus	Fruit-tree leaf roller
Insecta	Lepidoptera		[Catocala	nebulosa]	Clouded underwing
Insecta	Lepidoptera		[Plathypena	scabra]	Green cloverworm moth
Insecta	Lepidoptera		Acronicta	funeralis	Funerary dagger moth
Insecta	Lepidoptera		Acronicta	lobeliae	Lobelia dagger moth
Insecta	Lepidoptera		Agraphia	oxygramma	Sharp-stigma looper moth
Insecta	Lepidoptera		Agrotis	ipsilon	Ipsilon dart
Insecta	Lepidoptera		Allagrapha	aerea	Unspotted looper moth
Insecta	Lepidoptera		Allotria	elonympha	False underwing
Insecta	Lepidoptera		Amphion	floridensis	Nessus sphinx
Insecta	Lepidoptera		Amphipyra	pyramidoides	Copper underwing

Insecta	Lepidoptera	Anagrapha	falsifera	Celery looper moth
Insecta	Lepidoptera	Anaplectoides	prasina	Green arches
Insecta	Lepidoptera	Anathix	ralla	Dotted sallow
Insecta	Lepidoptera	Anticarsia	gemmatalis	Velvetbean caterpillar moth
Insecta	Lepidoptera	Argerotaena	volutinana	Red-banded leafroller moth
Insecta	Lepidoptera	Ascalapha	odorata	Black witch
Insecta	Lepidoptera	Atteva	punctella	Ailanthus webworm moth
Insecta	Lepidoptera	Autographia	biloba	Bilobed looper moth
Insecta	Lepidoptera	Autographia	precationis	Common looper moth
Insecta	Lepidoptera	Bomolocha	baltimoralis	Baltimore bomolocha
Insecta	Lepidoptera	Camaea	perlata	Pale beauty
Insecta	Lepidoptera	Catacola	palaeogama	Oldwife underwing
Insecta	Lepidoptera	Catocala	amatrix	The sweetheart
Insecta	Lepidoptera	Catocala	amica	Girlfriend underwing
Insecta	Lepidoptera	Catocala	cara	Darling underwing
Insecta	Lepidoptera	Catocala	cerogamma	Yellow-banded underwing
Insecta	Lepidoptera	Catocala	habilis	Habilis underwing
Insecta	Lepidoptera	Catocala	ilia	Ilia underwing
Insecta	Lepidoptera	Catocala	lacrymosa	Tearful underwing
Insecta	Lepidoptera	Catocala	maestosa	Sad underwing
Insecta	Lepidoptera	Catocala	minuta	Little underwing
Insecta	Lepidoptera	Catocala	muliercula	The little wife
Insecta	Lepidoptera	Catocala	neogama	The bride
Insecta	Lepidoptera	Catocala	piatrix	The penitent
Insecta	Lepidoptera	Catocala	recta	Yellow-gray underwing
Insecta	Lepidoptera	Catocala	relicta	White underwing
Insecta	Lepidoptera	Catocala	subnata	Youthful underwing
Insecta	Lepidoptera	Catocala	ultronia	Ultronia underwing
Insecta	Lepidoptera	Catocala	unijuga	Once-married underwing
Insecta	Lepidoptera	Catocala	vidua	Widow underwing
Insecta	Lepidoptera	Choristoneura	rosaceana	Oblique leafroller moth
Insecta	Lepidoptera	Cisseps	fulvicollis	Yellow-collared scape moth
Insecta	Lepidoptera	Coryphista	meadii	Barberry geometer
Insecta	Lepidoptera	Cyclophora	pendulinaria	Sweetfern geometer
Insecta	Lepidoptera	Cydia	pomonella	Codling moth
Insecta	Lepidoptera	Elaphria	grata	Grateful midgit
Insecta	Lepidoptera	Euparthenos	nubilis	Locust underwing
Insecta	Lepidoptera	Excelis	pyrolaria	Fine line gray
Insecta	Lepidoptera	Fulgoraecia	exigua	Plant hopper parasite moth
Insecta	Lepidoptera	Glyphipterix	linneella	Linden-bark borer
Insecta	Lepidoptera	Haemotopis	grataria	Chickweed geometer
Insecta	Lepidoptera	Halysidota	tessellaris	Banded tussock moth
Insecta	Lepidoptera	Heliothis	virescens	Tobacco budworm moth

Insecta	Lepidoptera		Heliothis	zea	Corn earworm
Insecta	Lepidoptera		Hemaris	diffinis	
Insecta	Lepidoptera		Hemaris	thysbe	
Insecta	Lepidoptera		Hydria	prunivorata	Ferguson scallop shell
Insecta	Lepidoptera		Hyphantria	cunea	Fall webworm moth
Insecta	Lepidoptera		Hyppa	xilinoides	Common hyppa
Insecta	Lepidoptera		Hypsopygia	costalis	Clover hayworm moth
Insecta	Lepidoptera		Idia	aemula	Common idia
Insecta	Lepidoptera		Idia	americalis	American idia
Insecta	Lepidoptera		Idia	lubricalis	Glossy black idia
Insecta	Lepidoptera		Lacinipolia	implicate	Implicit arches
Insecta	Lepidoptera		Lascoria	ambigualis	Ambiguous moth
Insecta	Lepidoptera		Leuconycta	diphtheroides	Green leuconycta
Insecta	Lepidoptera		Limantria	dispar	Gypsy moth
Insecta	Lepidoptera		Lithacodia	carneola	Pink-barred lithacodia
Insecta	Lepidoptera		Lithacodia	synochitis	Black-dotted lithacodia
Insecta	Lepidoptera		Macronoctua	onusta	Iris borer moth
Insecta	Lepidoptera		Moth	Caenurgina	Forage looper
Insecta	Lepidoptera		Nematocampa	limbata	Horned spanworm
Insecta	Lepidoptera		Noctua	pronobis	Large yellow underwing
Insecta	Lepidoptera		Orthonama	centrostrigaria	Bent-line geometer
Insecta	Lepidoptera		Orthonama	obstipata	The gem
Insecta	Lepidoptera		Panapoda	rufimargo	Red-lined panopoda
Insecta	Lepidoptera		Phalaenophana	paramusalis	Dark-banded owlet
Insecta	Lepidoptera		Platysenta	vecors	Dusky groundling
Insecta	Lepidoptera		Pseudoplusia	includens	Soybean looper moth
Insecta	Lepidoptera		Psudaletia	unipuncta	Armyworm moth
Insecta	Lepidoptera		Schinia	arcigera	Archigera flower moth
Insecta	Lepidoptera		Scoliopterix	libatrix	The herald
Insecta	Lepidoptera		Scopula	Limboundata	Large lace-border
Insecta	Lepidoptera		Spaelotis	clandestina	Clandestine dart
Insecta	Lepidoptera		Spanworm	Itame	Lesser maple
Insecta	Lepidoptera		Spilosoma	virginica	Virginia tiger moth
Insecta	Lepidoptera		Spotoptera	ornithogalli	Yellow-striped armyworm
Insecta	Lepidoptera		Tetanolita	mynesalis	Smoky tetanolita
Insecta	Lepidoptera		Tricholita	signata	Signate quaker
Insecta	Lepidoptera		Trichoplusia	ni	Cabbage looper moth
Insecta	Lepidoptera		Xestia	dolosa	Greater black letter dart
Insecta	Lepidoptera		Zale	lunata	Lunate zale
Insecta	Lepidoptera		Zale	minerea	Colorful zale
Insecta	Lepidoptera				Swarthy sootywing
Insecta	Odonata	Aeshnidae	Anax	junius	Green darner
Insecta	Odonata	Calopterygidae	Calopteryx	maculata	Ebony jewelwing

Insecta	Odonata	Coenagrionidae	Argia	fumipennis	Variable dancer
Insecta	Odonata	Coenagrionidae	Enallagma	civile	Familiar bluet
Insecta	Odonata	Coenagrionidae	Enallagma	doubledayi	Doubleday's bluet
Insecta	Odonata	Coenagrionidae	Enallagma	signatum	Orange bluet
Insecta	Odonata	Coenagrionidae	Ischnura	verticalis	Eastern forktail
Insecta	Odonata	Cordulegastridae	Epitheca	princeps	Prince basketail
Insecta	Odonata	Lestidae			Spread-winged damselflies (Little bluet)
Insecta	Odonata	Lestidae	Lestes	disjunctus	Common spreadwing
Insecta	Odonata	Lestidae	Lestes	eurinus	Amber-winged spreadwing
Insecta	Odonata	Lestidae	Lestes	rectangularis	Slender spreadwing
Insecta	Odonata	Libellulidae	Erythemis	simplicicollis	Eastern pondhawk
Insecta	Odonata	Libellulidae	Libellula	cyanea	Spangled skimmer
Insecta	Odonata	Libellulidae	Libellula	lydia	Common whitetail
Insecta	Odonata	Libellulidae	Libellula	pulchella	Twelve-spotted skimmer
Insecta	Odonata	Libellulidae	Pachydiplax	lonigpennis	Blue dasher
Insecta	Odonata	Libellulidae	Perithemis	tenera	Eastern amberwing
Insecta	Odonata				Azure bluet
Insecta	Odonata				Skimming bluet
Insecta	Odonata				Citrine forktail
Insecta	Odonata				Fragile forktail
Insecta	Odonata				Furtive forktail
Insecta	Odonata				Rambur's forktail
Insecta	Odonata				Sphagnum sprite
Insecta	Odonata				Spatterdock darner
Insecta	Odonata				Comet darner
Insecta	Odonata				Swamp darner
Insecta	Odonata				Unicorn clubtail
Insecta	Odonata				Calico pennant
Insecta	Odonata				Halloween pennant
Insecta	Odonata				Banded pennant
Insecta	Odonata				Martha's pennant
Insecta	Odonata				Seaside dragonlet
Insecta	Odonata				Dot-tailed whiteface
Insecta	Odonata				Slatey skimmer
Insecta	Odonata				Chalk-fronted corporal
Insecta	Odonata				Widow skimmer
Insecta	Odonata				Common whitetail
Insecta	Odonata				Needham's skimmer
Insecta	Odonata				Four-spotted skimmer
Insecta	Odonata				Painted skimmer
Insecta	Odonata				Great blue skimmer
Insecta	Odonata				Wandering glider

Insecta	Odonata				Spot-winged glider
Insecta	Odonata				Varigated meadowhawk
Insecta	Odonata				White-faced meadowhawk
Insecta	Odonata				Cherry-faced meadowhawk
Insecta	Odonata				Yellow-legged meadowhawk
Insecta	Odonata				Band-winged meadowhawk
Insecta	Odonata				Striped saddlebags
Insecta	Odonata				Carolina saddlebags
Insecta	Odonata				Black saddlebags
Insecta	Orthoptera	Tettigoniidae	Scudderia	furcata	Katydid

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