LONG TERM ARBOREAL CHANGE IN A LANDSCAPED URBAN PARK: CENTRAL PARK, NEW YORK

by Robert E. Loeb

Abstract. Historical records of the forest composition, structure, and environment of Central Park, New York City were examined to determine long term forest changes and what factors influenced the changes. Comparisons were made among eleven lists of tree species created between 1857 and 1982. Fifty-one families, 119 genera, 392 species (of which 279 were alien species and 113 native species) were identified. Species richness was highest after the initial park plantings in 1863 (244 species) and over 75% greater than Frederick Law Olmsted planned. Only 41% of all species, 34% of alien species, and 58% of native species reported in the past were on the1982 list.The history of Central Park can serve as a resource and guide for species selection and distribution of trees in park planting and management plans.

Records documenting long term forest change in urban park forests can provide opportunities to study the effects of human activities on urban trees. Using historical records, such as survey data, to determine forest changes is not a controlled experimental approach (33). Comparison of information on a forest among points in time requires assessment of how the data were collected before drawing conclusions of significant changes (18). With an understanding of the limitations of historical data interpretation, answers can be obtained to questions about which human activities cause changes in the urban forest. Which species do not survive over the long term in an urban park forest? Do plantings of alien species survive more frequently over the long term than native species? Does air pollution, such as ozone or sulfur dioxide, cause greater tree species losses? Is the intense human usage of urban park forests affecting species composition and forest structure? This study documents long term changes in the tree species composition and forest structure of Central Park, New York City and examines factors influencing the changes.

Methods

Central Park is located in the center of New York County, NY (40° 47" 00" N, 73° 58" 00" W) and covers 341.2 ha. Records describing the vegetation of Central Park and the factors affecting the plants in the Park were investigated. Library and archival sources on Central Park were reviewed to identify historic species records and patterns. Eleven species lists were available covering the period 1857-1982. The lists will be referred to by the publication year, if dates of field work were not given. An anonymous list prepared in 1857 (1) was combined with the research of Rawolle and Pilat (27) to ascertain species present before plantings were done in Central Park. Species to be planted according to Olmsted's plans (21, 22) are dated 1858. The anonymous list researched in 1863 (2) represents an in-progress summary for plantings under Olmsted's direction, while the work of Demcker (12) in 1873 shows the result of Olmsted's efforts. Two publications (24, 26) were coalesced to form the 1903 list. Lists from 1967 and 1970 (28, 14) were collated to provide the information for 1970. The most recent list was researched in 1982 (11).

Nomenclature, temperature zone, and designation as native (including species naturalized before 1850) or alien to the New York City area followed Hortus Third (8) except for a few cases noted with reference in Table 2. Identifying synonymous binomials required several references (4,5,6,7,8,10,13,29,30,31). Sensitivity to ozone and sulfur dioxide air pollution designations are drawn from Sinclair et al. (34). Species similarity indices, such as suggested by Jaccard (15) and Sorenson (35), are inappropriate for comparative purposes because the methods of survey for species were not reported (19).

Rawolle and Pilat (27) estimated the tree populations for 17 taxa (genus and species level identifications, Table 2) on the land before Park landscaping, however no diameter estimates were given. Other tree taxa were described as abundant or frequent without giving a numerical estimate. The canopy of 1934 was reconstructed from records of species and dbh (minimum 15 cm) on topographic maps of Central Park (20). A conservative interpretation of the 1934 data is appropriate because another study (18) using the topographic map series found errors in identification, diameter estimation, and incomplete notation of trees. Every tree >15 cm dbh (diameter at 1.37 m) within Central Park was tabulated in 1982 by identifying, mapping, and measuring dbh (11). In analyzing the 1934 and 1982 surveys, data are compared at the genus level (comparisons of species are from locally monospecific genera) to decrease the effect of possible errors in tree identifications. The number of trees in the 15-25, >25-35, >35-45, >45-55, >55-65, and >65 cm size classes, basal area (m^2/ha), density (stems/ha), and percentage of trees for each taxon were calculated from historical (1934) and recent (1982) data (Table 2). Only large differences between 1934 and 1982 data for major genera (>10% of total trees), such as an increase or decrease in 1982 of more than 50% of the statistic in 1934, were considered reliable indicators of change (19).

Results

Species changes through time. Central Park is the most famous park in New York City and has gained international renown because millions of visitors come each year to experience the beautiful landscape design and innovations of Frederick Law Olmsted and Calvert Vaux (32). The history of plantings in Central Park began after 1858 with the original work guided by Olmsted and Vaux. Planting notes prepared by Olmsted are not detailed as to location, numbers of trees, and species mix. Olmsted's plan for trees in Central Park included the 36,450 reported trees present on the land selected for the Park in 1857 (27) but did not specify placement (32). However, Olmsted planned to use 92.3% of the species present in Central Park (Table 1).

The species listing for 1863 shows the greatest species richness of all the listings (Table 1). However, the 1863 list also indicates the number of species planted far exceeded the planting plans. In comparison to the 1858 list, two thirds more species were planted by 1863 with nearly three times the number of alien species. Extensive tree cutting was done in Central Park under the direction of Frank Pollard, a Tammany Hall appointee, in 1870 and 1871 (32). The summary numbers for 1873 indicate a net loss of 32 species, including 16 alien species, from what existed in 1863. However, the losses were greater because 37 new species were listed for the Park in 1873 (Table 2). The large number of alien species planted during the development of the Park is related to the limited availability of native specimens from nurseries (25).

Samuel Parsons Jr., Central Park Landscape Architect from 1885 to 1897, directed the planting of native species to replace the alien species that had died following the period of Olmsted guided plantings (25). Perhaps his family relationship with the Flushing, New York nurseries influenced species availability. By 1903, the number of native species rose by 20 but alien species still represented more than half of the species in Central Park (Table 1).

A severe freeze during March 13-15, 1872 caused the death of 7,314 trees in Central Park (3). A second severe freeze during the middle of the 1917-1918 winter killed over 4,000 trees in the Park (23). The reports on both freezes did not specify that the population of any species was totally lost, nor the diameter of trees killed. The losses could have been primarily in poorly estab-

Table 1. Species lists from Central Park: 1857 (1, 27) 1858 - Olmsted (21, 22), 1863 (2), 1873 (12), 1903 (24, 26), 1970 (28, 14), and 1982 (11). Total number of tree species; total number of alien species (to New York City); and number of species in common with 1857, 1858, and 1982.

Year	1857	1858	1863	1873	1903	1970	1982
Tree Species	78	149	244	212	220	139	162
Alien Species	23	62	155	138	136	88	95
1857	78	72	76	61	66	45	48
1858	72	149	120	100	105	68	77
1982	49	80	105	96	113	94	162

lished plantings, since Olmsted planned only to plant species that would survive in the climate of New York City (21). This principle was apparently followed throughout the planting history of the Park, because only 13 species from climatic zones warmer than New York are listed in Table 2. Of the 13 species only valley oak (*Quercus lobata*) was reported to exist after 1970 (first listed in 1982). Perhaps the heat island effect, which has increased the average temperature and reduced snowfall in New York City (16), will help valley oak to survive.

During Robert Moses' tenure as Parks Commissioner (1934-1965) there were over 3,000 plantings of alien and native species (32). Moses developed a nursery that mass produced Norway maple (*Acer platanoides*), buttonwood (*Platanus occidentalis*), European linden (*Tilia europaea*), and American elm (*Ulmus americana*) for planting in the parks and streets (19). Perhaps Moses' focus on planting a few species rather than introducing new species or reintroducing lost species contributed to the over one third drop in species from 1903 to 1970. After 1965, visitors were allowed to freely traverse the entire Park which resulted in the destruction of the herb, seedling, shrub, and sapling layers in many parts of the Park (32)

Over the history of the Park more alien than native species have been planted but the percentage of native species surviving to 1982 was greater than the percentage of alien species (Table 2). Considering all years (1857-1982), there have been: 51 families; 119 genera; and 392 species (279 alien species and 113 native species) of trees in Central Park (Table 2). Only 41% of all species, 34% of alien species, and 58% of native species that were reported in the Park were listed in 1982.

Forest composition and structure. The four major genera in 1857 (Table 2) were oak (*Quercus* spp.) hornbeam (*Carpinus caroliniana*), sweet gum (*Liquidambar styraciflua*), and maple (*Acer* spp.) which was 90% swamp maple (*Acer rubrum*; 27). The 1857 tree population estimates cannot be strictly equated with the 1934 data because Rawolle and Pilat (27) reported on all trees and the 1934 data were for trees >15 cm dbh. However, the tree populations estimated by Rawolle and Pilat for hornbeam, sweet gum, and maple were more than twice the 1934 results (Table 2). Perhaps the drainage network created during Park construction (32) served to create dryer environments which resulted in the population declines for hornbeam, sweet gum, and swamp maple.

In 1934, density was 44.2 trees/ha and basal area was 3.7 m^2/ha for all of Central Park. From 1934 to 1982, density and basal area in Central Park rose by over 50% to 66.7 and 10.4 respectively. The density and basal area values are probably larger than what was desired in the original plan because the meadows and open landscape plantings created under Olmsted's direction provide a large amount of available growing space for new trees and the expansion of established specimens. Maps of forest cover in Olmsted's plan and 1982 (32) show how the long term forest expansion differs from the plan for the Park.

Comparison of diameter size distribution from 1934 to 1982 for the major genera maple, oak, and elm (*Ulmus* spp.) in Central Park showed a decline in the number of trees in the 15-25 cm size class to below the number of trees in >25-35 cm size class and an increase in all other size classes. The changes for maple, oak, and elm indicate that less replanting or regeneration has occurred than necessary to maintain the populations. In contrast, the fourth major genus, cherry (*Prunus* spp.), had more than double the number of trees in each size class in 1982 than were present in 1934, which indicates good potential for population expansion. Growing space released by the cutting of tree-of-heaven (32; Table 2) may partially explain the expansion of cherry but the extensive open growing space in the Park is another explanation. This large amount of open space between trees in Central Park does not support an interpretation of forest maturation causing the decline in the 15-25 cm size class for all major genera except cherry.

Discussion

Central Park can be viewed as a testing ground for the survival of native and alien species of trees in urban park conditions and Table 2 identifies species that have and have not survived by tracking the presence of species in each of the seven listings. The greater loss of alien species (66% of all identified) than native species (42% of all identified) over the history of Central Park indicates better survival by native species than alien species. The results in Table 2 may overestimate survival because there are no explanations for the 87 times a species did not occur on a list even though the species was present on the preceding and following lists. If the blanks in the species records indicate species were regularly replanted as versus oversight in the surveys, then ability to survive may be overestimated.

Species lists for Staten Island, a borough of New York City (15,934 ha), were created in 1879, 1930, and 1981 (9) which can be compared with the species changes in Central Park. A total of 145 tree species was recorded on Staten Island, including 47 alien species. The number of tree species in Staten Island increased from 90 in 1879 to 124 in 1930 and then decreased to 116 in 1981. However, alien species increased from 16 in 1879, to 30 in 1930, and to a high of 35 in 1981. The higher number of tree species and greater percentage of alien species in Central Park, than in the 46 times larger county of Staten Island, reflect the extensive plantings that occurred in Central Park. The increase in alien species on Staten Island since 1879, because of plantings in new residential areas, contrasts sharply with the decrease starting after 1885 in Central Park when a shift to planting native species occurred (25).

Of the 105 Central Park species (62 alien and 43 native) sensitive to sulfur dioxide and/or ozone air pollution (33; Table 2), only 40 species (31 alien and 9 native) were not in the 1982 list. Considering the high survival rate of known ozone and sulfur dioxide air pollution sensitive trees, air pollution does not appear to be the primary factor causing species loss. However, replantings during the history of Central Park may mask previous species losses to air pollution. Among the tree species recorded on Staten Island (9), 53 were sensitive to ozone and sulfur dioxide, air pollution and 52 of the sensitive species were reported in 1981. Although there is less air pollution in Staten Island than in Central Park (36), only losing one out of 53 sensitive species supports the inference from the Central Park information that air pollution does not appear to be a major factor in species loss. However, more species need to be evaluated for pollution sensitivity to ozone, sulfur dioxide, and other pollutants before coming to a conclusion on the effects of air pollution on species survival.

Seton Falls Park, Bronx, NY (5 ha) is the only other New York City park with a comparison of total surveys of the > 15 cm dbh trees as reported here for Central Park (between 1936 and 1979; 17). Also, Seton Falls has open space among the trees and is geologically similar to Central Park. In contrast, Seton Falls has not been maintained or planted; has far fewer visitors; has less surrounding urban development (17); and has a lower level of air pollution (36). The most outstanding similarity between the changes in the four major genera for Seton Falls and Central Parks is the more than doubling of the 15-25 cm dbh cherry tree population (primarily black cherry (*Prunus serotina*) which had twice the 1930's population of cherry in both Parks). Although an increased number of >25 cm dbh oak trees occurred in both Parks, the 15-25 cm size class in Seton Falls remained the largest in 1979 (17). Increased destruction of natural regeneration by human activities and limited plantings during the lean economic times after Robert Moses left the Commissioner's Office (32) may be a cause of the decline in the 15-25 cm size class in Central Park. The continued major genus status for elm in Central Park but near total loss of elm from Seton Falls (17) is related to plantings and intensive efforts to control Dutch elm disease in Central Park (32). Plantings permitted maple to remain a major genus in Central Park (19) while in Seton Falls the population continued to be small (17).

Knowing which species have survived and what changes have occurred in forest composition and structure during the history of an urban forest, provides a basis for examining the long term efficiency and effectiveness of planting and management plans. Since records of these changes are often not available for other urban park forests, the history of Central Park can serve as a resource and guide for species selection and distribution of trees in planting and management plans. The history of species changes in Central Park indicates that ozone and sulfur dioxide air pollution does not cause species losses but more of the species that have grown in Central Park need to be evaluated for air pollution sensitivity. The intense human disturbance in Central Park has caused a decline in the population of the smallest diameter size class trees which will eventually lead to the loss of forest when the larger diameter trees die. Following Olmsted's design principles, consideration of the forest's growing environment and the selection of native species or species that will survive in the conditions of the Park (21, 22), will result in more long term tree survival in Central Park (and in other urban park forests) than increasing species richness by planting untested alien species.The history of species changes in Central Park indicates that ozone and sulfur dioxide air pollution does not cause species losses but that more of the species grown in the park need to be evaluated for air pollution sensitivity. The intense human disturbance in Central Park has causes a decline in the population of the smallest diameter trees. The loss of forest will occur unless the species comprising the larger diameter trees are replaced.

Acknowledgments. Thanks are extended to the Central Park Conservancy for providing the 1982 survey data. Niel Calvanese, Marianne Cramer, Karl Loeb, Susan Loeb, George Profous, Rowan Rowntree, and Wayne Zipperer provided valuable suggestions and helpful commentary in reviewing the manuscript.

Literature Cited

1. Anonymous. 1857. List of trees and shrubs in Central Park, pp 25-35. In (No Ed). Report of the Engineer in Chief of Central Park. N. p. New York.
2. Anonymous. 1864. Catalogue of trees, shrubs, and herbaceous plants of the Central Park, December 31, 1863 with the months of flowering and fruiting of such as have conspicuous blossoms or fruits, pp 91-123. In (No Ed). Seventh Annual Report of the Board of Commissioners of Central Park. Wm. C. Bryant and Co, New York.
3. Anonymous. 1872. Disaster to trees, pp 19-25 and 202-203. In (No Ed). Fifteenth Annual Report of the Board of Commissioners of Central Park. Wm. C. Bryant and Co, New York.
4. Bailey, L. H. 1900. Cyclopedia of American Horticulture. Macmillan Publishing Co., New York. 2096 pp.
5. Bailey, L. H. and E. Z. Bailey. 1930. Hortus. Macmillan Publishing Co., New York. 652 pp.
6. Bailey, L. H. and E. Z. Bailey. 1941. Hortus Second. Macmillan Publishing Co., New York. 778 pp.
7. Bailey, L. H., E. Z. Bailey, and Staff of Bailey Hortorium. 1949. Manual of Cultivated Plants. Macmillan Publishing Co., New York. 1116 pp.
8. Bailey, L. H., E. Z. Bailey, and Staff of Liberty Hyde Bailey Hortorium. 1976. Hortus Third. Macmillan Publishing Co., New York. 1290 pp.
9. Buegler, R. and S. Parisio. 1981. A Comparative Flora of Staten Island 1879-1981. Staten Institute of Arts and Sciences, Staten Island, NY. 93 pp.
10. Chittenden, F. 1951. Dictionary of Gardening. Clarendon Press, Oxford. 2316 pp.
11. Cramer, M., J. Heintz, and B. Kelly. 1984. Vegetation in Central Park. Central Park Conservancy, New York. 505 pp.
12. Demcker, R. 1873. Central Park Plant List and Map Index of 1873. Central Park Community Fund, New York (reprinted 1979). 47 pp.
13. Fernald, M. L. 1970. Gray's Manual of Botany. D. Van Nostrand Co., New York. 1632 pp.
14. Graff, M. M. 1970. Tree Trails in Central Park. Greensward Foundation, Inc., New York. 189 pp.
15. Jaccard, P. 1901. *Distribution de la flore alpine dans le Bassin des Dranses et dans quelques regions voisines.* Bull. Soc. vaud. Sci. nat. 37: 241-272.
16. Jones, R. A. and J. E. Jiusto. 1980. *Some local climate trends in four cities of New York.* J. Appl. Meteorology 19: 135-141.
17. Loeb, R. E. 1982. Reliability of the New York City Department of Parks and Recreation's forest records. Bull. Torrey Bot. Club 109: 537-541.
18. Loeb, R. E. 1990. *Measurement of vegetation changes through time by resampling.* Bull. Torrey Bot. Club 117: 173-175.
19. Loeb, R. E. 1992. *Will a tree grow in Brooklyn? Developmental trends of the New York City street tree forest.* Jour. For. 90: 20-24.
20. New York City Department of Parks. 1934. Topographic Map of Central Park, Borough of Manhattan. Flushing Meadows, NY. 30 pp.
21. Olmsted, F. L. 1857. Report relative to trees, pp. 332-335. **In** F. L. Olmsted, Jr. and T. Kimball (Eds). Frederick Law Olmsted, Landscape Architect, 1822-1903. G. P. Putnam's Sons, New York (1928).
22. Olmsted, F. L. 1858. Descriptive guide to the arboretum, pp. 335-342. **In** F. L. Olmsted, Jr. and T. Kimball (Eds). Frederick Law Olmsted, Landscape Architect, 1822-1903. G. P. Putnam's Sons, New York (1928).
23. Pack, C. L. 1919. *Central Park trees starving to death.* Amer. For. 25: 1391-1400.
24. Parkhurst, H. E. 1903. Trees, Shrubs, and Vines of the Northeastern United States, Their Characteristic Landscape Features Fully Described for Identification by the Nonbotanical Reader; Together with an Account of the Principal Foreign Hardy Trees, Shrubs, and Vines Cultivated in Our Country, and Found in Central Park, New York City. Charles Scribner's Sons, New York. 451 pp.
25. Parsons, M. (Ed). 1926. Memories of Samuel Parsons. G. P. Putnam's Sons, New York. 150 pp.
26. Peet, L. H. 1903. Trees and Shrubs of Central Park. Manhattan Press, New York. 363 pp.
27. Rawolle, C. and I. A. Pilat. 1857. Catalogue of Plants

Gathered in August and September 1857 in the Terrain of the Central Park. M. W. Siebert, New York. 34 pp.
28. Reed, H. H. and S. Duckworth. 1967. Central Park a History and a Guide. Clarkson N. Potter Inc., New York. 163 pp.
29. Rehder, A. 1927. Manual of Cultivated Trees and Shrubs Hardy in North America, Exclusive of the Subtropical and Warmer Temperate Regions. Macmillian Publishing Co., New York. 930 pp.
30. Rehder, A. 1947. Manual of Cultivated Trees and Shrubs Hardy in North America, Exclusive of the Subtropical and Warmer Temperate Regions. Macmillian Publishing Co., New York. 996 pp.
31. Rehder, A. 1949. Bibliography of Cultivated Trees and Shrubs Hardy in North America, Exclusive of the Subtropical and Warmer Temperate Regions. Arnold Arboretum, Jamaica Plain, MA. 825 pp.
32. Rogers, E. B. 1989. Rebuilding Central Park, a Management and Restoration Plan. MIT Press, Cambridge, MA. 160 pp.
33. Schreuder, H. T. and C. E. Thomas. 1991. *Establishing cause-effect relationships using forest survey data.* For. Sci. 37: 1497-1512.
34. Sinclair, W. A., H. H. Lyon, and W. T. Johnson. 1987. Diseases of Trees and Shrubs. Cornell University Press, Ithaca, NY. 574 pp.
35. Sorenson, T. 1948. *A method of establishing groups of equal amplitude in plant sociology based on similarity of species content.* Biol. Skr. 5(4): 1-34.
36. Zupan, J. M. 1973. The Distribution of Air Quality in New York City Region. Resources for the Future, Inc., Washington, D. C. 87 pp.

Assistant Director of Academic Affairs
Penn State Altoona Campus
Altoona, PA 16601-3760

Résumé. Les données historiques concernant la composition, la structure et l'environnement de Central Park, New York, furent étudiées afin de déterminer les changements à long terme et les facteurs qui ont influencé ces changements. Des comparaisons ont été faites entre 11 listes d'espèces d'arbres produites entre 1857 et 1982. Ont été identifiées 51 familles, 119 genres et 392 espèces (desquelles 279 étaient des espèces introduites et 113 étaient indigènes). La diversité en espèces a été la plus forte après l'aménagement initial du parc en 1863 (244 espèces) et était de 75% plus élevée que celle planifiée à l'origine par Frederick Law Olmsted. Seulement 41% de toutes les espèces, 34% des espèces introduites et 58% des espèces indigènes, répertoriées dans le passé étaient présentes sur la liste de 1982. L'histoire de Central Park peut servir à titre de référence et de guide pour la sélection des espèces et la distribution des arbres dans les plans d'aménagement et de plantation des parcs.

Zusammenfassung. Historische Aufzeichungen über Waldzusammensetzung, Struktur und Umwelt des Central Parks, NYC, wurden untersucht, um langfristige Veränderungen des Waldes und die Ursachen dafür festzustellen. Es wurden Vergleiche angestellt zwischen elf Listen von Baumarten, die zwischen 1857 und 1982 entstanden sind. 51 Familien, 119 Gattungen und 392 Arten (von denen 279 fremde und 113 einheimische Arten) wurden identifiziert. Die gröβte Artenvielfalt hatte man 1863 gleich nach der begonnenen Anlegung des Parks (244 Arten), sie war 75% größer als ursprünglich von Frederick Law Olmsted geplant. Nur 41% aller Arten, 34% der fremden und 58% der einheimischen Arten, die in der Vergangenheit aufgezeichnet wurden, fanden sich auf der Liste von 1982. Die Geschichte des Central Parks kann als Quelle und Richtlinie zur Artenselektion und -verteilung in Parkanlagen und Parkmanagement dienen.

Table 2. Tree species in Central Park, 1 - 1857 (1, 27) ; 2 - 1858 (21, 22); 3 - 1863 (2); 4 - 1873 (12); 5 - 1903 (24, 26); 6 - 1970 (14, 28); and 7 - 1982 (11). Nomenclature, temperature hardiness, and alien or native species (to New York City) status follows Bailey et al. (8) except for species marked with 2 - Bailey and Bailey (6) and R - Rehder (30). Sensitivity to air pollution is from Sinclair et al. (34). Designations for temperature hardiness zone warmer than New York City - T; air pollution sensitivity - P; alien - A; native - N; and X - species present. Percent of all trees in 1857 (27) and percent of all trees dbh ≥15 cm in 1936 are numbers in parenthesis following genus name (1857 : 1936). Percent of all trees dbh ≥15 cm in 1982 are numbers in column 7.

			1	2	3	4	5	6	7
ACERACEAE									
Acer (24.6 : 12.0)									
campestre		A							<0.1
cappadocicum		A					X		
Ginnala		A							X
Lobelii	T	A			X				
macrophyllum		A			X	X	X		
Negundo	P	N		X	X	X	X		
Opalus		A			X	X			
palmatum	P	A			X	X	X	X	X
pensylvanicum		N		X	X	X	X		
platanoides		A							6.0
pseudoplatanus		A			X	X	X	X	4.2
rubrum	P	N	X	X	X	X	X	X	0.7
saccharinum	P	A		X	X	X	X	X	0.1
saccharum		N							0.2
truncatum		A					X		
ANACARDIACEAE									
Cotinus									
obovatus	P	A		X	X	X	X		
Rhus (- - : 0.1)									
copallina		N	X	X	X	X	X	X	X
glabra	P	N	X	X	X	X	X		
typhina	P	N	X	X	X	X	X	X	X
Vernix		N	X		X				
ANNONACEAE									
Asimina									
triloba		N		X	X				X
AQUIFOLIACEAE									
Ilex (- - : <0.1)									
ambigua		N	X	X	X				
Aquifolium		A			X	X	X	X	<0.1
crenata		A					X	X	X
decidua		A		X					
opaca		N		X	X	X	X	X	<0.1
verticillata		N		X	X	X	X	X	X
ARALIACEAE									
Aralia (0.1 : - -)									
chinensis	T	A			X		X		
elata		A						X	
spinosa		A	X	X	X	X	X		<0.1
BETULACEAE									
Alnus									
cordata		A			X	X	X		
glutinosa	P	A				X	X	X	
incana		A			X	X			
rugosa		N		X	X	X	X		
viridis		A						X	X
Betula (2.5 : 0.6)									
lenta		N	X	X	X	X	X	X	<0.1
nigra	P	N	X	X	X		X	X	0.2
papyrifera	P	N	X	X	X		X		<0.1
pendula	P	A				X	X	X	0.4
populifolia	P	N					X		<0.1
Carpinus (29.6 : 1.0)									
Betulus	P	A			X	X	X	X	X
caroliniana		N	X	X	X	X	X	X	1.2
Corylus (- - : <0.1)									
Colurna		A	X	X	X				X
Ostrya (- - : 2.0)									
virginiana		N			X	X	X	X	<0.1
BIGNONIACEAE									
Catalpa (- - : 1.3)									
bignonioides		A	X	X	X	X	X	X	
Bungei		A				X	X		
speciosa	P	A					X		0.2
Paulownia (- - : 0.5)									
tomentosa		A		X	X	X	X	X	0.2
CAPRIFOLIACEAE									
Sambucus									
nigra	P	A				X	X		X
pubens		N		X	X				
Viburnum									
cassinoides		N					X		
dentatum		N	X	X	X	X	X		
Lantana	P	A			X	X	X	X	
Lentago		N		X	X	X	X	X	
macrocephalum		A			X				
nudum		N		X		X			
Opulus		A		X	X	X	X	X	
plicatum		A					X	X	
prunifolium		N	X	X	X	X	X	X	<0.1
rhytidophyllum		A							<0.1
Sieboldii		A					X	X	

			1	2	3	4	5	6	7
CELASTRACEAE									
Euonymus									
atropurpurea		N		X		X			<0.1
europaea		A			X	X		X	X
latifolia		A			X				
CEPHALOTAXACEAE									
Cephalotaxus									
Fortunii		A			X	X	X		
Harringtonia		A				X			
CERCIDIPHYLLACEAE									
Cercidiphyllum (- - : <0.1)									
japonicum		A					X		<0.1
CORNACEAE									
Cornus (0.7 : 0.3)									
alternifolia		N		X	X		X		
florida		N	X	X	X	X	X	X	<0.1
Kousa		A						X	<0.1
mas	P	A			X	X	X	X	<0.1
CUPRESSACEAE									
Chamaecyparis									
Lawsoniana	P	A			X	X			
nootkatensis		A	X	X			X		
obtusa		A					X		
pisifera		A					X		
thyoides		N		X				X	
Cupressus									
macrocarpa	T	A			X				
Juniperus									
chinensis		A			X	X	X		
communis		N		X	X	X	X		X
drupacea		A			X				
flaccida (2)		A			X				
Oxycedrus	T	A			X				
recurva	T	A			X				
rigida		A			X				
virginiana		N	X	X	X	X	X		<0.1
Platycladus									
orientalis		A			X	X			
Thuja									
occidentalis		N		X	X	X	X		X
plicata		A			X	X	X		
Thujopsis									
dolabrata		A				X			
CYRILLACEAE									
Cyrilla									
racemiflora	T	A						X	
EBENACEAE									
Diospyros									

			1	2	3	4	5	6	7
Lotus		A			X				
virginiana		N	X	X	X	X	X		X
ELAEAGNACEAE									
Elaeagnus									
angustifolia	P	N		X	X	X	X		X
multiflora		N					X	X	X
pungens		N							X
Hippophae									
rhamnoides		A			X	X	X		
Shepherdia									
argentea		A		X		X	X		
canadensis		N		X	X				
ERICACEAE									
Kalmia									
latifolia		N		X	X	X	X	X	X
Oxydendrum									
arboreum		A		X	X	X	X	X	<0.1
Rhododendron (- - : <0.1)									
ponticum		A				X	X		
EUCOMMIACEAE									
Eucommia									
ulmoides		A							X
FAGACEAE									
Castanea (1.2 : 1.1)									
dentata		N	X	X	X	X	X		
pumila		A			X				
sativa		A			X	X	X		
Fagus (0.5 : 2.1)									
grandifolia	P	N	X		X	X	X	X	<0.1
orientalis		A						X	X
sylvatica	P	A			X	X	X	X	0.6
Quercus (19.7 : 11.2)									
alba	P	N	X	X	X	X	X	X	0.2
bicolor		N		X			X	X	0.3
cerris		A			X	X	X	X	1.8
coccinea	P	N	X	X	X		X	X	<0.1
falcata		A		X					
ilicifolia		N		X					<0.1
imbricaria		A		X			X	X	<0.1
lobata	T	A							<0.1
lyrata		A					X		
macrocarpa	P	N		X	X	X	X	X	<0.1
Muehlenbergii		N	X	X	X				
nigra		A	X	X	X	X	X		
palustris	P	N	X	X	X		X	X	6.7
petraea		A						X	
phellos		N		X	X	X	X	X	0.5
prinus		N	X	X	X		X	X	<0.1
robur	P	A			X	X	X	X	<0.1

			1	2	3	4	5	6	7
rubra		N	X	X	X	X	X	X	3.3
stellata		N					X		
velutina	P	N					X	X	0.6
FLACOURTIACEAE									
Idesia									
polycarpa		A					X		
GARRYACEAE									
Garrya									
elliptica	T	A			X				
GINKGOACEAE									
Ginkgo (- - : 1.3)									
biloba		A		X	X	X	X	X	1.9
HAMAMELIDACEAE									
Fothergilla									
Gardenii		A			X				
major		A		X					
Hamamelis									
virginiana	P	N	X	X	X	X	X	X	<0.1
Liquidambar (14.8 : 0.3)									
Styraciflua	P	N	X	X	X	X	X	X	1.1
HIPPOCASTANACEAE									
Aesculus (- - : 0.3)									
californica	T	A			X				
carnea		N		X	X	X			
glabra	P	A		X	X	X	X		<0.1
Hippocastanum	P	A	X	X	X	X	X	X	0.5
octandra		A	X	X		X	X		
parviflora		A		X	X	X	X		
Pavia		A		X	X	X	X		
JUGLANDACEAE									
Carya (3.9 : 1.7)									
cordiformis		N	X	X	X	X	X		0.3
glabra		N		X					0.2
illinoinensis		A		X	X				
laciniosa		A	X	X	X	X			
ovalis (R)		N							<0.1
ovata		N	X	X	X	X	X		<0.1
texana (R)		A							<0.1
tomentosa		N	X	X	X	X	X	X	0.3
Juglans (0.6 : 0.1)									
cinerea		A	X	X	X	X	X	X	
nigra	P	N	X	X	X	X	X	X	0.2
regia	P	A			X	X		X	
Pterocarya									
fraxinifolia		A				X			
LAURACEAE									
Sassafras (- - : 0.7)									
albidum	P	N	X	X	X	X	X	X	1.5

			1	2	3	4	5	6	7
LEGUMINOSAE									
Albizia									
Julibrissin		A						X	X
Caragana									
arborescens		A			X	X	X	X	X
Cercis									
canadensis	P	N		X	X	X	X		<0.1
chinensis	P	A				X	X		
Siliquastrum		A				X			
Cladrastis (- - : <0.1)									
lutea		A		X	X		X	X	<0.1
Gleditsia (- - : 0.1)									
caspica		A			X				
sinensis	T	A			X		X		
triacanthos	P	N		X	X	X	X	X	0.7
Gymnocladus (- - : <0.1)									
dioica	P	N	X	X	X	X	X	X	0.1
Laburnocytisus									
Adamii		A			X				
Laburnum									
alpinum	P	A			X	X			
anagyroides		A				X	X	X	
Robinia (7.4 : 6.1)									
Pseudoacacia	P	N	X	X	X	X	X	X	7.2
viscosa		A		X	X	X			
Sophora									
japonica		A			X	X	X	X	0.5
MAGNOLIACEAE									
Liriodendron (1.2 : 0.8)									
Tulipifera	P	N	X	X	X	X	X	X	0.4
Magnolia (- - : 0.2)									
acuminata		N		X	X	X	X	X	0.2
Fraseri		A		X	X				
grandiflora		A						X	X
heptapeta		A		X			X	X	
hypoleuca		A		X	X	X			
macrophylla		A		X	X	X	X		
soulangiana		A					X	X	<0.1
stellata		A					X		X
tripetala		A		X	X	X	X		<0.1
virginiana		N		X	X	X	X	X	<0.1
MORACEAE									
Broussonetia									
papyrifera		A		X	X	X	X	X	0.3
Morus (- - : 2.3)									
alba	P	A	X	X	X		X	X	0.5

			1	2	3	4	5	6	7
nigra		A			X		X		
rubra		N	X	X	X	X	X	X	1.7
Maclura (- - : 0.3)									
pomifera		A	X	X	X	X	X	X	0.3
MYRICACEAE									
Myrica									
cerifera		A	X	X	X	X	X		
NYSSACEAE									
Nyssa (1.4 : - -)									
aquatica		A	X	X	X	X			
sylvatica	P	N	X	X	X	X	X	X	0.1
OLEACEAE									
Chionanthus									
virginicus		A			X	X	X	X	X
Fontanesia									
Fortunei		A					X		
Forestiera									
acuminata		A			X				
Fraxinus (0.4 : 2.6)									
americana	P	N	X	X	X	X	X		3.7
excelsior	P	A			X	X	X		
nigra		N	X	X	X	X	X		
Ornus		A			X	X	X		
pennsylvanica	P	N	X	X	X	X	X		0.8
quadrangulata		A		X	X	X			
Ligustrum									
indicum		A			X				
japonicum		A			X	X			
lucidum		A			X	X			
Phillyrea									
latifolia		A				X			
Syringa									
reticulata	P	A							X
vulgaris	P	A	X		X	X	X	X	
PINACEAE									
Abies (- - : <0.1)									
alba		A		X		X			
balsamea	P	N		X	X	X	X		
cephalonica		A				X	X		
concolor	P	A					X		<0.1
Fraseri		A		X	X		X		
grandis		A			X	X			
			1	2	3	4	5	6	7
Nordmanniana		A				X	X		<0.1
Pinsapo		A			X	X			
procera		A				X			
sibirica		A				X			

			1	2	3	4	5	6	7
Cedrus									
atlantica		A			X	X	X	X	<0.1
Deodara		A			X		X		<0.1
libani		A			X	X	X		
Larix (- - : <0.1)									
decidua	P	A		X	X	X	X		X
laricina	P	N		X	X	X	X	X	0.1
Picea (- - : 0.1)									
Abies	P	A		X	X		X		<0.1
Brewerana		A			X				
mariana		N	X	X	X				
orientalis		A		X	X		X		
pungens	P	A			X	X	X	X	<0.1
Smithiana		A			X	X			
Pinus (- - : 2.0)									
Ayacahuite	T	A			X				
Banksiana	P	N			X				
Cembra	P	A			X	X	X		<0.1
cembroides		A			X				X
densiflora		A							<0.1
echinata	P	N		X	X		X		
edulis		A							<0.1
flexilis	P	A							<0.1
Gerardiana		A			X				
Jeffreyi	P	A			X	X			
koraiensis		A						X	<0.1
Lambertiana		A			X				
Montezumae		A			X				
monticola	P	A			X				
Mugo		A			X	X	X		<0.1
nigra	P	A			X	X	X	X	1.1
palustris		A			X	X	X		
parviflora	P	A							<0.1
Peuce	P	A							<0.1
Pinaster		A			X				
ponderosa		A			X	X	X		
pungens		A		X	X		X		
resinosa	P	N		X	X	X			<0.1
rigida	P	N		X	X	X	X		
Sabiniana	T	A			X				
Strobus	P	N	X	X	X	X	X	X	0.3
sylvestris	P	A		X	X	X			<0.1
Thunbergiana		A							<0.1
virginiana	P	N							X
Wallichiana		A			X			X	<0.1
Pseudolarix									
Kaempferi		A					X	X	
Pseudotsuga									
Menziesii	P	A			X		X	X	
Tsuga (- - : <0.1)									
canadensis	P	N	X	X	X	X	X	X	<0.1
caroliniana		A							X

			1	2	3	4	5	6	7
PLATANACEAE									
Platanus (0.7 : 7.1)									
acerifolia	P	A						X	5.5
occidentalis	P	N	X	X	X	X	X	X	0.5
orientalis		A			X	X	X	X	
PODOCARPACEAE									
Podocarpus									
macrophyllus	T	A				X			
RHAMNACEAE									
Rhamnus (- - : <0.1)									
Alaternus		A					X		
Frangula	P	A			X	X	X	X	
ROSACEAE									
Amelanchier (- - : 0.2)									
arborea	P	N							<0.1
asiatica		A					X		
Crataegus (- - : 1.2)									
Calpodendron		N	X	X	X	X	X		
coccinoides		A						X	
collina		A				X			
crus-galli		N		X	X	X	X	X	
flava		A		X			X		
laevigata	P	A		X	X	X	X	X	
monogyna		A				X			
nigra (R)		N			X				
Phaenopyrum	P	A						X	
prunifolia		N				X		X	
punctata		N					X		
sanguinea		A				X			
spathulata		A		X		X			
succulenta		N					X		
Cydonia (- - : <0.1)									
oblonga	P	A				X	X		
sinensis		A			X	X			
Malus (- - : <0.1)									
atrosanguinea	P	A						X	
Halliana		A						X	
ioensis		A					X		
spectabilis		A			X	X	X		
sylvestris	P	A			X		X		X
toringoides		A				X	X		
Photinia									
serrulata		A			X	X			
villosa		A						X	
Prunus (- - : 13.3)									
spp. ("ornamental")								1.6	
americana		N		X	X	X			
angustifolia		A		X					
avium	P	A					X		
caroliniana		A				X			
Cerasus	P	A					X		
dulcis		A					X		

			1	2	3	4	5	6	7
lusitanica		A				X			
Mahaleb		A			X	X	X		
maritima		N	X	X	X	X	X		X
Padus		A			X		X		
pensylvanica		N		X		X	X		X
Persica	P	A			X	X	X	X	
pumila		A		X					
serotina	P	A	X	X	X	X	X	X	18.7
serrulata	P	A			X		X	X	
subhirtella		A							X
virginiana		N	X	X	X	X	X	X	X
Pyrus									
Calleryana		A							<0.1
communis	P	A					X		
salicifolia		A			X				
Sorbus									
americana		N		X	X	X			<0.1
Aria		A			X	X	X		
Aucuparia		A			X	X	X	X	
Spiraea									
crenata	P	A				X	X		
RUBIACEAE									
Cephalanthus									
occidentalis		N	X	X	X	X	X		
RUTACEAE									
Evodia									
spp.		A						X	
Phellodendron (- - : 0.1)									
amurense		A					X	X	0.4
Ptelea									
trifoliata		N	X	X	X	X	X	X	X
SALICACEAE									
Populus (1.2 : 1.2)									
alba		A		X	X	X	X		
balsamifera		N	X	X	X	X	X	X	0.3
canescens		N			X				
deltoides	P	N	X	X	X	X			0.1
heterophylla	P	N	X	X	X				
laurifolia		A			X				
nigra	P	A	X	X	X	X	X		<0.1
Simonii		A							0.2
tremula		A			X	X			
tremuloides	P	N	X	X	X		X		<0.1
Salix (3.0 : 2.6)									
alba		A	X			X	X		
babylonica	P	A	X	X	X	X	X		0.2
caprea	P	A				X			
daphnoides		A			X				
dasyclados		A				X			
discolor		N	X		X		X		
eriocephala		A	X		X				

			1	2	3	4	5	6	7
fragilis	P	A	X		X				
lucida		N	X		X	X	X		
Matsudana		A						X	<0.1
nigra	P	N				X	X		0.4
pentandra	P	A			X		X	X	
sepucralis		A			X			X	
triandra		A			X				
viminalis		N				X			
SAPINDACEAE									
Koelreuteria									
paniculata	P	A			X	X	X	X	0.3
SAPOTACEAE									
Bumelia									
languinosa		A		X					
SAXIFRAGACEAE									
Hydrangea									
paniculata		A			X	X	X		X
SIMAROUBACEAE									
Ailanthus (- - : 6.9)									
altissima	P	A	X	X	X	X	X	X	2.2
STYRACACEAE									
Halesia (- - : 0.1)									
carolina		A			X	X	X	X	<0.1
diptera	T	A		X					
Styrax									
americanus	P	A		X					X
japonicus		A					X	X	<0.1
TAMARICACEAE									
Tamarix									
gallica		A			X	X	X		
TAXACEAE									
Taxus									
baccata		A			X	X	X		
cuspidata		A					X	X	
Torreya									
nucifera		A				X			
taxifolia	T	A			X	X			
TAXODIACEAE									
Cryptomeria									
japonica		A			X	X	X	X	X
Cunninghamia									
lanceolata		A				X			

			1	2	3	4	5	6	7
Metasequoia									
glyptostroboides		A						X	
Sciadopitys									
verticillata		A						X	X
Sequoia									
sempervirens		A			X				<0.1
Wellingtonia		A			X	X			
Taxodium (- - : <0.1)									
distichum		A		X	X	X	X	X	<0.1
THEACEAE									
Gordonia									
Lasianthus		A		X					
TILIACEAE									
Tilia (- - : 3.9)									
americana	P	N	X	X	X	X	X	X	0.5
cordata	P	A						X	0.4
dasystyla		A					X		
euchlora	P	A						X	<0.1
europaea		A			X	X	X	X	1.1
heterophylla		A	X	X	X			X	
tomentosa		A			X			X	0.8
ULMACEAE									
Celtis (1.2 : 1.8)									
australis		A			X	X			
laevigata		A				X			
occidentalis		N	X	X	X	X	X	X	1.7
Planera									
aquatica		A			X				
Ulmus (1.5 : 10.2)									
alata		A		X					
americana	P	N	X	X	X	X	X	X	5.9
angustifolia		A				X			
carpinifolia	P	A			X	X	X	X	X
glabra	P	A				X	X		<0.1
laevis		A					X		
parvifolia	P	A				X	X	X	0.1
procera		A							2.3
pumila		A			X	X		X	0.6
rubra		N	X	X	X	X	X	X	<0.1
Thomasii		A		X				X	
Zelkova									
serrata	P	A							<0.1
VERBENACEAE									
Vitex									
Agnus-castus		A			X	X			