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A first approximation of the historical and extant vascular flora of New York City: Implications for native plant species conservation[1]

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DeCandido, R. (Department of Biology, The City College of the City University of New York, New York, NY 10031), A. A. Muir (Graduate Group in Ecology, 2148 Wickson Hall, University of California, Davis, CA 95616), and M. B. Gargiullo (City of New York Department of Parks and Recreation, Natural Resources Group, 1234 Fifth Avenue, New York, NY 10029). A first approximation of the historical and extant vascular flora of New York City: Implications for native plant species conservation. J. Torrey Bot. Soc. 131: 243–251. 2004.—This historical and extant vascular flora of greater New York City is a literature review supplemented with field work and examination of herbarium specimens held in New York State. For the historical and modern periods combined, 2177 species in 779 genera and 161 families were found in New York City. The City retains 57.4% of its native plant species diversity with 779 extant native species compared to 1357 ever recorded. Extirpations have disproportionately affected native vs. non-native species. Staten Island (Richmond County) has the greatest diversity of the five boroughs with 154 families and 1633 species known from both the historical and modern time periods combined, as well as the greatest number of extant species (921), and the greatest number of native extant species (621). However it has lost approximately 35% of its native flora in the last 70 years. Brooklyn (Kings County) has the lowest diversity of any borough with 695 native and alien species known from both the historical and modern periods combined. Manhattan (New York County) and Brooklyn have lost more than 75% of their native species. Queens County has lost the greatest number of native species (585). In New York City since the mid-19th century, 46.4% of all native herbaceous species have been extirpated, while 22.9% of native woody plants have been lost. In the last 70 years, extirpations have continued even in natural areas protected in parks. Strategies are recommended for preserving New York City's significant native plant species diversity.

Key words: New York City, native species, historical flora, extant flora, diversity, extirpation.

Urban areas present opportunities to study changes in plant species diversity. There can be a history of species collected at particular sites documented with herbarium specimens, published papers, field trip accounts, personal notebooks, and lists that may extend back to the early 19th century. In New York City, remaining natural areas are easily accessible and can be surveyed frequently, facilitating comparison between time periods. From a broader perspective, the study of urban environments is important because most people in North and South America, Europe, and Australia now live in cities. The urban environment is overlooked by many ecologists, yet encountered by most people on a daily basis (McDonnell and Pickett 1990). By 2025 it is expected that almost two thirds of the world's people will live in urban areas (World Resources Institute 1996). Throughout the world, many conservation areas and nature reserves are becoming isolated habitat fragments as land around them is developed. Understanding the effects of rapid development and urbanization upon plant species diversity will help biologists decide which kinds of species and habitats to watch carefully in the coming years, as development and urban sprawl affects an in-

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[2] A Database of the New York City flora in Microsoft *Excel* format is available from the senior author.

[3] This paper is dedicated to the late Jess Hanks of the City College of New York (CUNY) since he encouraged everyone to take an active interest in the local flora. We also want to thank the Andrew M. Greller, Professor Emeritus of Biology, Queens College (CUNY) for his encouragement and thoughtful suggestions.

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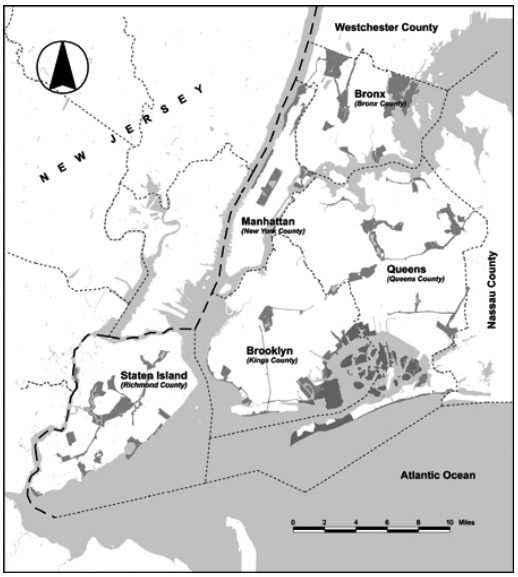

Figure 1. Map of New York City with natural areas indicated in gray.

creasing number of natural areas throughout the world (Thompson 1994).

New York City (40°(47′ N, 73°(58′ W), is located between the Atlantic coast, Long Island Sound and Hudson River estuary in the southern most part of New York State (Figure 1), and encompasses diverse geologic and geographic areas. As a result, numerous ecosystem types and high numbers of native plant species occur in an area that is relatively small compared to the rest of New York State. Overall, 60.3% of the native plant species ever recorded in the state have been collected in New York City.

The formal study of the flora of New York City began with John Torrey and his catalogue of plants found in the vicinity of New York (Torrey 1819). Beginning in the 1880s with the creation of the New York (Bronx) Botanical Garden, a significant effort was made under the aegis of the Torrey Botanical Club to collect plant species from the metropolitan area (Rusby 1906a, 1906b). Early botanists and naturalists who collected plant specimens in New York City and environs included Nathaniel Lord Britton on Staten Island (1875–1930, see Britton 1877, 1880; New York Botanical Garden 2003); William T. Davis on Staten Island (1870–1935, see Davis 1892a, 1892b, 1895, 1902, 1917, 1918); E.P. Bicknell in the Bronx (1875–1901, see Bicknell 1898, Griscom 1926); Harry Ahles in the Bronx (1946–1950, see Ahles 1947, 1948, 1951; Tippo 1982); and Sam Yeaton in Queens (1925–1988, see Yeaton 1988).

Historically many plant species throughout New York City, were found or collected from locales that were not parkland at the time; these areas have since been developed (see Griscom 1926, Sefferien 1932, Kieran 1959). In the Bronx and Manhattan, most of the parks with the largest natural areas were established in the 19th century, while in Brooklyn, Queens and Staten Island, most parks were established in the 20th century (Table 1). Significant portions of many natural areas of parks in the boroughs outside of Manhattan were converted into landfills from the 1930′s through the 1970′s (Caro 1974, Pons 1987). Development, although on a smaller scale, continues to the present. Today, the City of New York Department of Parks and Recreation owns and maintains approximately 11,332.0 hectares of parkland, yet only those parks listed in Table 1 have significant tracts of natural areas. The Federal Government owns approximately 3,645.0 hectares in Brooklyn, Queens and Staten Island as part of the Gateway National Recreation Area. Other agencies own smaller parcels of parkland: the New York State Department of Environmental Conservation owns 177.4 hectares throughout the city and New York State Parks owns 41.0 hectares of natural area on Staten Island. Overall, 17% (14,175.0 hectares) of New York City (83,365.2 hectares) is designated as parkland. However, only about 25% of this parkland (3543.8 hectares) can be considered ''natural area,'' specifically set aside to protect and maintain the flora and fauna found therein.

Materials and Methods. Data used in this research about historical (pre-1980) and/or extant (post 1980) occurrence of a particular species (DeCandido 2001) were compiled primarily from published papers (e.g., Denslow 1924, Graves 1930, Sefferien 1932, Brooks 1960, Kaltman 1971, Greller 1977, Stalter 1981, Profous and Loeb 1984, Greller 1985, Loeb 1986, Rudnicky and McDonnell 1989, Clemants 1990, New York Flora Association 1990, Greller 1991, Yost et al. 1991, Greller et al. 1992, Loeb 1993, Robinson et al. 1994, Clemants 1999). These were supplemented by reports to agencies (Cramer et al. 1984, Natural Resources Group 1988a, b, c, 1990; Venezia and Cook 1991, Andropogon Associates 1994, Anderson 1998, Young and Weldy 2003). We examined museum collections, primarily at NYBG. We also did extensive field work in most natural areas throughout New York

Table 1. New York City parks (>40.0 ha) with significant tracts of natural areas, the year the park was established and literature source(s) for extant plant species occurrence.

Borough	Park	Year	Status	Hectares	Literature Source
Bronx (2763.7)*	Bronx River Park	1888	NYC Dept. of Parks	292.0	Rudnicky and McDonnell (1989)
	Ferry Point Park	1937	NYC Dept. of Parks	167.3	
	Pelham Bay Park	1888	NYC Dept. of Parks	1119.4	DeCandido (2001)
	Van Cortlandt Park	1888	NYC Dept. of Parks	464.1	Natural Resources Group (1990)
N.Y. (1065.2)*	Central Park	1863	NYC Dept. of Parks	341.4	Cramer et al. (1984), Loeb (1993)
	Inwood Hill Park	1916	NYC Dept. of Parks	79.4	Loeb (1986)
	Riverside Park	1872	NYC Dept. of Parks	131.2	
Kings (2263.5)*	Gateway National Rec. Area	1954	National Park Service	474.3	Venezia and Cook (1991)
	Marine Park	1917	NYC Dept. of Parks	323.2	Natural Resources Group (1988c)
	Prospect Park	1866	NYC Dept. of Parks	213.0	Andropogon Associates (1994)
Queens	Alley Pond Park	1935	NYC Dept. of Parks	264.6	Stalter (1981), Natural Resources Group (1988a)
(4759.2)*	Baisley Pond Park	1931	NYC Dept. of Parks	44.6	
	Cunningham Park	1927	NYC Dept. of Parks	145.0	Greller (1977, 1985), Greller et al. (1991)
	Forest Park	1898	NYC Dept. of Parks	217.9	
	Gateway National Rec. Area	1954	National Park Service	1858.1	Venezia and Cook (1991)
	Idlewild Park	1956	NYC Dept. of Parks	91.1	
	Kissena Park	1927	NYC Dept. of Parks	95.1	Natural Resources Group (1988b)
	Rockaway Beach	1938	NYC Dept. of Parks	102.5	
S.I (3323.4)*	Arden Heights Woods	1993	NYC Dept. of Parks	74.1	
	Blue Heron Park	1982	NYC Dept. of Parks	89.9	Bridges (1991)
	Bloomingdale Park	1968	NYC Dept. of Parks	55.9	
	Clay Pit Pond	1974	New York State	101.3	
	Clove Lakes Park	1921	NYC Dept. of Parks	80.2	
	Conference House	1926	NYC Dept. of Parks	107.0	Greller et al. (1992), Anderson (Unpublished)
	Gateway National Rec. Area	1954	National Park Service	492.9	Venezia and Cook (1991)
	Great Kills Park	1964	NYC Dept. of Parks	124.1	
	Greenbelt	1924	NYC Dept. of Parks	1012.5	Robinson et al. (1994)
	Lemon Creek	1964	NYC Dept. of Parks	42.5	
	Mt. Loretto	2000	NYC Dept. Env. Cons.	177.4	
	Mariner's Marsh	1997	NYC Dept. of Parks	43.4	
	Saw Mill Creek Park	1994	NYC Dept. of Parks	45.2	
	Silver Lake	1971	NYC Dept. of Parks	84.8	
	Staten Island Industrial Park	1997	NYC Dept. of Parks	91.5	
	Wolfe's Pond Park	1929	NYC Dept. of Parks	138.1	

* The number of hectares of parkland (exclusive of playgrounds) in the borough.

City from 1985 to the present. In the case of a few extant herbaceous species (less than 50), verbal reports were accepted from reliable field workers (e.g., members of the Natural Resources Group of the New York City Department of Parks).

Clemants (1990) and the New York Flora Association (NYFA 1990) were the key references for the historical occurrence of plant species in New York City. NYFA (1990) provides pre-1980 and post 1980 occurrence for each plant species in New York State by county, if a specimen is held at the New York State Museum for either/both of these time frames. After reviewing Clemants (1990), NYFA (1990) and examining herbarium specimens, we developed a comprehensive plant list of extirpated and extant, native and non-native plant species in New York City. We then compared this list to published floras in each borough (see below), and our own research in New York City to compile the final list used in this research.

For extant plant species in each New York City borough, we consulted Clemants (1990) and for woody species, Clemants (1999). We also checked published floras for parks throughout the city (see Table 1). For the Gateway National Park areas in Queens, Brooklyn and Staten Island the key source was Venezia and Cook (1991). For Staten Island, Robinson et al. (1994) and the database used in that paper (Robinson 1999), were the primary sources of information. For extant plant species occurrence in Queens, we consulted Greller (1977) since he made updates and corrections to the list (Greller, 1985, Greller et al., 1991). For the Bronx, Profous and Loeb (1986), the Natural Resources Group (1990), Yost et al. (1991), and DeCandido (2001) were the primary sources for extant plant species occurrence. We also relied upon our own field work from 1985 to 2003 in natural areas, abandoned lots, etc. in each borough to determine the current status of plants throughout New York City.

Table 1 lists all parks in New York City greater than 40.0 hectares in size that also contain a significant amount of natural area, and the year in which the park was established. Also provided is the source(s) where the most comprehensive data on extant plant species occurrence for the park can be found. For the purposes of this study, a natural area is defined as one that is composed mostly of unmanaged vegetation. Typically, such lands have never been developed, although significant disturbances may have occurred in the past. The vegetation consists of native species typical of the region, often with a large number of non-native species as well. In certain highly disturbed areas, such as abandoned landfills and filled coastal marshes, a natural area may be dominated by non-native species.

There are many natural areas in New York City for which no comprehensive published flora is available (Table 1). These natural areas include parks as well as land owned by the private sector or agencies other than the City of New York Department of Parks and Recreation. Obtaining information for extant occurrence of many herbaceous species was difficult for these natural areas that are primarily concentrated in Brooklyn, Queens and Manhattan. Similarly for plant species that we (and the other sources that were consulted) consider to be extirpated, there exists a degree of uncertainty (see Palmer 1995). A few species that we consider extirpated may be re-discovered, especially on Staten Island where extensive research is now being conducted. However, we believe that the pattern of plant extirpations in New York City we outline in this paper will not change significantly.

For data analysis in this paper, if more than one subspecies or variety of a particular species has been extirpated in New York City, but another variety or subspecies still exists, then that species is considered to be extant. We used chi-square tests with one degree of freedom to compare the proportion extirpated of native herbaceous versus native woody species compared to the proportion (herbaceous vs. woody) still remaining in New York City. We also compare the proportion extirpated of native vs. non-native species ever known from New York City.

All nomenclature follows Mitchell and Tucker (1997) with minor revisions found in Mitchell (2000) including designation as a native, non-native (alien) or introduced species. Alien species are defined here as not native to the northeastern United States, not planted (uncultivated) and reproducing to a significant degree. Introduced species have escaped from cultivation and are not reproducing to any significant degree in New York City. Designation of a species to woody or herbaceous status follows Gleason and Cronquist (1991). Most of the species from the historical period were collected beginning in the 1870s, though some were collected prior to this time. The complete list of species can be found in DeCandido (2001).

Table 2. Plant species diversity of New York City by borough.

	Number of species					Native Species Unique to the Borough	
Borough	Families	Native	Alien	Escaped	Total Spp.	Total	Extirpated
KINGS	109	451	244	48	743	14	11 (78.6%)
NY	127	440	286	69	795	13	13 (100%)
QU	137	940	390	86	1416	57	13 (23%)
BX	146	988	417	106	1511	73	18 (25%)
SI	154	1109	438	86	1633	136	37 (27%)
NYC	161	1357	610	210	2177	x	x

Results. In New York City, the historical and extant flora includes a total of 161 plant families with 779 genera and 2177 native and alien species, collected from the mid-19th century to 2000 (DeCandido 2001). The City retains 57.4% of its native plant species diversity with 779 extant native species compared to 1357 ever recorded or collected (Tables 2 and 3). New York City has also lost 409 (of 820) alien species in this same time period. However, native plant species have been significantly more likely to become extirpated than non-native species ($\chi^2 = 10.9$, $P < 0.05$). Of the 1357 native species known from New York City, 1139 are herbaceous and 218 are woody. New York City has lost 46.4% of its native herbaceous species and 22.9% of its native woody species. Differences between the rate of extirpation between native herbaceous (528 extirpated) and native woody species (50 extirpated) are significant ($\chi^2 = 41.0$, $P < 0.05$).

Seven plant families in New York City with the greatest number of species contain 41.2% of the total known flora of New York City (Table 4). The largest of these families are Asteraceae (226 species, 136 native), Poaceae (199 species, 123 native) and Cyperaceae (184 species, 177 native). Most of the extant diversity of these seven families is due to high numbers of native species, except in Brassicaceae in which 68.0% of the extant species are non-native. Overall 24 (14.9%) of the 161 families ever found in New York City contain only non-native species (DeCandido 2001).

There are 9 families containing only native species that have been extirpated from New York City: Azollaceae, Eriocaulaceae, Isoetaceae, Juncaginaceae, Limnanthaceae, Najadaceae, Ruppiaceae, Selaginellaceae and Zannichelliaceae (DeCandido 2001). These families are all composed of herbaceous species, and all except for species of Limnanthaceae and Selaginellaceae, are aquatic or amphibious species (Gleason and Cronquist 1991, DeCandido 2001).

Native species in nine plant families have been particularly prone to extirpation with an extirpation rate of 50% or more (Table 5). Of these families, all except for one (Ericaceae) are composed exclusively of herbaceous species. Even within Ericaceae, most of the extirpations have been of herbaceous species (7 of 12; DeCandido 2001). Of the 481 herbaceous species in these nine families, 274 species (57.0%) have been extirpated. Of 30 known native species of Orchidaceae that once existed in New York City, 24 (80%) have been extirpated.

By comparison, 15 plant families containing only woody species, such as the Betulaceae, Cornaceae, Fagaceae, Juglandaceae, Salicaceae and Ulmaceae, have lost 10 of 89 species (11.2%). Only one woody family (Aquifoliaceae) has lost at least 50% of its species (three

Table 3. The number of extant and extirpated plant species (excluding planted/escaped species) in New York City.

	No. of Extant Species			No. of Extirpated Species			
Borough	Native	Alien	Total	Native	Alien	Total	Total All
KINGS	107	125	232	344	119	463	695
NY	103	126	229	337	160	497	726
QU	355	259	614	585	131	716	1330
BX	464	316	780	524	101	625	1405
SI	621	300	921	488	138	626	1547
NYC	779	411	1190	578	199	777	1967

Table 4. Plant families with the most number of species in New York City, and the proportion of extirpated species in each.

	Number of Species				
Family	Total	Alien	Alien Extirpated	Native	Native Extirpated
Asteraceae	226	90	27 (30%)	136	28 (20.6%)
Poaceae	199	76	25 (33%)	123	52 (43%)
Cyperaceae	184	7	5 (71%)	177	115 (65%)
Rosaceae	88	25	6 (24%)	53	19 (36%)
Fabaceae	86	44	14 (32%)	42	16 (38%)
Lamiaceae	63	28	18 (64%)	35	14 (40%)
Brassicaceae	50	34	7 (21%)	16	5 (31%)

of six species). Differences between the rate of extirpation for species in the nine herbaceous families (Table 5) versus species in these 15 woody plant families are significant ($\chi^2 = 62.8$, $P < 0.05$).

Staten Island, the least heavily developed borough, has the greatest number of families (154) and largest number of extant species (921) of the five boroughs, including the most native species (621). However, Staten Island has also lost approximately 35% of its native species (334) in the last 70 years (Robinson et al. 1994, Robinson 1999). Of the native plants that were extirpated, 94.6% (316) were herbaceous species. In New York City, Queens has the most extirpated native species (585). Brooklyn has the smallest number of families (109), as well as the lowest number of extant and historical plant species (695). In Brooklyn and Manhattan the number of extant alien species is greater than the number of extant native species. Of the five boroughs, only Staten Island has more native extant species than native extirpated species (Table 3).

Discussion. This study shows both the great diversity of the New York City flora, with 2177 extant and historical species recorded, as well as the great loss of native plant species in the metropolitan area (42.6%; 578 of 1357 native species). New York City has 56.8% of the plant species ever recorded in New York State (2177 of 3835 reported in NYS), and 60.3% of the native species recorded in the state (1357 of 2250). The vast majority of native and alien extant plant species in New York City are herbaceous plants. Of the remaining 1190 extant species in New York City, 65.5% (779) are native. However, in each borough except Staten Island, more native species have been extirpated than can still be found (Table 3). Since 1850 in New York City, native plant species have been significantly more likely to be extirpated than non-native species. Native plants that were extirpated were significantly more likely to be herbaceous rather than woody species. Of the 1357 native species ever recorded in New York City, 134 (9.9%) are currently considered rare, imperiled or critically imperiled in New York State (Young and Weldy 2003).

Other studies in New York City and nearby metropolitan areas have also shown that native herbaceous species are much more likely to be extirpated than native woody species (Robinson et al. 1994, Drayton and Primack 1996, DeCandido Mss). In New York City, most herbaceous species are found in meadows and other open habitats (forest edges, along riparian areas, canopy gaps, etc.). Meadows in New York City parks have declined primarily due to development to ball fields, golf courses, landfills, etc.

Table 5. Plant families with >10 species in New York City having the highest native plant species extirpation rates.

	Number of Species			Number of Species	
Family	Total Native	Ex. Native	Family	Total Native	Ex. Native
Cyperaceae	177	115 (65%)	Ericaceae	28	12 (43%)
Poaceae	123	52 (43%)	Violacaeae	26	15 (58%)
Orchidaceae	30	24 (80%)	Juncaceae	26	13 (50%)
Aspleniaceae	30	17 (57%)	Potamogetonaceae	12	10 (83%)
Scrophulariaceae	29	16 (55%)			

Meadows are also disappearing through the process of natural succession to shrubland and closed canopy forest. The ecology of herbaceous species is also a contributing factor in their overall decline: they often occur in small, discrete patches in specific habitats (Kruckeberg and Rabinowitz 1985) that are vulnerable to a variety of other extirpation factors (e.g., see Greller et al. 1990, DeCandido 2001). Analysis of the habitat requirements of species from herbaceous plant families with high rates of species extirpation in New York City (Table 5) indicates that they were found primarily in meadows (Poaceae) and freshwater/riparian/mesic areas (Cyperaceae, Juncaceae, Potamogetonaceae). Species from families such as Orchidaceae may have been over-collected (see Denslow 1924).

Remnant areas of native plant species diversity are in jeopardy even today. Ongoing threats include highway expansion and infrastructure construction (water treatment facilities, parking lots, buildings, etc). Increased recreational use of parks by people can have a negative impact as well. In New York City, illegal fires, dumping, walking dogs off-leash, dirt bikes and all-terrain vehicles have an adverse impact on many parks, particularly in riparian areas and on steep slopes. Abiotic factors include summer drought, the heat-island effect, and pollution such as high soil levels of lead, nickel and copper, and increasing soil acidity since the 1940s (Bornstein 1968, Volchok 1967, Sharpe 1978, White and McDonnell 1988, Greller et al. 1990). Biotic factors such as succession and competition with aggressive alien plant species have played a role in extirpations as well. Other biological factors include the introduction of non-native earthworms and the high density of small mammals such as squirrels and rats. Disturbance has allowed non-native species to invade (and frequently dominate) large expanses of parklands. Development, natural succession and disturbance have caused a net loss of habitat for many species, primarily native herbaceous ones.

During the coming years, the proportion of non-native species in New York City parks may be predicted to grow as more native species are extirpated. Over the last century this is most evident in Brooklyn and Manhattan where the combined average of native species extirpation is 69.6 %. Even Queens, where most parks were established from the 1920′s to the 1950′s, has lost 62.2% of its native species (Table 3). Staten Island, the borough with the greatest extant native plant species diversity, is also the borough whose remaining natural areas are undergoing the most rapid development (Robinson et al. 1994). Few of the remaining natural areas have been protected in parkland, making herbaceous species in such tracts vulnerable to extirpation (see Drayton and Primack 1996). If trends for the other four boroughs are any indication, then on Staten Island the number of extirpated native species will soon exceed extant native ones. This would mean the loss of at least another 60–70 native species from the borough in the coming years. Staten Island has the greatest number of plant species found only in that borough (99), as well as the most native extant species that have special rarity designations by the New York Natural Heritage Program (97). The loss of remaining natural areas not yet protected in parks on Staten Island will be particularly unfortunate.

Even areas protected as parkland have suffered significant losses of native plant species. This is most evident in Pelham Bay Park in the Bronx, the largest park managed by the City of New York Department of Parks and Recreation. From 1948 to 1998, 142 native species (24.4% of the native species in the park) were extirpated, while 135 alien species invaded the park in the same time period (DeCandido Mss.). Most of these extirpations likely occurred because natural areas in the park were developed with sports fields, a landfill, highway expansion and other construction from approximately 1955–1970. Clearly, the establishment of parks is neither sufficient to insure the preservation of native plant species diversity, nor the invasion of remaining habitats by non-native species. Rather, strategies to protect native plant species and natural areas are required. These include direct intervention through actively protecting and restoring natural areas; managing open areas in parks so that they remain meadows; propagating rare and uncommon native species; and especially, educating the public about the importance of preserving native plant species diversity.

One strategy to reintroduce and maintain the local flora in the urban environment is to use native plants as a key component of any restoration or urban renewal project. New York City has a number of landfills that are being restored, as well as grass strips within parks and highway shoulders that are mowed regularly. If the largest of these could be planted with native herbaceous species as has been done in the Chicago area (see Blumberg 1998), it might be possible to both increase meadow-type habitats and reestablish native species in the wild. Such efforts

will need to be coordinated between members of the Department of Parks and Recreation and the many landscape architects, gardeners and even horticulturists employed by the City of New York in the Housing Department and the Department of Highways.

The rapid loss of native plant species diversity throughout New York City is cause for alarm. Although scientists tend to interpret plant species diversity and species extirpations in terms of biological processes, the future of native species in New York City depends on seeing the issue from a different perspective. The critical factor in preserving plant species diversity will be developing public support for natural areas in parks. More effort needs to be directed at explaining why preserving native plant species diversity is important (Tilman, 2000). Increased security presence such as trained enforcement/educators (e.g., Urban Park Rangers) is needed in park areas that receive high volume recreational use. Finally, a simultaneous commitment is needed from those in decision-making capacities in government to value natural areas as much as ball fields, buildings and other ''developed'' areas in parks.

Literature Cited

AHLES, H.E. 1947. Letter to Dr. H. D. House at the New York State Museum. 19 March 1947. New York State Museum at Albany. Albany, NY. Unpublished.

AHLES, H.E. 1948. Letter to Dr. H.D. House at the New York State Museum. 18 March 1948. New York State Museum. Albany, NY. Unpublished.

AHLES, H.E. 1951. Interesting weeds in New York City. Bull. Torrey Bot. Club 78: 273–274.

ANDERSON, K. 1998. Plants of Conference House Park, Staten Island, NY. Unpublished.

ANDROPOGON ASSOCIATES. 1994. A landscape management plan for the natural areas of Prospect Park The Prospect Park Landscape Management Office, Brooklyn, NY. 237 pp.

BICKNELL, E.P. 1898. Two new grasses from Van Cortlandt Park, New York City (*Savastana nashii, Chaetocloa versicolor*). Bull. Torrey Bot. Club 25: 104–107.

BLUMBERG, A. 1998. Born to burn. Chicago Wilderness. Summer 1998: 4–9.

BORNSTEIN, R.D. 1968. Observations of the urban heat island effect in New York City. J. Appl. Meteorol. 7: 575–582.

BRITTON, N. L. 1877. Staten Island plants. Bull. Torrey Bot. Club 6: 177–179.

BRITTON, N. L. 1880. On the northward extension of the pine barren flora on Long Island and Staten Islands. Bull. Torrey Bot. Club 7: 81–83.

BROOKS, K. L. 1960. Field Trip Report: August 30, 1959. Marine Park, Brooklyn. Bull. Torrey Bot. Club 87: 62–64.

CARO, R. A. 1974. The power broker. Robert Moses and the fall of New York. Alfred A. Knopf, NY. 1246 p.

CLEMANTS, S. E. 1990. New York metropolitan flora. New York City checklist. The Brooklyn Botanic Garden. Brooklyn, NY. 44 p.

CLEMANTS, S. E. (Ed.). 1999. Woody Plant workbook. Brooklyn Botanic Garden. Brooklyn, NY. 307 p.

CRAMER, M., J. HEINTZ, AND B. KELLY. 1984. Vegetation in Central Park. Central Park Conservancy. NY. Unpublished report.

DAVIS, W. T. 1892a. Interesting oaks recently discovered on Staten Island. Bull. Torrey Bot. Club 19: 301–303.

DAVIS, W. T. 1892b. Days Afield on Staten Island. *In* 1992 Commemorative reprint, 1937 second edition. Staten Island Institute of Arts and Sciences. Staten Island, NY. 122 p.

DAVIS, W. T. 1895. A zone of vegetation on the perpendicular bluff at St. George. Proceedings of the Natural Science Association of Staten Island 4: 83.

DAVIS, W. T. 1902. Local notes on vanishing wildflowers. Proceedings of the Natural Science Association of Staten Island 8: 29.

DAVIS, W. T. 1917. *Juniperus communis* on Long Island and Staten Island. Torreya 17: 99–100.

DAVIS, W. T. 1918. The cold winter and its effects upon vegetation on Staten Island, New York. Proceedings of the Staten Island Institute of Arts and Sciences 1: 49.

DECANDIDO, R. 2001. Recent Changes in plant species diversity in Pelham Bay Park, Bronx County, New York City, 1947–1998. PhD thesis. The City University of New York, NY. 316 p.

DECANDIDO, R. 2005. Recent changes in plant species diversity in urban Pelham Bay Park. Biol. Conserv. 120: 129–136.

DENSLOW, H. M. 1924. Native orchids of Manhattan Island. Journal of the New York Botanical Garden 25: 290–293.

DRAYTON, B. AND R. B. PRIMACK. 1996. Plant species lost in an isolated conservation area in metropolitan Boston from 1894 to 1993. Conserv. Biol. 10: 30–39.

GLEASON, H. A. AND A. CRONQUIST. 1991. Manual of vascular plants of northeastern United States and Adjacent Canada, 2nd edition. The New York Botanical Garden, New York, NY. 910 p.

GRAVES, A. H. 1930. Inwood Park, Manhattan. Torreya 30: 117–129.

GRELLER, A. M. 1977. A vascular flora of the forested portion of Cunningham Park, Queens County, New York, with notes on the vegetation. Bull. Torrey Bot. Club 104: 170–176.

GRELLER, A. M. 1985. A vascular flora of the forested portion of Cunningham Park, Queens County, New York: Corrections and additions—II. Bull. Torrey Bot. Club 112: 312.

GRELLER, A.M., D.C. LOCKE, V. KILANOWSKI, AND G. E. LOTOWCYZ. 1990. Changes in vegetation composition and soil acidity between 1922 and 1985 at a site on the North Shore of Long Island, New York. Bull. Torrey Bot. Club 117: 450–458.

GRELLER, A. M., M. K. PANUCCIO, AND C. M. DURANDO. 1991. A vascular flora of the forested portion of Cunningham Park, Queens County, New York:

Corrections and Additions—III. Bull. Torrey Bot. Club 118: 330–332.

GRELLER, A. M., R. BUEGLER, E. JOHNSON, R. MATARAZZO, AND K. ANDERSON. 1992. Two unusual plant communities in Tottenville, Staten Island, New York, with *Celtis occidentalis* and *Asimina triloba*. Bull. Torrey Bot. Club 119: 446–457.

GRISCOM, L. 1926. The observations of the late Eugene P. Bicknell at Riverdale, New York City, fifty years ago. Abstract of the Proceedings of the Linnaean Society of New York 1925–26 for the two years ending March 23, 1926. Numbers 37–38.

KALTMAN, H. 1971. Field Trip Report. 16 June 1971. Pelham Bay Park, Bronx, New York. Bull. Torrey Bot. Club 98: 282.

KIERAN, J. F. 1959. Natural history of New York City. Houghton Mifflin Company. Boston, MA. 428 p.

LOEB, R. E. 1986. Plant communities of Inwood Hill Park, New York County, New York. Bull. Torrey Bot. Club 109: 46–52.

LOEB, R. E. 1993. Long term arboreal change in a landscaped urban park: Central Park, New York. J. Arboriculture 19: 238–248.

MCDONNELL, M. J. AND S. T. A. PICKETT. 1990. Ecosystem structure and function along urban-rural gradients: an unexploited opportunity for ecology. Ecology 71: 1232–1237.

MITCHELL, R. S. AND G. C. TUCKER. 1997. Revised checklist of New York State Plants. Bull. No. 490. New York State Museum. Albany, NY. 400 p.

MITCHELL, R. S. 2000. Database and revised checklist of New York State plants. Part 1. A database of New York state plants. In *Microsoft Access*. 3779 entries. CD-ROM format. New York State Museum. Albany, NY.

NATURAL RESOURCES GROUP. 1988a. Natural areas management plan: Alley Pond Park, Queens. City of New York Parks & Recreation, New York. Unpublished.

NATURAL RESOURCES GROUP. 1988b. Natural areas management plan: Kissena Park, Queens. City of New York Parks & Recreation, New York, NY. Unpublished.

NATURAL RESOURCES GROUP. 1988c. Natural areas management plan: Marine Park, Brooklyn. City of New York Parks & Recreation, New York, NY. Unpublished.

NATURAL RESOURCES GROUP. 1990. Natural areas management plan: Van Cortlandt Park, Bronx. Natural Resources Group, City of New York Parks & Recreation. Unpublished.

NEW YORK BOTANICAL GARDEN. 2003. Records of the herbarium (RG4): Nathaniel Lord Britton (1875–1934). New York Botanical Garden, Bronx, NY. http://www.nybg.org/bsci/libr/Britwb2.htm

NEW YORK FLORA ASSOCIATION. 1990. Preliminary vouchered atlas of the New York State Flora. New York Flora Association of the New York State Museum Institute. Albany, NY. (Xerographic) 498 p.

PALMER, M. W. 1995. How should one count species? Natural Areas Journal 15: 124–135.

PONS, L. 1987. Pelham Bay Park: Creating the Sanctuaries. Pelham Bay and Van Cortlandt Park Administrator's Office, City of New York Department of Parks and Recreation. 24 p.

PROFOUS, G. V. AND LOEB, R. E. 1984. Vegetation and plant communities of Van Cortlandt Park, Bronx, New York. Bull. Torrey Bot. Club 111: 80–89.

ROBINSON, G. R. 1999. Updated database of the Staten Island Flora, 1979–1991. Microsoft Excel format. Unpublished.

ROBINSON, G. R., M. E. YURLINA, AND S. N. HANDEL. 1994. A century of change in the Staten Island flora: ecological correlates of species losses and invasions. Bull. Torrey Bot. Club 12: 119–129.

RUDNICKY, J. L. AND M. J. MCDONNELL. 1989. Forty-eight years of canopy change in a hardwood-hemlock forest in New York City. Bull. Torrey Bot. Club 116: 52–64.

RUSBY, H. H. 1906a. A historical sketch of the development of botany in New York City. Torreya 6: 101–111.

RUSBY, H. H. 1906b. A historical sketch of the development of botany in New York City. Torreya 6: 133–145.

SEFFERIEN, M. L. 1932. Wild flowers of the Spuyten-Duyvil and Riverdale sections of New York City. Torreya 32: 119–127.

SHARPE, W.P. 1978. Symposium on environmental effects of sulfur oxides and related oxides and related particulates, New York City, U.S.A., March 23–24. Bulletin New York Academy of Medicine 54: 983–127.

STALTER, R. 1981. A thirty-nine year history of the arborescent vegetation of Alley Pond Park, Queens County, New York. Bull. Torrey Bot. Club 108: 485–487.

THOMPSON, K. 1994. Predicting the fate of temperate species in response to human disturbance and global change. p. 61–76. *In* T.J.B. Boyle and C.E.B. Boyle [eds.], Biodiversity, Temperate Ecosystems and Global Change. Springer-Verlag, Berlin.

TILMAN, D. 2000. Causes, consequences, and ethics of biodiversity. Nature 405: 208–211.

TIPPO, O. 1982. Harry E. Ahles, 1924–1981. Bull. Torrey Bot. Club 109: 84–86.

TORREY, J. 1819. Catalogue of plants growing spontaneously within 30 miles of New York City. Lyceum of Nature Museum of New York, Webster and Skinner, Albany, NY.

VENEZIA, K. AND R. P. COOK. 1991. Flora of Gateway National Recreation Area. United States Department of the Interior, National Park Service, Gateway National Recreation Area, Division of Natural Resources and Compliance. 40 p.

VOLCHOK, H.L. 1967. Sr-90 deposition in New York City. Science 156: 1487–1489.

WHITE, C. S., AND M. J. M MCDONNELL. 1988. Nitrogen cycling processes and soil characteristics in an urban environment. Journal of Biogeochemistry 5, 243–262.

WORLD RESOURCES INSTITUTE. 1996. World Resources 1996–97: The Urban Environment. Oxford University Press, New York, NY.

YEATON, S. 1988. Early Northeastern Queens. *In* H. H. Roth [ed.], Queens County Bird Club, News & Notes. 1990–1991. Queens County Bird Club. Queens, NY.

YOST, S. B., S. D. ANTENEN, AND G. M. HARTVIGSEN. 1991. The vascular flora of the natural area of Wave Hill. Bull. Torrey Bot. Club 118: 317–325.

YOUNG, S. M AND T.W. WELDY. May 2003. New York Rare Plant Status List. New York Natural Heritage Program. Albany, NY. 82 pp.