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Recent changes in plant species diversity in urban Pelham Bay Park, 1947–1998

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Abstract

Anthropogenic activity and natural successional processes negatively affected native plant species diversity in Pelham Bay Park, New York City. From 1947 to 1994, 25.5% of the native species were extirpated from this urban park, a rate of 2.9 species lost per year. Native species of the flora declined from 71.7% in 1947 to 59.6% in 1994–98. Native herbaceous species were significantly more likely to be extirpated than native woody species. Native species of meadow-type habitats were significantly more likely to be extirpated than species found in woodlands. By comparison, the number of non-native species found increased by 39.7% since 1947. Each of the different habitats in the park had a greater proportion of alien species in 1994–1998 than in 1946–1947. The key element in creating support for preserving the extant biodiversity of Pelham Bay Park is conservation education that stresses the importance of the city's biological heritage.

Keywords: Flora; Urban; Extirpation; Change; Diversity; New York City

1. Introduction

Since 1920, substantial changes have been made to the landscape of New York City. Development has affected both privately owned and publicly held land such as parks, whose natural areas have often been fragmented by highways or otherwise greatly disturbed (Kieran, 1959; Loeb, 1989). This development has been larger in scale and different in nature than anthropogenic changes made to the landscape prior to the 20th century. As a result, the flora of New York City has been significantly affected as the number of native species declined from the 1357 once found in the city to the 774 species extant today, a net loss of approximately 43% of the native flora (DeCandido et al., 2004a).

At approximately 1093.5 ha, Pelham Bay Park (PBPK) is the second largest park in New York City, and the largest tract of land under the jurisdiction of the City of New York Department of Parks and Recreation (Fig. 1). The land for the park was originally set aside in 1884 during the New Parks Movement and received official status as a park in 1888 (Schnitz and Loeb, 1984). According to an analysis of changes in vegetation cover types of PBPK from 1885 to 1984, the amount of land classified as meadow declined by 85% from 172.3 ha to 26.0 ha. During this same one hundred year interval, forest cover increased by 173% from 133.1 to 309.2 ha (Sisinni and Ohea-Anderson, 1993). Currently it is estimated that of the 67% of the park is natural area: 28% is mixed deciduous woods, 22% marine, 7% salt marsh, 5% salt flats, 3% meadows, and 2% shrub or scrub land. The remainder (33%) is classified as developed including golf courses, parking lots, buildings, a Police Department pistol range and the man-made Orchard Beach (Wells, 1998).

In the 1940s, PBPK served as a plant collecting area for Harry E. Ahles (1924–1981), who would later assist in compiling several floras in eastern North America (see Radford et al., 1964). During his two years of field work in PBPK in 1946–1947, Ahles collected 1531 specimens and later donated them to the herbarium at the New York State Museum in Albany (Ahles, 1947, 1948).

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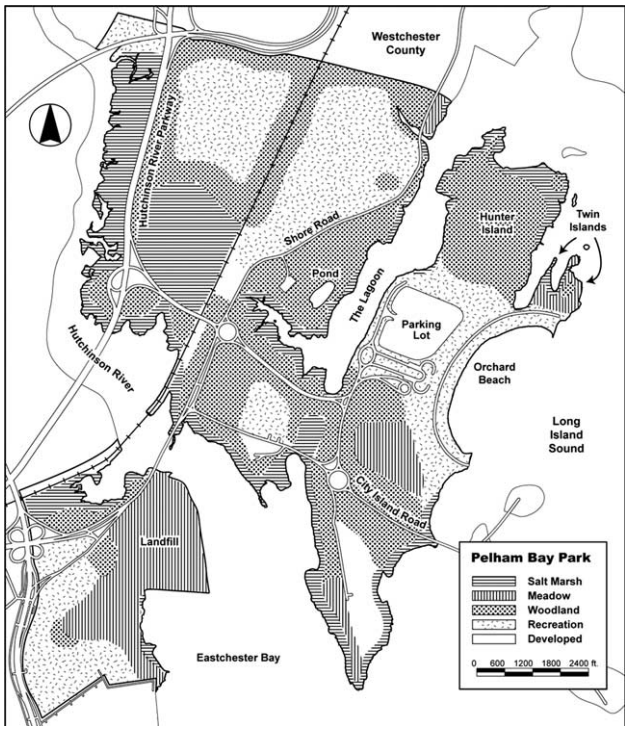

Fig. 1. Habitat map of Pelham Bay Park, Bronx Co., NY 1994–1998.

Ahles left New York by the early 1950s, publishing only one short paper on the Bronx and New York City (Ahles, 1951; Tippo, 1982).

The present study was undertaken to assess recent changes in the flora of PBPK by comparing the unpublished Ahles flora to one compiled by the author from 1994–1998. PBPK provided an ideal opportunity to assess the effects of increasing urbanization upon a large natural area that was accessible on a regular basis in all seasons. Specific research questions included: Have native species been more likely to be extirpated than non-native (alien) species? Were certain types of native plants (woody or herbaceous, annual or perennial), and certain families of plants, more vulnerable to extirpation than others? Were certain habitats such as meadows and other open areas significantly more likely to lose native species than woodland habitats? What were the likely causes of the changes in plant species diversity, and what can be learned from them?

From a broader perspective, PBPK presented an opportunity to study a type of ecosystem that is increasing in the world. Currently, most people in North America, South America, Australia and Europe live in a city; this will also be true of Africa and Asia within the next quarter century (World Resources Institute, 1996). By studying an urban ecosystem, it was possible to examine the habitat that most Americans encounter on a regular basis, as well as assess the effects of human activities upon that landscape (McDonnell and Pickett, 1990). Many conservation areas, nature reserves, and other protected areas are becoming isolated habitat fragments as land around them is developed. Understanding the effects of rapid development and urbanization upon plant species diversity in a fragmented urban park will help biologists decide which kinds of species and habitats to watch carefully in the coming years, as development and urban sprawl affects natural areas throughout the world (Thompson, 1994).

2. Materials and methods

A recensus of the flora of Pelham Bay Park, Bronx County, New York (40°52′30″N, 73°47′30″W) was undertaken from 1994–1998 and compared to an unpublished flora of the park compiled by Ahles in 1946–1947 (Ahles, 1947, 1948). For the modern flora, Pelham Bay Park (PBPK) was sampled at minimum two times per week, from April to August, and at least once per week in February and March, as well as September and October, from 1994 to 1998 (inclusive). In all, a minimum total of 200 field days over five years were spent searching for plants in PBPK. The park was walked on average for five hours at each visit, in such a way that all areas of the park were sampled at least every other week. Herbarium voucher specimens of each taxon with collection notes were prepared and sent to the New York State Museum in Albany. One voucher specimen collected in 1991, *Hibiscus laevis* (formerly *Hibiscus militaris*), was deposited in the herbarium at the New York Botanical Garden (DeCandido, 1991). Nomenclature follows Mitchell and Tucker (1997) and Mitchell (2000).

For the 1946–1947 flora compiled by Ahles, his notes and herbarium specimens held at the New York State Museum in Albany were examined and analyzed. Ahles spent a total of at least 33 days during 1946, from 10 March to 6 October, making these collections (Ahles, 1947). In 1947, Ahles did not record the specific date a specimen was collected, so it is unknown how many days he spent collecting plants at PBPK that year (Ahles, 1948). After examining these specimens and collection notes, a flora was compiled listing the section of the park (from 1 to 29) in which Ahles collected each of his 1531 specimens (DeCandido, 2001). The identification that Ahles made for each specimen collected has been retained for this analysis. In one instance a paper by Lamont (1994) was consulted for information regarding a species collected by Ahles in 1946. If the nomenclature by which a species was known and listed by Ahles in 1946–1947 had been changed, the appropriate updates were made to those used by Mitchell and Tucker (1997) and Mitchell (2000). For the statistical analysis, native species found in 1994–1998 and not collected by Ahles in 1946–1947 have been listed as present in the earlier flora of PBPK, since many of these were overlooked by Ahles at that time. However for Table 1, numbers of species

Table 1
The number of vascular plant species of the 1946–1947, Ahles' flora compared to the 1994–1998 flora of Pelham Bay Park, Bronx Co., NY

	Native	Non-native	Var./ssp.	Planted	Total	No. of extirpated species
Ahles 1946–1947	474	187	7	3	671	140 native/25 alien = 165
1994–1998	439	298	13	49	789	5 native/16 alien = 21
Total no. of species	569	321	13	52	955	145 native/41 alien = 186
Ahles unique spp.	140	25	1		166	Not applicable
1994–98 unique spp.	101	136	6		243	Not applicable
Shared species	328	160	6		494	Not applicable
Total	569	321	13		903	Not applicable

represent actual totals compiled by Ahles in 1946–1947 and the author in 1994–1998.

For the database, plant species were listed as native, non-native or rare escape (and not reproducing to any significant degree). In addition, the status of each native and non-native species was evaluated during the 1994–1998 re-census. Ahles did not indicate or evaluate the status of plants in his 1947–1948 notes. A rare species in 1994–1998 was defined as follows: If an herbaceous species then it must only have been present at three different sites or fewer, with no more than 25 individuals present at any one site; or, present at one site with no more than 50 total individuals. If a tree or shrub, it must only have been present at six or fewer locations, with no site having more than five individuals; or present at one site with no more than 10 individuals.

All taxa were classified as woody or herbaceous, and as perennial or annual/bienniel based upon information in Gleason and Cronquist (1991). In addition, the dispersal modes of plants were given a separate classification (spores, fruits) when such information could be determined. Each species was assigned to one of seven habitat categories: (1) marine (salt marsh, beach, gravelly shore) (2) freshwater marsh, (3) dry forest (upland wooded areas), (4) wet forest (lowland wooded areas), (5) dry meadow, (6) wet meadow (including riparian areas along streams), and (7) wasteland (including landfill, roadsides, and recently disturbed areas). Categories for species recorded in 1994–1998 were determined by field observation regarding where a plant was found growing. For species that have been extirpated since the Ahles flora of 1946–1947, his field notes were used to determine the habitat of the species in question. Ahles had divided the park's habitats (salt marsh, meadow, upland woods, etc.) into 29 sections of varying sizes delineated via natural and/or man-made features such as water bodies, roads, railway lines and recreation areas (see Ahles, 1947 for his map of PBPK). Particular attention was directed at re-locating species believed to have become extirpated since 1948 and/or New York State rare species.

If questions arose, habitat information published in books (e.g., Gleason and Cronquist, 1991; Newcomb, 1977) was consulted. Each species was assigned to only one habitat type. For the database, even though some species may be found in more than one habitat, only the one most typical for that species was selected. For the purposes of the statistical analyses, there are 13 species on the database that have more than one variety or subspecies. Each of these varieties and subspecies was treated as a full species.

The Ahles' flora of 1946–1947 was compared to the 1994–1998 flora with respect to the number of species lost or retained. χ^2 tests were employed with one degree of freedom. It was hypothesized that the rate of extirpation for native species would be significantly greater than the rate of extirpation for non-native species. Similarly, a comparison was also made between the rate of extirpation for all species and the rate for species that utilize fleshy-fruit to disperse seeds. In previous research, Robinson and Handel (1993) had suggested that dispersal by birds of fleshy-fruited species such as members of the Rosaceae had made these species less prone to extirpation. Also tested was whether non-native wasteland species known from 1946 to 1947 were more persistent in the flora compared to all other species known from that time.

Next, characteristics of both native and non-native species (woody or herbaceous, perennial or annual/biennial) that appeared only on the Ahles' flora but not seen subsequently were compared to the entire flora. The percentage of all woody species extirpated from the Ahles' flora was compared to the extirpation rate for all herbaceous species. The rate of extirpation for non-native herbaceous species was tested against the rate for native herbaceous species. By performing these analyses it was thought possible to determine if large-scale changes to the park as a whole were equally eliminating both native and non-native herbaceous species, or if native species (especially herbaceous ones) were significantly more vulnerable to extirpation. It was hypothesized that herbaceous species would be more vulnerable to a variety of disturbances and have a significantly higher rate of extirpation. Also, the percentage of native and non-native herbaceous perennial species extirpated from the 1946–1947 flora was compared to the percentage of extirpated herbaceous annuals and biennials. It was hypothesized that longer-lived herbaceous species might be more vulnerable to extirpation than shorter-lived ephemerals. In order to have a better understanding of the declines in native species over the last 50

years at Pelham Bay Park, non-native species were excluded from the following analyses, because they may not be representative of the ecological characteristics of natives: the rate of extirpation of native woody species was compared to the rate for native herbaceous species. Native woody species were further separated into trees, shrubs and woody vines, and the percentage of extirpation for each of these was compared to the percentage of extirpation of native herbaceous species.

In order to evaluate whether certain habitats were more likely to lose native species, the rate of extirpation for all natives preferring dry habitats (upland forest and dry meadow) versus those found in wet habitats (rich forest, wet meadow, freshwater marsh and marine) was evaluated. Native species of wasteland habitats were excluded from this analysis. Finally, the rate of extirpation of only the herbaceous species from dry habitats (upland forest, dry meadow) was compared to the rate for herbaceous species from wet habitats (rich forest, wet meadow, freshwater marsh and marine).

3. Results

There have been 942 species (with an additional 12 varieties and one subspecies) collected in Pelham Bay Park when the Ahles' flora of 1946–1947 and the 1994–1998 flora are combined (Table 1). These included native plant species (569), non-native (alien) species that have been established and reproducing in the park (321), and species that have escaped from cultivation but were not reproducing to any great degree (52). If only native and established alien species are considered, then 890 species have been identified in the park. PBPK has lost 19.5% of its flora in the last 50 years. At the species level, 25.5% of the native plants (145 of 569) have been extirpated in the intervening 50 years, while only 12.8% of non-native species (41 of 321) have been eliminated during this same time (Table 1). The proportion of native species in the flora has declined from 71.7% in 1946–1947 to 59.6% in 1994–1998, as the absolute number of native species has declined from the 474 collected by Ahles to the 439 found in 1994–1998 (Table 1). In all, 101 native species and/or subspecies and varieties were discovered in this survey. These have not been classified as new arrivals to the park, since the majority were probably overlooked by Ahles in his study. At higher taxonomic levels, 22 native genera (of 253 total genera) were extirpated from PBPK. Six families (of 106) composed entirely of native herbaceous species (Callitrichaceae, Gentianaceae, Hydrophyllaceae, Ophioglossaceae, Santalaceae, and Selaginellaceae) were extirpated from PBPK from 1947 to 1994. No families or genera composed entirely of non-native species were extirpated from the park.

Over the 50 years encompassed by this study, native species have been lost at the rate of 2.9 species per year (0.36% per year). During this same time, non-native species have established themselves in PBPK at the rate of 2.7 species per year, as the absolute number of non-natives has increased from 187 on the Ahles' flora to the 298 species collected in 1994–1998. This is an increase of 39.7% in 50 years. Each of the seven habitats at PBPK has a greater proportion of non-native species now than in 1946–1947 (Fig. 2).

Of the 140 native plant species collected in 1946–1947, and since extirpated from Pelham Bay Park, 96

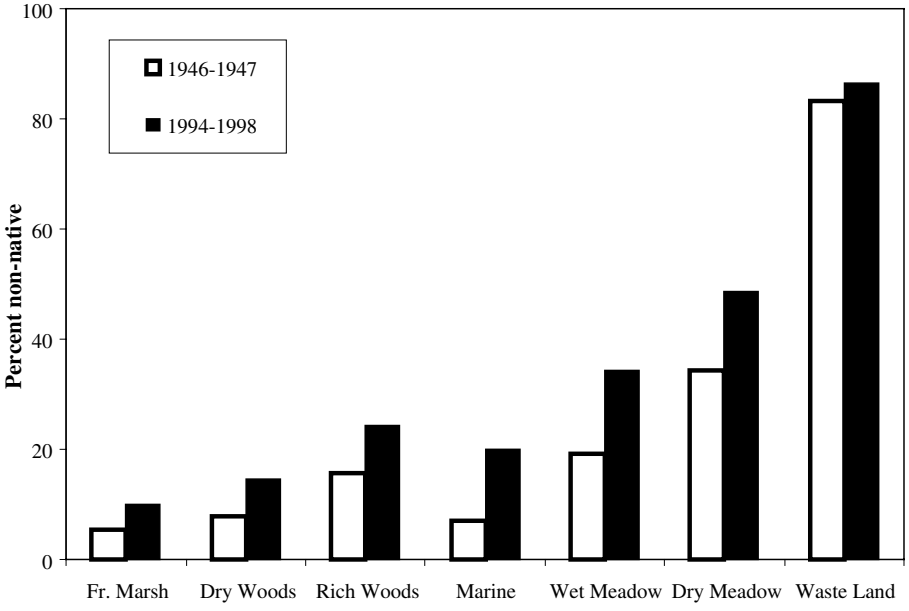

Fig. 2. Percent of non-native species by habitat at Pelham Bay Park, Bronx Co., NY in 1946–1947 and 1994–1998.

(68.6%) were collected by Ahles in only one section of the park. It is estimated that 61 (43.6%) became extirpated when the meadow or other open area of the section in which they were collected succeeded to shrubland or forest. An additional 21 native meadow species (15.0%) of these 140 native extirpated species were lost when the only section of the park where they were originally collected was eliminated by construction projects. Another 58 (41.4%) became extirpated for unknown reason(s). By comparison, from 1994 to 1998, a total of 21 plant species became extirpated (5 native; 16 non-native) from PBPK. Each was an herbaceous species. The five extirpated native species had been reduced to small populations of less than three individuals when initially discovered. It was difficult to determine whether proximate or long-term factors were the decisive causes of particular native plant species extirpations. Overall, 100 of 439 (22.8%) native species collected from 1994 to 1998 were considered rare or uncommon at PBPK.

At PBPK, certain plant families had a higher rate of native species extirpation than the extirpation rate for native species in the entire park. Native plant families with rates of native species' extirpation equal to or exceeding 25% include: Cistaceae (4 native spp; 2 extirpated); Cyperaceae (55 native spp; 27 extirpated); Fabaceae (18; 5 ex.); Juncaceae (9; 4 ex.); Orchidaceae (3; 2 ex.); Poaceae (59; 16 ex.); Polygalaceae (3; 2 ex.); Saxafragaceae (3; 2 ex.); Scrophulariaceae (16; 5 ex.); Violaceae (8; 6 ex.). All of the native species extirpated from these 10 families were herbaceous species. However, native species in other plant families were less prone to extirpation. There were 12 families that did not have a single native species extirpated from PBPK in the last 50 years. These are Araceae (3 native spp.); Asclepiadaceae (5 native spp.); Betulaceae (7); Brassicaceae (9); Caprifoliaceae (9); Cornaceae (5); Fagaceae (10); Juglandaceae (6); Osmundaceae (3); Salicaceae (5); Smilacaceae (3); Ulmaceae (3). Six of these families are composed entirely of woody species in the park. Overall, only eight native woody species were extirpated from PBPK in the last 50 years.

Results of the χ^2 tests show that native species were significantly more likely to be extirpated than non-native species ($\chi^2 = 20.1$, $p < 0.05$). Similarly, native herbaceous species were significantly more likely to be extirpated than non-native herbaceous species ($\chi^2 = 14.7$, $p < 0.05$). There was no significant difference in the rate of extirpation of species with fleshy-fruits compared to the rate of extirpation for all species ($\chi^2 = 0.002$, $p < 0.05$). There was no significant difference between the number of species extirpated from wasteland habitats and the total number of species extirpated from the entire park ($\chi^2 = 0.01$, $p < 0.05$). Overall, herbaceous species were significantly more likely to be extirpated than woody species ($\chi^2 = 16.6$, $p < 0.05$). There was a significant difference between the rate of extirpation for native herbaceous species and the rates for each of the following native woody groups: shrubs ($\chi^2 = 14.1$, $p < 0.05$), lianas ($\chi^2 = 7.7$, $p < 0.05$) and trees ($\chi^2 = 11.9$, $p < 0.05$). There was no significant difference between the rate of extirpation of native perennial species vs. native annual/biennial species ($\chi^2 = 0.6$, $p < 0.05$). There was no significant difference in the rate of extirpation for native species of wet habitats vs. native species of dry habitats ($\chi^2 = 0.001$, $p < 0.05$). There was also no significant difference in the rate of extirpation between native herbaceous species of wet habitats and native herbaceous species of dry habitats ($\chi^2 = 0.02$, $p < 0.05$). However, native species from open areas (freshwater marsh, wet meadow, dry meadow and marine) were significantly more likely to become extirpated than native species from woodlands ($\chi^2 = 6.3$, $p < 0.05$).

Of the 955 species on the database for PBPK, there were 31 native plant species once collected or still present at Pelham Bay Park that received special designation by the Natural Heritage Program as being critically imperiled (S1) or imperiled (S2) in New York State (Young and Weldy, 2003). The majority (27 of 31) were herbaceous species. Of these, 13 species (all herbaceous) have been extirpated from PBPK since 1947. These were *Crotalaria sagittalis*, *Desmodium humifusum*, *Panicum scabriusculum*, *Plantago maritima* ssp. *juncoides*, *Polygonum erectum*, *Salicornia bigelovii*, *Solidago sempervirens* var. *mexicana*, *Spiranthes vernalis*, as well as five species of sedges/rushes: *Carex buxbaumii*, *C. polymorpha*, *Cyperus lupulinus* ssp. *lupulinus*, *Eleocharis halophila* and *Juncus scirpoides*.

On the other hand, five pernicious non-native species that are now found at PBPK were unknown to Ahles in 1946–1947. These were: *Ampelopsis brevipedunculata* var. *brevipedunculata*, *Celastrus orbiculata*, *Polygonum cuspidatum*, *Rhamnus frangula*, and *Viburnum sieboldii*. Each of these is listed by The Nature Conservancy as being among the most serious invading species in New York State (New York State Ad Hoc Invasive Plant Group, 1998). Four of these five invasives are shrubs or woody vines, while one, *P. cuspidatum*, is a stout, perennial herb (Gleason and Cronquist, 1991).

4. Discussion

From 1947 to 1998, the plant species composition of Pelham Bay Park (PBPK), Bronx County, New York City significantly changed. Analysis of plant collections made by Ahles in 1946–1947 showed that both woodland species and herbaceous meadow plants typical of the region were present. By 1994, many of the native herbaceous species once found in the park had been eliminated. Also, non-native species invaded each of the habitat types to a greater degree than before (Fig. 2).

During the last 50 years, native species were lost at the rate of 2.9 species per year (Table 1). Most of the native extirpated species (63.5%) were lost from open habitats such as meadows and marshes, while 36.5% were lost from woodlands. Since 1948, of the 145 native plants extirpated from PBPK, 94.5% (137) were herbaceous species. Some of the native extirpated herbaceous species found in 1946–1947, but not in 1994–1998, were widely distributed and had been collected by Ahles in more than one section of the park. At higher taxonomic levels, six families and 22 genera composed exclusively of native species were extirpated from PBPK during this time. The loss of native species was expected to continue since there were an additional 100 native species classified as being rare in PBPK during the 1994–1998 survey (DeCandido and Lamont, 2004b). Most of these extant rare plants (71%) were herbaceous species that existed in discrete patches in a single type of habitat. These were vulnerable to a variety of factors including disturbance, abiotic events (drought), natural biological processes (succession) and stochastic events.

By comparison in the last 50 years, alien species have been much less prone to extirpation in PBPK. In all, 41 non-native species have been lost, a rate of 0.82 alien species lost per year. Differences in the rate of extirpation between alien and native species are statistically significant. This disparity in the rate of extirpation between alien and native species has probably occurred because non-native species are widespread in distribution, are often favored by disturbance events and able to expand their populations relatively quickly (Goodwin et al., 1999; Hobbs and Huenneke, 1992).

In recent studies of changes in plant species diversity in areas where population and/or human activity have increased, (see Drayton and Primack, 1996; Robinson et al., 1994; Thompson and Jones, 1999), native plant species declined while alien species increased. Land-use change by people has been identified as the primary global threat to biodiversity in this century (Chapin et al., 2000). In this study, herbaceous plants, especially native herbaceous species, were significantly more likely to be extirpated than woody shrubs, vines or trees. Plant families that were either eliminated from the park or that had the highest rates of native plant species extirpations were composed primarily of herbaceous species. Similarly, in their study of the ecological characteristics of plant species extirpated from the borough of Staten Island in New York City, Robinson et al. (1994) were able to identify only one life history trait correlated with a high risk of extirpation: herbaceousness. Herbaceous plants are more vulnerable to extirpation because many exist in small (frequently discrete) populations, and require particular soil pH and moisture conditions (Kruckeberg and Rabinowitz, 1985).

That a number of native species were lost from all habitats, and several native plant species eliminated from more than one section of the park points to large-scale events affecting the park. These include man-made changes to PBPK from 1948 to 1994 such as construction of roads and the placement of a landfill in the park. The most important biological process that has led to a decline in native species is natural succession of open fields to shrubland, and the closure of the forest canopy in some areas. Plant extirpations have probably also occurred from summer drought, and small-scale disturbance events in the understorey such as recreational use of the park by people for all-terrain biking or horseback riding. At PBPK, the use of herbicides, intensification of mowing, installation and expansion of sports fields, the construction of bicycle paths and other small-scale disturbances have certainly played a role in plant extirpations and invasions, but these are difficult to document precisely. Other biological factors operating in the park include: the introduction of non-native earthworms, and the high density of small mammals such as squirrels and rats. Abiotic factors include unfavorable environmental conditions such as summer drought, the heat-island effect, car-dumping, arson, and pollution such as high soil levels of lead, nickel and copper, and increasing soil acidity since the 1940s (Bornstein, 1968; Sharpe, 1978; Volchok, 1967; White and McDonnell, 1988; Greller et al., 1990; Sisinni and Emmerich, 1995).

The field notes of Ahles briefly describe several types of meadows in PBPK where he collected plant specimens in 1946–1947. These include six types of meadows and fields, as well as roadsides and railway lines, the edges of riparian areas, sandy shores, and rocky ledges (Ahles, 1947, 1948). The recensus of the park in 1994–1998 indicated that many of these open areas no longer existed. For example, Ahles collected a total of 129 herbaceous species from two areas in the park that have become mixed woodlands of shrubs and trees. Species once found in these meadows such as *Aquilegia canadensis*, *Physalis heterophylla*, and *Plantanthera lacera* could not be re-located anywhere in PBPK in 1994–1998. Similarly, Ahles collected several herbaceous species such as *Saxifraga virginiensis* from more than one section of the park in 1946–1947. The extirpation of these species indicates that a larger process, most likely succession, changed plant species diversity in the park. Other open areas such as the edge of the railway line that might have served as secondary habitat for native species were observed being sprayed with herbicides during the course of this study. Within the woodlands in 1994–1998, the only real refugia for many herbaceous species were rocky areas that created canopy gaps in the overstorey, allowing light to penetrate to the forest floor.

Evidence for a net loss in open habitats in PBPK also came from another source. Young (1958) in a breeding bird survey of PBPK done in 1955, found four species of

grassland nesting sparrows: grasshopper *Ammodramus savannarum*, seaside *Ammospiza maritima*, sharp-tailed *Ammodramus caudacatus*, and vesper *Pooecetes gramineus*). By 1990, three of these species had been extirpated from the park. The fourth (sharp-tailed *A. caudacatus*), a formerly common breeder at PBPK with at least 121 pairs counted in 1955 (Young, 1958), had become an uncommon nesting species by 1990 (DeCandido, pers. obs.).

Beginning in the late 1950s two large development projects and several smaller ones transformed natural areas of PBPK to a greater degree than had occurred previously. First, an interstate thruway was built through the northern portion of the park. (For a brief description of this area, see Monachino, 1958). Approximately 60.8 ha of parkland were completely lost, and several more hectares were transformed into the present mixture of mostly alien species combined with a few hardy native ones. During his study in 1946–1947, Ahles had collected 113 native herbaceous species in this area. These included *Agalinis tenuifolia* var. *tenuifolia*, *C. sagittalis*, *Juncus dudleyi*, and *Physostegia virginiana*. Fifteen species (10.6% of the native species collected by Ahles) became extirpated in PBPK when this section was developed. Second, in 1964 and continuing through 1978, a 36.5 ha area of the park was converted into a landfill. Ahles had collected 57 native herbaceous species in this area including *E. halophila*, *Hydrophyllum virginianum*, and *Sisyrinchum atlanticum*. Finally, smaller scale disturbance affected other areas of PBPK where Ahles made important collections. For example, at some point between 1947 and 1994, a natural area on the golf course was cleared. Ahles had collected 56 native herbaceous species from this area including *Actaea pachypoda*, *Krigia biflora*, and *Panax trifolius*. Each of the native herbaceous species from these three areas that were developed since 1946–1947 could not be relocated in 1994–1998.

Although Pelham Bay Park has become isolated from nearby populations of native species, many non-native plants have made their way into the park in the last 50 years. There were more non-native species in each of the seven habitat types now than in 1947, and their proportion in each of these habitats increased as well (Fig. 2). By 1998, 40.3% of the 740 species of the flora were non-native species in PBPK. In comparison, 35.0% of the 617 species in nearby, suburban Caumsett State Park in Suffolk County on the Long Island Sound are non-native. The latter is mowed annually to preserve meadows and extensive lawns (Greller et al., 2004).

Ahles did not record several common alien plants found in PBPK today. Although he may have simply not found many of these non-native species, it is just as likely that these invaders arrived in the park after 1947. It is also possible that small populations of the non-native species present in 1946–1947 and overlooked by Ahles, rapidly increased after large-scale disturbance events beginning in the late 1950s. The four most important of the alien species that are the greatest threat to natural areas of the park are *A. brevipedunculata* var. *brevipedunculata*, *C. orbiculata*, *P. cuspidatum*, and *R. frangula*.

The rapid loss of native plant species diversity in PBPK and throughout New York City is cause for alarm. Part of New York's natural heritage is being lost at a disturbing rate, and only a small minority of scientists and interested persons are taking notice. This decline also points to a larger problem: the continuing loss and significant alteration of many of New York City's remaining natural areas.

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). The degree to which biologists and educators create opportunities for people to appropriately enjoy the remaining natural areas will help determine the future of native species within them, and the natural areas themselves.

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