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Patterns of Species Richness in Eight Northeastern United States Cities*

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Abstract

In this paper, the native and nonnative floras of Boston, New York, Philadelphia, Washington, D.C., Detroit, Chicago, Minneapolis, and St. Louis urban areas are compared, and overall native diversity and nonnative diversity are correlated with a variety of factors. A total of 4,159 species has been reported in the eight urban areas. Of these, 2,708 (65.1%) are native to one or more of the urban areas and 1,451 (34.9%) are nonnative. Only 316 (11.6%) of the native species and only 109 (7.5%) of the nonnative species are common to all of the urban areas. When the similarity of native species is compared, Boston, New York, Philadelphia, and Washington, D.C., form a cluster, as do Detroit, Chicago, and Minneapolis; St. Louis is least similar to the other seven urban areas. Correlating climatic variables (growing season, temperature) and geographical variables (area, latitude, longitude) with species richness showed that nonnative species richness was most strongly correlated with longitude (probably as a function of age of settlement). This is in contrast with past research on native species showing a strong correlation of native species richness with latitude and elevations due to climatic differences present at different latitudes and elevations. Further studies that incorporate data from additional urban areas are needed to determine if nonnative species richness continues to be strongly correlated with time of a city's settlement.

Introduction

Patterns of species richness have long interested biologists (Wallace, 1878). The persistent and predictable patterns, even though actual numbers of species in the studies may vary, suggest that there are underlying, controlling factors. What those factors are and how they affect species richness has been the subject of numerous papers (Barthlott & Mutke, 2001; Currie, 1991; Currie & Paquin, 1987; O'Brien, 1998).

The best-known and most studied pattern is the latitudinal gradient. It has been demonstrated that there is a strong negative correlation between latitude and species richness for a number of species (i.e., as one samples in higher and higher latitudes, species richness diminishes

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[Fischer, 1960]). Other patterns that have been recognized are strong correlations between species richness and longitude, precipitation, temperature, potential evapotranspiration (PET), and insolation (sunlight) (Currie, 1991; Currie & Paquin, 1987; Palmer, 1995; Barthlott & Mutke, 2001). In North America, distinct latitudinal and longitudinal patterns have been recognized for several groups of organisms, including trees (Currie & Paquin, 1987), mammals and amphibians (Currie, 1991), and vascular plants (Palmer, 1995). These patterns can be modeled using climate data (O'Brien, 1998).

Urban areas are known to have different climates, soils, hydrology, etc., than nonurban areas (Pickett et al., 2001). One would therefore expect the patterns of species diversity to be different in these areas. Pysek (1998) compared 54 central European cities and concluded that the "occurrence of native and alien species in urban floras follows rather different pattern(s)."

One aspect of species richness that is particularly relevant in urban areas is the occurrence of nonnative species. In nonurban areas, Lonsdale (1999) found that 70% of nonnative species richness could be accounted for by three factors: native species richness, whether or not a site was a preserve, and whether a site was on an island or mainland. Similarly Stadler et al. (2000) found a correlation between nonnative species richness and native species richness. In urban areas, Pysek (1998) found that city size (area and population) was the best predictor of nonnative species richness.

This study was conducted to examine patterns of species richness in eight large northeastern United States cities and to determine what relationship there is between these floras and various factors that might be influencing native and nonnative species diversity.

Methods

Urban Areas

The urban areas in this study are defined as all the contiguous counties in and around the city with more than 86% of their populations living in urban areas, as measured by the United States Geological Survey (2000). The only exception is the New York urban area: We excluded Hartford and New Haven Counties in Connecticut and Hampden County in Massachusetts because including them would have greatly expanded the size of this urban area (already the largest) and because these counties are outside the study area covered by the New York Metropolitan Flora Project (Moore, 2002).

A database containing all species in the eight urban areas and their native/nonnative status can be found in Database 1 accessible at http://www.urbanhabitats.org/v01n01/speciesdiversity_full.html#database.. Table 1 provides information on the boundaries and data sources for each of the eight areas studied.

Predictors

Data for various predictors were calculated or compiled from a variety of sources (Table 2). Latitude, longitude, and elevation information was derived from airports within each urban area (Santos, 2002). The land area was calculated by totaling areas of counties taken from the United States Census Bureau (2001). Climate data (growing season, temperature, precipitation) were gathered from three sources on the Internet: WorldClimate (2002), the National Oceanographic and Atmospheric Administration (NOAA, 2000), and Koss et al. (1988). For most data, airports were used as the standard location within the urban area; however, we used the nearest available reporting station to gather growing-season data (see Table 1). Settlement dates are from *Encyclopaedia Brittanica* (1997). Current population data came from the U.S. Census Bureau (2001). Historical population data came from the University of Virginia Geospacial and Statistical Data Center (1998), except for that of the District of Columbia, which was obtained from Gilmore (1996).

Potential evapotranspiration (PET) was calculated using the Thornthwaite equation, $E = 16C(10T_m/I)^a$, where E is monthly potential evapotranspiration in mm, C is the daylight coefficient, T_m is the average monthly temperature in Celsius, and a is an exponent derived from the heat index (I). $I = \Sigma\ (T_m/5)^{1.51}$ and $a = (67.5 \times 10^{-8} I^3) = (77.1 \times 10^{-6} I^2) + (.0179I) + (.492)$. Temperature data came from NOAA (2000). Daylight coefficient was derived by adding the median day length for each month and dividing by 12.

Statistics

To compare the similarity of the native and nonnative floras of the eight urban areas, we calculated a Jaccard index of similarity (Ludwig & Reynolds, 1988) for the native and nonnative floras of each urban area. This index was then used to generate a cluster analysis of community similarity using the UPGMA (Unweighted Pair Group Method With Arithmetic Mean) program of the NTSYSpc (Numerical Taxonomy System, version 2.01) statistical package (Rohlf, 1997). Because it has been suggested that factors influencing nonnative species richness and native species richness are different (Pysek, 1998), separate analyses were conducted on native and nonnative species.

To determine which factors were most correlated with native or nonnative species richness, a Pearson correlation matrix was calculated using the natural logarithm of the native/nonnative plant species ratio, area, latitude, longitude, growing season, mean January temperature, and mean annual rainfall. Principal component analysis was also calculated using the same set of variables. These statistical tests were performed in Systat 10.2 statistical software (Systat, 2000).

This set of variables was chosen from a larger set of variables (i.e., those reported in Table 2). From this larger set of variables, only one was chosen from variable pairs that were significantly correlated. For example, date of settlement was strongly correlated with longitude. Therefore, only longitude was used on the correlation analysis reported in Table 3.

Results

Floristic Similarity

A total of 4,159 species have been reported as occurring in the eight urban areas. Of this total, 1,451 (34.9%) species are not native to any of the urban areas, and 2,708 (65.1%) species are considered to be native to one or more of the urban areas. The highest percentage of nonnative species is in Boston (45.71%), the lowest in

Minneapolis (19.27%). See Table 2 for further details for each urban area.

Although all urban areas are part of the Eastern Deciduous Forest Formation (Braun, 1950), they have relatively few species in common. A total of 316 (11.6%) native species are found in all eight urban areas, and 109 (7.5%) nonnative species are found in all eight urban areas; overall, 425 species (10%) are found in common.

The cluster analysis of the nonnative species for each urban area (Figure 1) shows Minneapolis to have the most dissimilar flora, followed by St. Louis. The other two main clusters are Chicago-Detroit and Boston-New York-Philadelphia-Washington. In this second main cluster, Boston is the most dissimilar, followed by Washington (Figure 1).

The cluster of the native species for each urban area (Figure 2) has St. Louis as the most dissimilar, followed by a Minneapolis-Chicago-Detroit cluster, with Detroit and Chicago again clustered together. The clustering of Boston, New York, Philadelphia, and Washington is the same as that in the analysis for nonnative species.

Factors Affecting the Native and Nonnative Flora Diversity

From the correlation matrix (Table 3) the natural logarithm of the native/nonnative species ratio was significantly correlated with longitude. Another significant correlation was between latitude and mean January temperature. In the factor analysis (Table 4, Figure 3), 96% of the variation is explained in the first three components (factors).

Discussion

Floristic Similarity

The similarity patterns of the native floras of the eight areas studied basically follow the current understanding of the vegetation of eastern North America. The first cluster (Figure 3), Boston, New York, Philadelphia, and Washington, are all part of the Oak-Chestnut Forest Region (Braun, 1950) and the Eastern Broadleaf Forest (Oceanic) Province (Bailey, 1995). These areas also have coastal-plain and shore floras not found in the inland cities. Detroit, Chicago, and Minneapolis are part of the Maple-Basswood Forest Region (Braun, 1950), whereas St. Louis, and to some extent Chicago, are part of the Oak-Hickory Forest Region (Braun, 1950). All four of these cities are part of the Eastern Broadleaf Forest (Continental) Province (Bailey, 1995).

While the cluster analyses based on native and nonnative species richness show some similar trends, there is one point in which they differ. Minneapolis is very similar to Chicago and Detroit in native species, but it has the least similarity of any of the urban areas when nonnative species are considered. This probably reflects the fact that Minneapolis is the farthest from a major seaport, where most nonnative species have been introduced.

Factors Affecting the Native and Nonnative Flora Diversity

The most striking correlation found in this study was between nonnative species richness and longitude. Currie and Paquin (1987) found a correlation between native tree diversity and longitude in North America, but no other study has found such a correlation. Though they don’t present correlation statistics, Withers et al. (2000) show a defined longitudinal gradient for native and nonnative plant species in eastern North America. We believe that the nonnative species richness–longitude correlation found in our study is most likely the result of the history of plant introduction into North America. Longitude is strongly correlated with date of settlement. Furthermore, the cities that were settled earliest also are the cities with active seaports (all of them are on the East Coast). Most species were probably introduced via ocean ports along the East Coast and then spread inland. As a result, it is reasonable to conclude that seaports have the greatest number of nonnative species (as shown here) and that the number gradually declines as one moves inland.

Therefore, while we concur with the finding that factors influencing native and nonnative plant diversity are not the same, we have found different factors influencing nonnative diversity in North America than those found by Pysek in Europe. However, comparing our results with Pysek's (1998) is somewhat problematic because in his study—as in most Old World studies—species diversity was divided into native species (those that evolved in the region or arrived there before the Neolithic) and nonnative species (those that have been introduced to the region since the Neolithic); the nonnative species were further subdivided into archaeophytes (species introduced before 1500) and neophytes (species introduced after 1500). North American cities cited in this study have no archaeophytes because none were settled before 1500.

In Table 5, the results of this study are compared with Pysek's figures for 54 urban areas in central Europe (Pysek, 1998). It is evident that in our study the data samples for both population and area are much larger: Pysek included settlements of as few as 5,000 individuals, whereas our study included only settlements of more than 1 million individuals. The numbers of nonnative and native species in our study are much larger as well (although the percentage of nonnative species is in the same range as that for the European cities). From this we surmise that the floras of European cities are either depauperate compared with those of U.S. cities, or that area is a major factor in accounting for the more diverse floras. Pysek found a strong correlation between species diversity and area, which supports this latter supposition.

This history of plant introduction would also support the other strong correlations we found between nonnative species richness and the date a city was first settled (by way of the correlation with longitude). The longer a city has been in existence, the longer nonnative plants have had a chance to become established. In addition, the greater the shipping activity, the greater the numbers of plants coming into a port.

For neophyte diversity, Pysek (1998) found significant regressions with population, area, and population density (all multiplicative regressions), as well as with temperature (multiplicative regression) and altitude (exponential regression). In this study we found significant correlations between nonnative species diversity and longitude. Furthermore, elevation and settlement date were strongly correlated with longitude. We did not find significant correlations between nonnative species diversity and area, latitude, temperature, or growing season. In addition, potential evapotranspiration and population for the year 2000 were strongly correlated with latitude and area, respectively.

One possible explanation for these very different results is that we selected eight cities with populations of over 1 million, while Pysek selected 54 cities with populations ranging from 5,000 to 1.9 million. If there were a stronger population gradient among the U.S. cities, we might see the same correlations. But it could equally reflect a much longer time line for European urban development.

In summary, the results of this study lead to one significant conclusion: The factors influencing native and nonnative plant diversity in urban areas are not the same. Thus, the well-established correlations between climatic factors and native species diversity do not apply for nonnative species richness. Nonnative species diversity is more complicated and appears to be significantly influenced by factors regarding the settlement of the city (e.g., date of settlement, presence of a seaport).

The results of this study are preliminary and cannot be used to establish any general patterns regarding nonnative species diversity in North America. Future studies should include additional urban areas in North America to determine whether factors such as settlement date are causing the strong correlation noted in this study between nonnative species diversity and longitude.

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Table 1. General information About the Eight Urban Areas Studied

URBAN AREA	COUNTIES IN AREA	PLANT DATA SOURCE	AIRPORT	GROWING SEASON
Boston	Massachusetts: Essex, Middlesex, Norfolk, Suffolk	Sorrie & Somers (1999)	Boston: Logan International Airport	Framingham, Massachusetts
Chicago	Illinois: Cook, DuPage, Lake; Indiana: Lake	Swink & Wilhelm (1994)	Chicago: Midway Airport	Chicago: Midway Airport
Detroit	Michigan: Macomb, Oakland, Wayne	Voss (1972, 1985, 1996)	Detroit: Metropolitan Airport	Ypsilanti, Michigan
Minneapolis	Minnesota: Anoka, Dakota, Hennepin, Ramsey	Ownbey & Morley (1991); Cholewa (2000)	Minneapolis International Airport	Maple Plain, Minnesota
New York	Connecticut: Fairfield; New Jersey: Bergen, Essex, Hudson, Middlesex, Monmouth, Passaic, Union; New York: Bronx, Kings, Nassau, New York, Queens, Richmond, Rockland, Suffolk, Westchester	Moore et al. (2002)	New York: LaGuardia Airport	Central Park, New York, New York
Philadelphia	Delaware: New Castle; New Jersey: Camden; Pennsylvania: Delaware, Montgomery, Philadelphia	Rhoads & Klein (1993); Hough (1983); Tatnall (1946)	Philadelphia International Airport	Wilmington, Delaware
St. Louis	Illinois: St. Clair Missouri: St. Louis, City of St. Louis	Steyermark (1963); Yatskievych (1999); Mohlenbrock & Ladd (1978)	St Louis Lambert Airport	St. Charles, Missouri
Washington	District of Columbia; Maryland: Anne Arundel, Baltimore, City of Baltimore, Montgomery, Prince Georges; Virginia: City of Alexandria, Arlington; Fairfax, City of Fairfax, City of Falls Church	Harvill (1986); Shetler & Orli (2000)	Baltimore-Washington International Airport	Baltimore, Maryland

Table 2. Species Diversity, Geographic, Climatic, Historical Data for Eight Study Areas

Cities	Y_1	Y_2	Y_3	Y_4	Y_5	X_1	X_2
Boston	1252	1054	2306	45.71	.17215	42.36	71.01
New York	1649	881	2530	34.82	.62687	40.78	73.87
Philadelphia	1612	922	2534	36.39	.55869	39.87	75.24
District of Columbia	1561	813	2374	34.25	.65235	39.18	76.67
Detroit	1121	495	1616	30.63	.81742	42.21	83.35
Chicago	1176	577	1753	32.92	.71203	41.79	87.75
Minneapolis	1131	270	1401	19.27	1.4324	44.88	93.22
St. Louis	1352	404	1756	23.01	1.2079	38.75	90.36

Cities	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
Boston	71.01	1783	-1.80	149	5.8	1091	666	1630	3.5
New York	73.87	4212	-0.30	203	6.7	1083	723	1614	17.5
Philadelphia	75.24	2582	-0.80	181	11.6	1044	727	1638	3.8
District of Columbia	76.67	1450	-0.10	207	44.5	1050	805	1690	4.6
Detroit	83.35	1967	-5.00	148	196.9	822	635	1701	4.0
Chicago	87.75	2225	-5.30	165	189.0	924	653	1803	7.4
Minneapolis	93.22	1707	-11.2	126	256.3	702	628	1823	2.3
St. Louis	90.36	1234	-1.50	168	184.1	941	782	1764	1.6

Key: Y_1: Native species; Y_2: Alien species; Y_3: Total species; Y_4: Percent alien; Y_5: ln natives/aliens; X_1: Latitude; X_2: Longitude; X_3: Area (square miles); X_4: Mean January temperature (°C); X_5: Growing season (days); X_6: Elevation (m); X_7: Mean annual rainfall (mm); X_8: Potential evapotranspiration (see text for discussion); X_9: Settlement date; X_{10}: Population in 2000 (millions)

Table 3. Pearson Correlation Matrix

	Y_5	X_1	X_2	X_3	X_4	X_5
Y_5	1.000					
X_1	0.229	1.000				
X_2	0.901	0.307	1.000			
X_3	-0.309	0.002	-0.445	1.000		
X_4	-0.640	-0.858	-0.732	0.262	1.000	
X_5	-0.387	-0.788	-0.542	0.435	0.819	1.000

Key: Y_5: ln natives/aliens; X_1: Latitude; X_2: Longitude; X_3: Area (square miles); X_4: Mean January temperature (°C); X_5: Growing season (days)

Table 4. Results of Factor Analysis

Component loadings

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
Eigenvalues	3.674	1.282	0.830	0.126	0.080	0.008
Y_5	0.754	0.469	0.418			
X_1	0.722	-0.678	-0.011			
X_2	0.849	0.429	0.231			
X_3	-0.461	-0.530	-0.701			
X_4	-0.953	0.234	0.098			
X_5	0.861	0.290	0.318			
% total variance explained	61.237	21.371	13.830			

Key: Y_5: ln natives/aliens; X_1: Latitude; X_2: Longitude; X_3: Area (square miles); X_4: Mean January temperature (°C); X_5: Growing season (days)

Table 5. Comparison of Data for Eastern United States and Central European Studies

	Eastern U.S. (this study)	Central Europe (Pysek, 1998)
Native species	1,121–1,649	98-947
Alien species[1]	270–1,054	97-748
Percent alien	19–45	20-56
Population (× 1000)	1,620–17,520	11,079
Area (km^2)	1,234–4,212	8-480

[1]Includes both archaeophytes and neophytes.

Figure 1. Cluster Diagram of Nonnative Species Similarity Using Jaccard Index

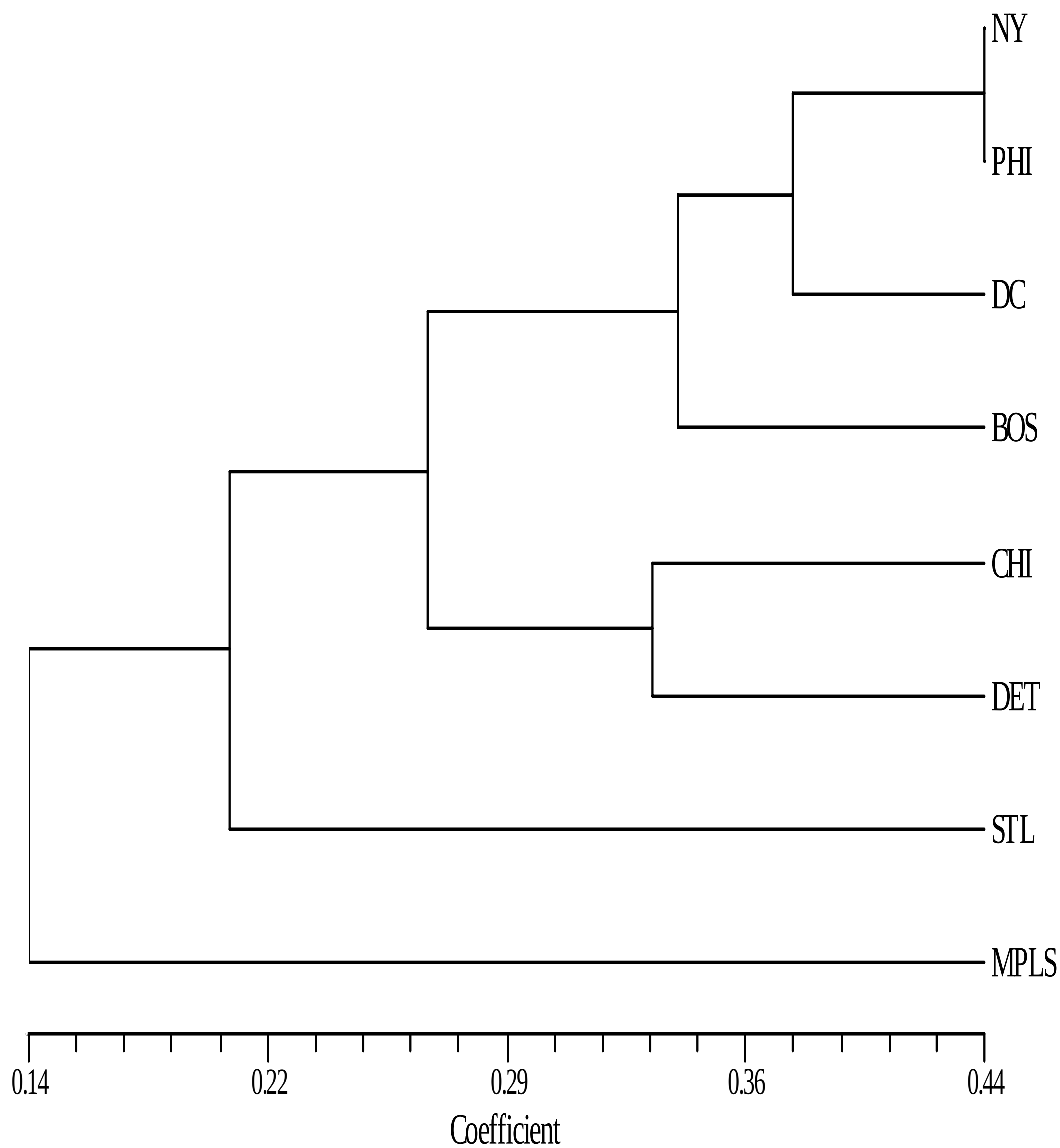


Figure 2. Cluster Diagram of Native Species Similarity Using Jaccard Index

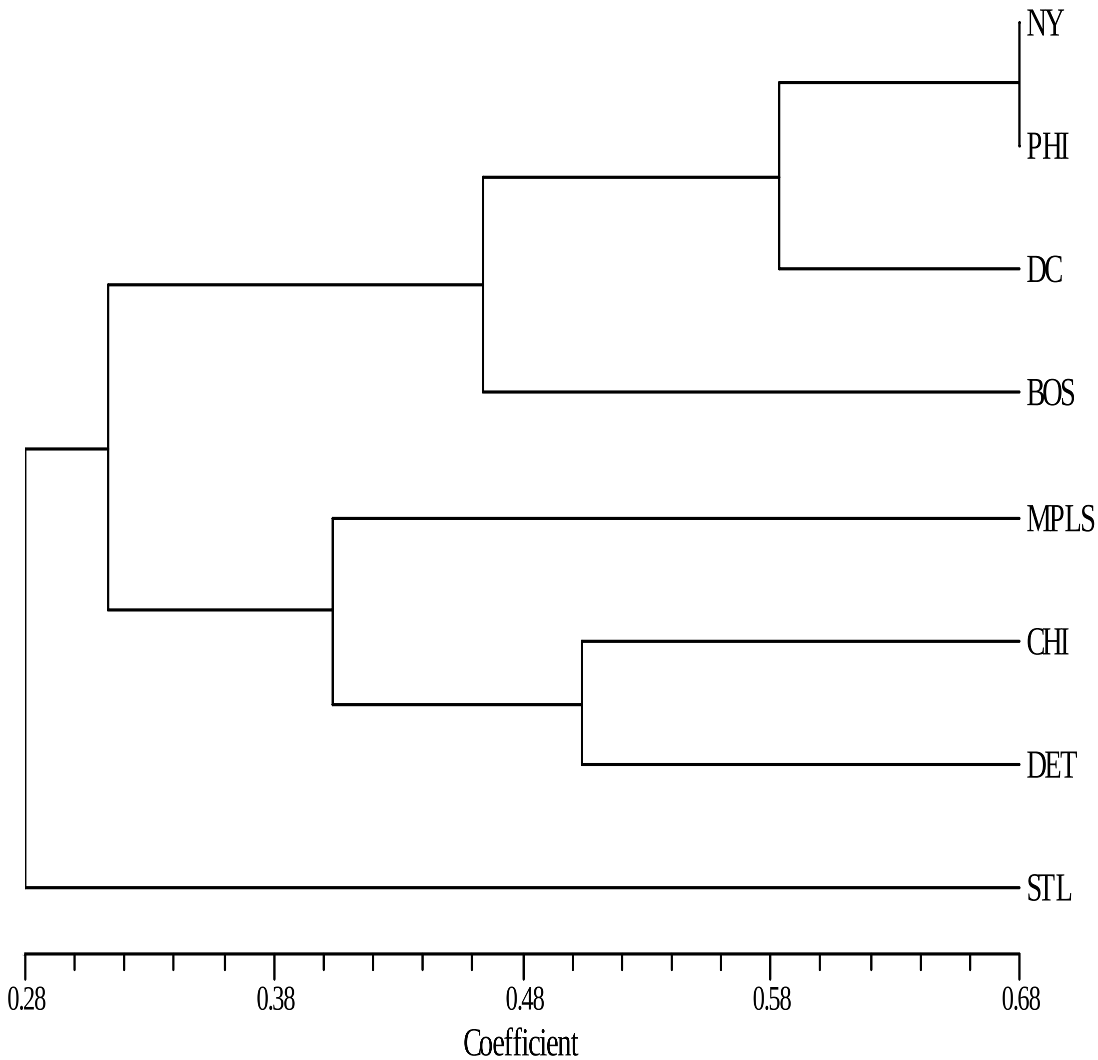
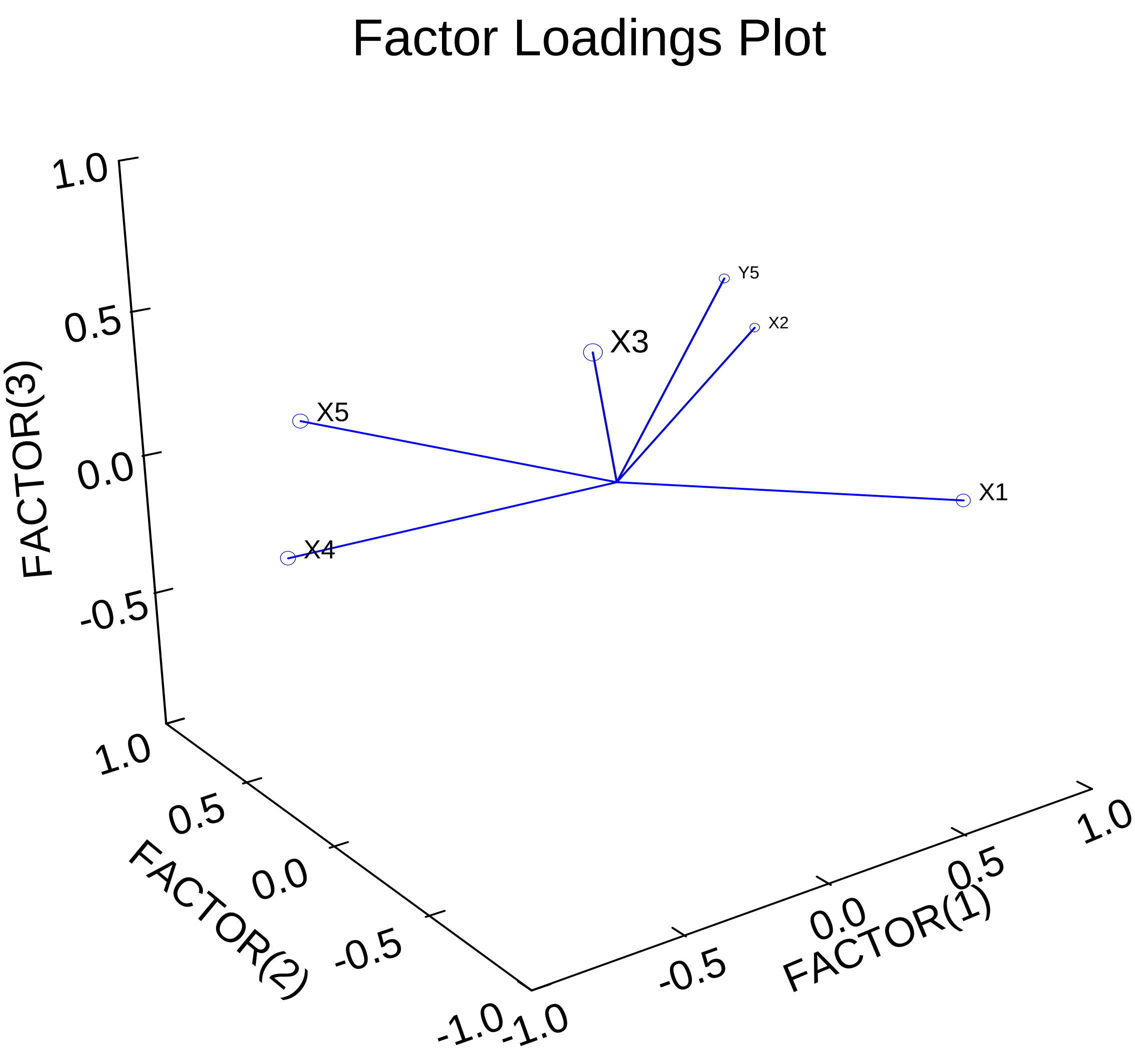


Figure 3. Factor Loading Plot of Factor Analysis



An Overview of the New York Metropolitan Flora Project*

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Abstract

This paper provides an overview of Brooklyn Botanic Garden's New York Metropolitan Flora (NYMF) project. Previous efforts to document the flora of the New York metropolitan region are reviewed, including the contributions of many notable botanists (e.g., Arthur Cronquist, Merritt Fernald, Asa Gray, and John Torrey), institutions (e.g., Harvard University and The New York Botanical Garden), and groups (e.g., Torrey Botanical Society and Philadelphia Botanical Club). The methodologies used for the NYMF project are discussed, such as the area covered by the flora project, how data are collected, and how data are stored and analyzed. Some results of the NYMF project are considered, highlighting the two major trends that are found in the flora: the decline of native species and the spread of nonnative plants. The paper also covers how the results of the NYMF project are being made available to the public not only through publications but also by the NYMF Web site maintained by Brooklyn Botanic Garden.

Introduction: A Review of Floristic Research in the Region

The flora of New York City and its environs has been studied in one form or another for the past 250 years. Cadwallader Colden published one of the first accounts (if not the first account) of the region's plants with his *Plantae Coldenhamiae* (1743, 1751). Other early botanical explorers of the region included John Bartram, William Bartram (son of John Bartram), Jane Colden (daughter of Cadwallader Colden), and Peter Kalm.

By the mid-18th century, much of the New York metropolitan area's flora had been documented. Of the roughly 3,000 species (including native and nonnative species) that now occur here, approximately 50% were accounted for in Linnaeus's 1753 compendium of the world's plants, *Species Plantarum* (1753).

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Following a century of basic exploration, botanists began to assemble the data into floras (in this case, floras of the northeastern United States). Among the earliest of these were A. Michaux's *Flora Boreali-Americana* (1803), C.H. Persoon's *Synopsis Plantarum* (1805-1807), F. Pursh's *Flora Americae Septentrionalis* (1814), and T. Nuttall's *Genera of North American Plants* (1818). The tradition of publishing regional floras has continued to the present.

A center of regional floristic study developed in New York under John Torrey. In 1824, Torrey published *Flora of the Northern and Middle Sections of the United States.* This was followed roughly 75 years later by Nathaniel Lord Britton and Addison Brown's *An Illustrated Flora of the Northern United States* (1896, 1897) and the *Manual of the Flora of the Northern States and Canada* (1901). The most recent floristic treatments are Henry Allan Gleason and Arthur Cronquist's *Manual of Vascular Plants of Northeastern United States and Adjacent Canada* (1991) and Noel H. Holmgren's *The Illustrated Companion to Gleason and Cronquist's Manual* (1998), the standard texts for plant identification in the region today.

Asa Gray, a student of John Torrey's, founded a second center of northeastern U.S. floristics at Harvard University. In 1848, he published *A Manual of Botany of the Northern United States* (1848). The eighth edition of his book, now known as *Gray's Manual of Botany* (Fernald, 1950), is still frequently used for the identification of plants in the northeastern United States.

In addition to regional floras, numerous studies of the flora in the immediate area around New York City have been steadily produced. John Torrey published the first catalog of these plants in 1819. This was one of the earliest local floras in the country, preceded only by Jacob Bigelow's *Florula Bostoniensis* (1814) and William Barton's *Compendium Florae Philadelphicae* (1818). It has been followed periodically by other floras, catalogs, and checklists of the metropolitan region (see Table 1).

Torrey was also influential in developing amateur botanical expertise in New York City. He and his colleagues founded the Torrey Botanical Club (now the Torrey Botanical Society) in 1867. Botanical clubs were founded in other cities in the Northeast as well, most notably the Philadelphia Botanical Club (1891) and the New England Botanical Club (1895).

These clubs played, and continue to play, a very important role in the understanding of local flora. Each publishes a scholarly journal (the *Journal of the Torrey Botanical Society*, *Bartonia*, and *Rhodora*, respectively). Each has amassed and cared for extensive herbaria (the Torrey Botanical Society herbarium is now incorporated into The New York Botanical Garden; collections made by Philadelphia Botanical Club members are incorporated into the Academy of Natural Sciences, in Philadelphia; the New England Botanical Club herbarium is housed within the Harvard University Herbaria collections). And each has organized local field trips every year for the past century.

These clubs and their activities have been vital to our current study and will continue to be important components of any future studies. New botanical clubs, such as the Connecticut Botanical Club and the Long Island Botanical Society, are extending and deepening this heritage.

Table 1

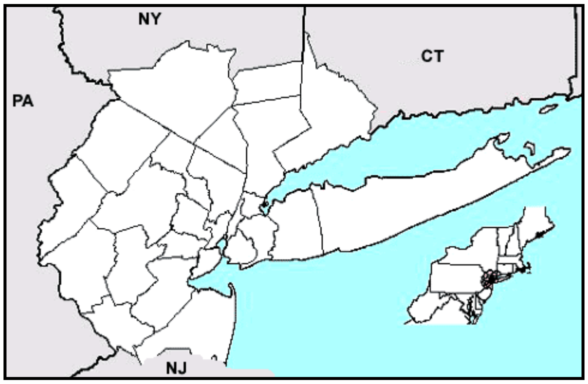
Regional Floras, Catalogs, and Checklists of the New York Metropolitan Region

Date of Publication	Author(s)	Publication Title
1743, 1751	C. Colden	*Plantae Coldenhamiae* (revised edition published in 1751)
1819	J. Torrey	*A catalogue of plants growing spontaneously within thirty miles of the City of New York*
1857	P. D. Knieskern	*Catalogue of plants growing without cultivation in the counties of Monmouth and Ocean, New Jersey*
1870–1874	W. Leggett	A revised catalogue of plants native and naturalized, within thirty-three miles of New York (published as a series of articles in the *Bulletin of the Torrey Botanical Club*)
1874, 1878	O. Willis	*Catalogue of plants growing without cultivation in the state of New Jersey* (revised edition published in 1878)
1885	J. Bishop	A catalogue of all phaenogamous plants at present known to grow without cultivation in the state of Connecticut
1888	N.L. Britton, A. Brown, A. Hollick, J.F. Poggenburg, T.C.Porter, E.E.Sterns	*Preliminary catalogue of Anthophyta and Pteridophyta reported as growing spontaneously within one hundred miles of New York City.*
1890	N. L. Britton	*Catalogue of plants found in New Jersey* (previously published in 1881 as *A preliminary catalogue*)
1899	S.E. Jelliffe	*The flora of Long Island*
1910	C.B. Graves, E.H. Eames, C.H. Bissell, L. Andrews, E.B. Harger, C.A. Weatherby	Catalogue of the flowering plants and ferns of Connecticut growing without cultivation
1912	W. Stone	The plants of southern New Jersey with especial reference to the flora of the Pine Barrens and the geographic distribution of the species
1915	N. Taylor	Flora of the vicinity of New York
1924	H.D. House	Annotated list of the ferns and flowering plants of New York State
1927	N. Taylor	The vegetation of Long Island
1935, 1947, 1962	H.A. Gleason	*Plants of the vicinity of New York* (revised editions published in 1947, 1962)
1979	K. Anderson	*A checklist of the plants of New Jersey*
1983	M.Y. Hough	*New Jersey Wild Plants*
1986, 1997	R.S. Mitchell	A checklist of New York State plants (revised edition published by R.S. Mitchell and G.C. Tucker in 1997)
1994	J.A. Schmid and J.T. Kartesz	*Checklist and synonymy of higher plants in New Jersey and Pennsylvania with special reference to their rarity and wetland indicator status*

Project Background

In 1989, Brooklyn Botanic Garden recognized the importance of local flora studies by hiring Steven Clemants as its director of Science (he is now the institution's vice president of Science). The following year, Clemants founded the New York Metropolitan Flora project (NYMF). The project's purpose is to document all vascular plants that grow without cultivation in the metropolitan area. The NYMF range extends to all counties within roughly a 50-mile radius of New York City, and it includes all of Long Island, all of northern New Jersey (south to Mercer and Monmouth Counties), part of southeastern New York (Orange, Putnam, Rockland Counties), and Fairfield County, Connecticut. The region covers approximately 7,650 square miles and includes a total of 25 counties (see Figure 1).

Figure 1
Range of the New York Metropolitan Flora Project



In addition to the authors of this paper, several other scientists have contributed to NYMF research. They include Kerry Barringer (current curator of Brooklyn Botanic Garden Herbarium), Bryan Dutton (a former research taxonomist at Brooklyn Botanic Garden, currently on the faculty at Western Oregon University), and Katherine Gould (another former research taxonomist at Brooklyn Botanic Garden, currently on the faculty at Austin Peay State University). Many volunteers, especially members of the local botanical clubs and societies, have also contributed to the project.

For collecting and surveying purposes, the project uses a grid system based on the New York Transverse Mercator Grid (a variation of the Universal Transverse Mercator Grid). The same grid used in the *Atlas of Breeding Birds of New York State* (Andrle & Carroll, 1988), it breaks down the metropolitan region into 964 five-by-five-kilometer cells or blocks (Figure 2). As far as possible, every record in the NYMF database corresponds to one of these blocks.

On a typical NYMF map, record(s) of the same species in one block appear as a dot (see Figures 3 and 4 for examples). The most current records supersede older ones.

Data entered into the database are derived from three main sources: 1) collections made in the field; 2) observations made in the field; 3) published data. To date, the NYMF database consists of more than 200,000 records taken from these three sources.

Collections are constantly being made in the field by all NYMF staff. Sixty blocks were randomly selected to serve as voucher blocks. In these voucher blocks, collections are made of all species encountered. These specimens are deposited in the herbarium of Brooklyn Botanic Garden. Furthermore, all herbaria that have significant collections in the NYMF range have been inventoried. These herbaria include the Academy of Natural Sciences, Philadelphia (PH) (abbreviations follow Holmgren, Holmgren & Barnett, 1990); Brooklyn Botanic Garden (BKL); Cornell University (BH, CU); Harvard University (A, GH, NEBC); The New York Botanical Garden (NY); New York State Museum (NYS); Rutgers University (CHRB); Smithsonian Institution's National Museum of Natural History (US); Staten Island Institute of Arts and Sciences (SIM); University of Connecticut (CONN); and Yale University (Y). The field-collection data of the NYMF staff are significant because most records from herbaria were obtained before 1990.

Figure 2
NYMF Range With 5 x 5 km UTM Block Grid

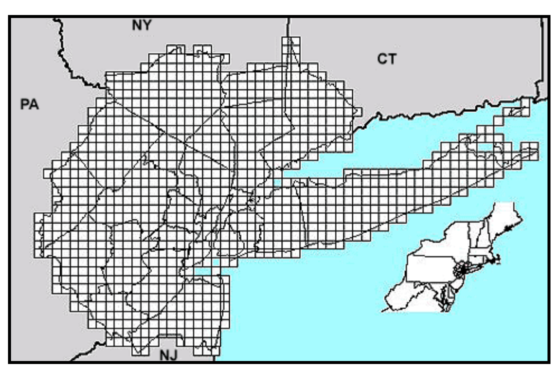


Figure 3
Distribution of *Chimaphila umbellata* in NYMF Area

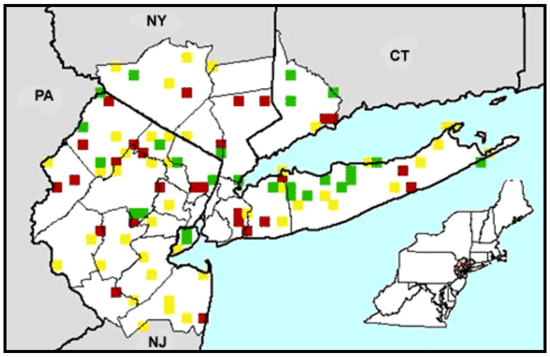
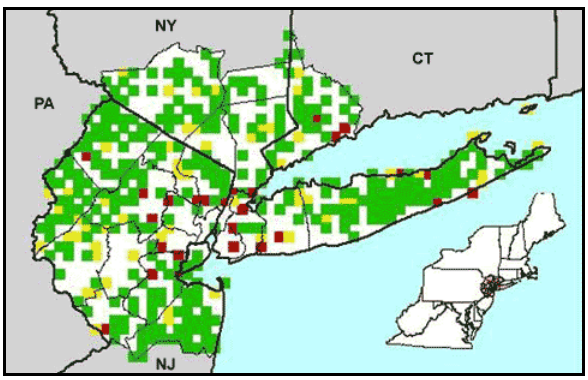


Figure 4
Distribution of *Chimaphila maculata* in the NYMF Area



Plant last seen before 1900
Plant last seen between 1900 and 1950
Plant last seen after 1950

In addition to compiling vouchered data, the NYMF staff makes nonvouchered observations in the field, and these records are also entered into the database. Observations made by others are also entered (for example, the records of Stanley Smith, the first curator of the herbarium of the New York State Museum, are included). Since some questions regarding species identity cannot be answered without a voucher specimen, this approach could be criticized. However, a parallel may be drawn in the common use of observational data in bird studies. Furthermore, the presence of a detailed vouchered database for comparison lessens the risk of error in using nonvouchered data. Moreover, it is the only practical way to get a reasonably complete picture of distributions. The NYMF range is large, and it is not feasible to have collections for all species in each block. Because each block unit is small, most questions regarding records may be answered by physically visiting a particular block.

Published records of plants are also entered into the NYMF database. Most of these are from floristic articles or field-trip reports that have appeared in *Bartonia, Bulletin (Journal) of the Torrey Botanical Club (Society),* and *Torreya.*

Publishing Results

The NYMF project is divided into six distinct research segments: 1) woody plants; 2) aquatic and wetland plants; 3) grasses, sedges, and rushes; 4) ferns; 5) wildflowers; and 6) weeds. So far, fieldwork for the woody-plant phase has been completed, and a volume on the woody plants of the metropolitan region is in preparation. Our current fieldwork is focused on aquatic and wetland plants.

In addition to printing volumes on the research segments of the project, we are also publishing our results online at http://www.bbg.org/sci/nymf/ as they are produced. On the NYMF Web page, technical and nontechnical information is provided for each species. The technical information consists of nomenclature (accepted name and synonyms), description, habitat, distribution, rarity status, species biology, and references. The nontechnical information consists of common name, field-identification data, food uses, and relevant Brooklyn Botanic Garden student projects.

Identification keys are also provided. Currently these consist of keys to genera and general keys to the woody plants. Interactive keys will soon be available on the Web site.

Conclusion: A Dynamic Tool

Several components of the NYMF project make it different from previous floristic studies of the area. NYMF does not focus on some areas more than others but rather attempts to survey the entire region uniformly. Sampling occurs in all the five-by-five-kilometer blocks, and this buffers against sampling bias in the floristic accounts. The small block unit also permits the creation of highly detailed range maps (as opposed to county-sized range maps). Our database also allows its users to "mine" it to develop such lists as the most widespread woody plants in the area (Table 2) and arrival dates of common woody invasive plant species (Table 3).

The NYMF project is unique because it documents *all* vascular plants that occur without cultivation in the region. It focuses on nonnative plants as well as native ones, common species as well as rare or endangered ones. Our approach differs from that of earlier floristic studies in which nonnative species were often ignored or only casually mentioned. An example of this kind of study is W. Stone's flora of southern New Jersey (1912). In it, the author writes, "Important as is the study of weeds from an economic standpoint, they have little or no significance in a geographic discussion of plant life, their principal function being to aid in obliterating all trace of the original range of the native vegetation."

Besides destruction of habitat, the greatest threat to native plants in the metropolitan region is the introduction and spread of nonnative plants. Our staff has documented the occurrence and spread of numerous nonnative plant species. For example, A.

Table 2
Most Widespread Woody Species
(as percentage of covered blocks)

1. *Prunus serotina*	72%
2. *Acer rubrum*	71%
3. *Toxicodendron radicans*	70%
4. *Parthenocissus quinquefolia*	69%
5. *Rosa multiflora*	67%
6. *Quercus alba*	65%
7. *Sassafras albidum*	64%
8. *Celastrus orbiculatus*	63%
9. *Robinia pseudoacacia*	62%
10. *Betula populifolia*	62%

Table 3:
Arrival Dates of Alien Species

Rosa multiflora	1909
Celastrus orbiculatus	1919
Robinia pseudoacacia	1850
Berberis thunbergii	1876
Acer platinoides	1879
Lonicera japonica	1875
Ailanthus altissima	1857
Solanum dulcamara	1846
Lonicera morrowii	1897

Steward, S.E. Clemants, and G. Moore have documented how the aggressive nonnative Oriental bittersweet (*Celastrus orbiculatus*) has rapidly spread and become a common weed in the NYMF range, while the native American bittersweet (*C. scandens*) has become increasingly scarce. It is hypothesized that the spread of *C. orbiculatus* is contributing to the decline of *C. scandens* (Steward, Clemants & Moore, in press).

NYMF is also documenting the occurrence of rare plants in the region and noting the decline of species that were at one time more abundant. For example, S.D. Glenn (2001) recently rediscovered *Rhododendron (Ledum) groenlandicum* in New Jersey. Prior to Glenn's discovery, the species had not been seen there since 1977 (Hough, 1983; Glenn, 2001). It also appears that *Chimaphila umbellata*, which once occurred frequently in the New York metropolitan range, has declined considerably (Figure 3). Meanwhile, the closely related species *C. maculata*, which grows in similar habitats, appears to have remained stable (Figure 4).

The NYMF flora is being compared with other urban floras (Clemants, 2002) to discover possible large-scale floristic trends. Future research may focus on changes in plant ranges and blooming times that might be the result of global warming or other major climatological changes. An example of a plant whose range has changed recently is the composite *Heterotheca subaxillaris*, which was not known north of Delaware in the early 1900s; today it is common in the NYMF region.

The publication of floristic treatments of the region in the 20th century in no way precludes the need for floristic research programs in the 21st century. Indeed, when the NYMF project is finally completed and treatments have been written for all the species that occur in the region, it will be time to start over again.

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A Short Bibliography of Urban Floras*

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Following is a list of some urban floras from around the world, in alphabetical order by city. Apparently no floras are available for 27 of the 50 most populated cities in the world, as listed by One World - Nations Online (2002) (see Tables 1 and 2). Many of the cities for which there are no floras are located in tropical areas. I welcome any additions or corrections to this list.

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New York (United States)

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Shanghai (China)

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Table 1

The Most Populated Cities in the World

The following list of the 50 most populated cities in the world, organized by population size from most (No. 1) to least (No. 50), is from One World - Nations Online (2002).

1. Seoul (South Korea)
2. Mumbai (India)
3. São Paulo (Brazil)
4. Jakarta (Indonesia)
5. Moscow (Russia)
6. Mexico City (Mexico)
7. Shanghai (China)
8. Tokyo (Japan)
9. Istanbul (Turkey)
10. Beijing (China)
11. New York (United States)
12. Delhi (India)
13. London (England)
14. Hong Kong (China)
15. Cairo (Egypt)
16. Tehran (Iran)
17. Lima (Peru)
18. Bangkok (Thailand)
19. Tianjin (China)
20. Rio de Janeiro (Brazil)
21. Shenyang (China)
22. Calcutta (India)
23. St. Petersburg (Russia)
24. Santiago (Chile)
25. Bogotá (Colombia)
26. Guangzhou (China)
27. Madras (India)
28. Baghdad (Iraq)
29. Wuhan (China)
30. Pusan (South Korea)
31. Sydney (Australia)
32. Caracas (Venezuela)
33. Harbin (China)
34. Los Angeles (United States)
35. Chengdu (China)
36. Berlin (Germany)
37. Yokohama (Japan)
38. Alexandria (Egypt)
39. Melbourne (Australia)
40. Singapore (Singapore)
41. Wuxi (China)
42. Chongqing (China)
43. Ho Chi Minh City (Vietnam)
44. Hyderabad (India)
45. Madrid (Spain)
46. Buenos Aires (Argentina)
47. Ahmadabad (India)
48. Ankara (Turkey)
49. Chicago (United States)
50. Pyongyang (North Korea)

Table 2

The Most Populated Cities That Lack Floras

Following is a list of the 27 most populated cities (One World - Nations Online, 2002) for which floras do not exist. They are in alphabetical order by city name.

Ahmadabad (India)
Alexandria (Egypt)
Ankara (Turkey)
Baghdad (Iraq)
Bangkok (Thailand)
Cairo (Egypt)
Caracas (Venezuela)
Chengdu (China)
Chongqing (China)
Harbin (China)
Ho Chi Minh City (Vietnam)
Hyderabad (India)
Istanbul (Turkey)
Lima (Peru)
Pusan (South Korea)
Pyongyang (North Korea)
Rio de Janeiro (Brazil)
Bogotá (Colombia)
São Paulo (Brazil)
Seoul (South Korea)
Shenyang (China)
Tehran (Iran)
Tianjin (China)
Tokyo (Japan)
Wuhan (China)
Wuxi (China)
Yokohama (Japan)

Flora of Beijing: An Overview and Suggestions for Future Research*

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Abstract

This paper reviews *Flora of Beijing* (He, 1992), especially from the perspective of the standards of modern urban floras of western countries. The geography, land-use and population patterns, and vegetation of Beijing are discussed, as well as the history of *Flora of Beijing*. The vegetation of Beijing, which is situated in northern China, has been drastically altered by human activities; as a result, it is no longer characterized by the pine-oak mixed broad-leaved deciduous forests typical of the northern temperate region. Of the native species that remain, the following dominate: *Pinus tabuliformis*, *Quercus* spp., *Acer* spp., *Koelreuteria paniculata*, *Vitex negundo* var. *heterophylla*, *Spiraea* spp., *Themeda japonica*, and *Lespedeza* spp. Common cultivated species include *Juglans regia*, *Castanea mollissima*, *Ziziphus jujuba*, *Corylus* spp., *Prunus armeniaca*, *Hydrangea bretschneideri*, and *Lonicera* spp. Crop plants such as corn and wheat are also very common. Few species are endemic to Beijing, but some semiendemic species are shared with the neighboring province of Hebei. This paper includes lists of plants, including native, endemic, cultivated, nonnative, invasive, and weed species, as well as a lst of relevant herbarium collections. We also make suggestions for future revisions of *Flora of Beijing* in the areas of description and taxonomy. We recommend more detailed categorization of species by origin (from native to cultivated, including plants introduced, escaped, and naturalized from gardens and parks); by scale and scope of distribution (detailing from worldwide to special or unique local distribution); by conservation ranking (using IUCN standards, for example); by habitat; and by utilization. Finally, regarding plant treatments, we suggest improvements in the stability of nomenclature, descriptions of taxa, and the quality and quantity of specimens used. We also recommend that information on and treatment of cultivated species, along with illustrations of species and maps, should be included in *Flora of Beijing* to promote a deeper understanding of the flora.

General Information

Beijing, the capital of the People's Republic of China, is one of the largest cities in the country; with more than 13 million people, it is also one of the largest

* Published online November 19, 2003

cities in the world. More than 3,000 years old, Beijing has been China's capital since A.D. 1272 with only a few interruptions. Today, Beijing is an independently administered municipality, with an area of 16,808 square kilometers (6,490 square miles) stretching 160 kilometers from east to west and more than 180 kilometers from north to south. There are 18 districts and counties in the municipality: the districts of Xicheng, Dongcheng, Xuanwu, and Chongwen in the central city; Shijingshan, Haidian, Chaoyang, and Fengtai in the inner suburbs; and in the outer suburbs, Fangshan, Mentougou, Changping, Shunyi, Tongxian, and Daxing, as well as the counties of Yanqing, Huairou, Miyun, and Pinggu. The metropolitan area is composed of the first eight districts (see Map 1 and Table 1).

Geography

Beijing is located at latitude 39º54'27" north and longitude 116º23'17" east. It lies at the northwest end of the North China Plain, about 150 kilometers from the Gulf of Bohai in the southeast, at an elevation of 43.5 meters above sea level. About two thirds of the city is located on the plains, the rest on low mountains less than 1,000 meters high; the highest peak, at 2,303 meters, is in the northwest part of the city. The climate is a typical four-season continental climate of the Northern Hemisphere, with cold and dry winters and hot and wet summers. January is the coldest month (mean low –4ºC), and July is the warmest (mean high 26ºC). The frost period extends from October 14 to April 1. Beijing straddles Hardiness Zones 6 and 7, with mean annual minimum temperatures of –23.3ºC to –17.8ºC and –17.7ºC to –12.3°C (for more on the Hardiness Zones of China, see http://www.plantapalm.com/vpe/hardiness/chinaHZ.gif). Annual precipitation is about 638.8 millimeters per year; most precipitation occurs in summer.

Map 1: Administrative Map of Beijing

Note: Due to differences in transliteration methods, the spelling of geographic names in this paper's graphics may vary slightly from those in the text.

Table 1: **Area and Population Distribution of Beijing (11/01/2000)***

Name	**Area** (sq. km)	**Population** (1,000)	**Density** (pop. per sq. km)
Central City	**90.63**	**2,115**	**23,336.6**
Chongwen District	16.46	346	21,020.7
Dongcheng District	25.98	536	20,631.3
Xicheng District	31.66	707	22,331.0
Xuanwu District	16.53	526	31,820.9
Inner Suburbs	**1,294.54**	**6,388**	**4,934.6**
Chaoyang District	470.8	229	4,864.1
Fengtai District	308.0	1,369	4,444.8
Haidian District	430.0	2,240	5,209.3
Shijingshan District	85.74	489	5,703.3
Outer Suburbs	**15,221**	**5,067**	**332.9**
Changping District	1,352	615	454.9
Daxing District	1,039	672	646.8
Fangshan District	2,019	814	403.2
Huairou County	2,129	296	139.0
Mentougou District	1,455	267	183.5
Miyun County	2,227	420	188.6
Pinggu County	1,075	397	369.3
Yanqing County	1,992	275	138.1
Shunyi District	1,021	637	623.9
Tongxian District	912	674	739.0
Total	**16,808**	**13,819**	**822.18**

* The metropolitan area of Beijing is composed of the first eight districts listed in the table, including those of the central city and inner suburbs.

Land Use

During the past 50 years, the city's population has quadrupled (see Figure 1). However, it has grown little in area for the past several thousand years. Since the 1980s there has been a great deal of development, especially around the inner suburbs, but the mix of land uses in Beijing has not changed much.

Flora of Beijing

The inventory of the flora in and around Beijing began as early as the 1700s (Bretschneider, 1898); however, the modern *Flora of Beijing* was not completed until the middle of the last century. The first edition consisted of three volumes (He, 1962, 1964, 1975). The second, revised edition originally consisted of two volumes covering 169 families, 898 genera, and 2,088 species of vascular plants (He, 1984, 1987), including naturalized and escaped species cultivated in gardens and parks, and even some woody plants grown in greenhouses. It included nine families and 437 species more than the first edition. The second edition was expanded and reprinted in 1992, with an additional 118 species, bringing the total number of vascular plants in Beijing to 169 families, about 900 genera, and 2,206 species (He, 1992).

Vegetation

Geographically, the native vegetation of north China should be pine-oak mixed broad-leaved deciduous forest, especially in the lower mountains around the Beijing area. However, long-term large-scale human activities—deforestation, farmland clearing, and urbanization—have altered the original vegetation as well as its character. Within the city and in outlying suburban areas, farmland, orchards, and villages have long since replaced the native forest. In surrounding mountainous areas, most of the native vegetation is also gone, and oak (*Quercus* spp.), aspen (*Populus davidiana*), and birch (*Betula* spp.) have become dominant species, with lespedeza (*Lespedeza* spp.), early deutzia (*Deutzia grandiflora*), and spiraea (*Spiraea* spp.) in the shrub layer, and some grasses in the ground layer. See Table 2 for a list of representative trees and shrubs that can be found at various elevations.

Figure 1: Rate of Population Increase in the Past 50 Years (1950–2000)

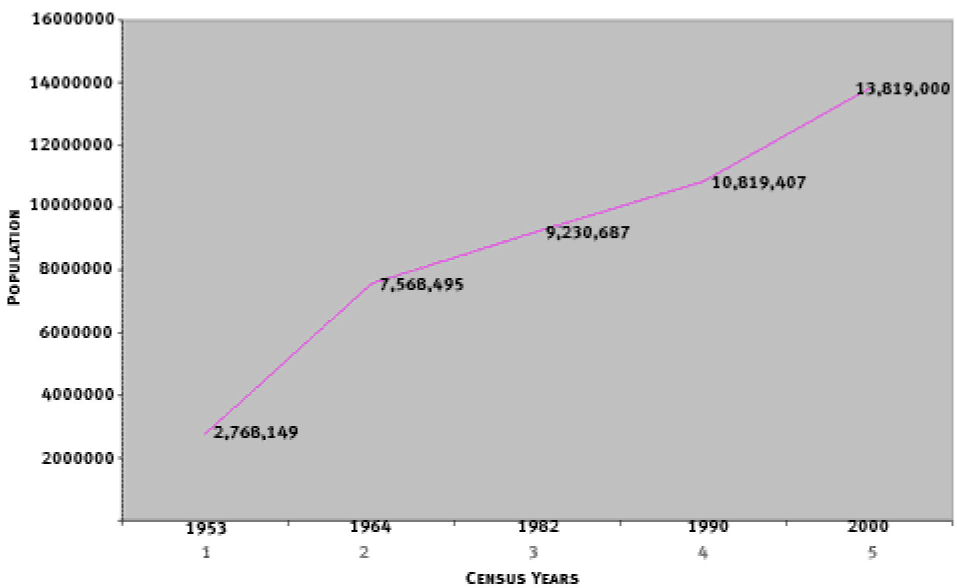


Figure 1. Population figures are from the five official state censuses of China (see the China Population Information and Research Center website at http://www.cpirc.org.cn/eindex.htm):

Census	Date	Population
First Census	June 3, 1953	2,768,149
Second Census	June 30, 1964	7,568,495
Third Census	July 1, 1982	9,230,687
Fourth Census	July 1, 1990	10,819,407
Fifth Census	November 1, 2000	13,819,000

Native Plants

The number of native vascular plants in Beijing, broken down by group (ferns, gymnosperms, and angiosperms) and location within the city (central city, inner suburbs, and outer suburbs) is shown in Table 3.

From these data, it is clear that most of the native plants are found in the suburbs, especially the outer suburbs. A significant number of vascular plants are found only in the remote mountainous areas of the outer suburbs. About one third of the total native flora (455 of 1,502 species) are found in these areas. In contrast, in the central city, as in most highly urbanized areas around the world, there are few native plants. See Map 2 for a breakdown of numbers of species and percentages of total native flora by district and county.

Table 2: Representative Native Plants of Beijing, Grouped by Elevation

Below 800 meters
Trees
Pine (*Pinus tabulaeformis*)
Oaks (*Quercus variabilis*, *Q. dentata*)
Maple (*Acer truncatum*)
Golden rain tree (*Koelreuteria paniculata*)
Tree of heaven (*Ailanthus altissima*)
Chinese toon (*Toona sinensis*)
Hornbeam (*Carpinus turczaninowii*)
Shrubs
Cutleaf chaste tree (*Vitex negundo* var. *heterophylla*)
Spiraea (*Spiraea dasyantha*)
Bunge's Chinese myripnois (*Myripnois dioica*)
Japanese themeda (*Themeda japonica*)

800–1,200 meters
Trees
Liaotong Oak (*Quercus liaotungensis*)
Linden (*Tilia* spp.)
Elm (*Ulmus* spp.)
Ash (*Fraxinus rhynchophylla*)
Peking mock-orange (*Philadelphus pekinensis*)
Nut trees, mostly cultivated
Persian walnut (*Juglans regia*)
Chinese chestnut (*Castanea mollissima*)
Chinese date (*Ziziphus jujuba*)
Shrubs
Hazelnut (*Corylus* spp.)
Lespedeza (*Lespedeza* spp.)
Apricot (*Prunus armeniaca*)
Shaggy hydrangea (*Hydrangea bretschneideri*)
Honeysuckle (*Lonicera* spp.)
Buckthorn (*Rhamnus* spp.)
Peking Mock-orange (*Philadelphus pekinensis*)
Herbs
Sedge (*Carex* spp.)
Solomon's seal (*Polygonatum* spp.)

1,200–1,500 meters
Trees
North China larch (*Larix principis-rupprechtii*)
Liaotong oak (*Quercus liaotungensis*)
Wild walnut (*Juglans mandschurica*)
Liaotong aspen (*Populus maximowiczii*)
Aster willow (*Salix viminalis*)

Above 1,500 meters
Trees
Larch (*Larix* spp.)
Spruce (*Picea wilsonii*, *P. meyeri*)
Oak (*Quercus* spp.)
Maple (*Acer* spp.)
Willow (*Salix spp.*)
Shrubs
Spiraea (*Spiraea* spp.)
Honeysuckle (*Lonicera* spp.)
Spiraea (*Spiraea* spp.)
Twinflower abelia (*Abelia biflora*)
Hazelnut (*Corylus* spp.)
Herbs
Chinese shinleaf (*Pyrola rotundifolia* var. *chinensis*)
Gold saxifrage (*Chrysosplenium* spp.)
Twoleaf beadruby (*Maianthemum bifolium*)
Lily-of-the-valley (*Convallaria majalis*)
Lady slipper orchid (*Cyperipedium* spp.)
Bluegrass (*Poa* spp.)

Mountaintops (2,000 meters)
Sedge (*Carex* spp.)
Grass (*Poa* spp.)
Saussurea (*Saussurea* spp.)
Lousewort (*Pedicularis* spp.)
Grass of Parnassus (*Parnassia* spp.)
Anemone (*Anemone* spp.)
Chinese globe flower (*Trollius chinensis*)
Japanese buttercup (*Ranunculus japonicus*)
Chinese poppy (*Papaver nudicaule* var. *chinensis*)
Knotweed (*Polygonum* spp.)
Primrose (*Primula maximowizii*)

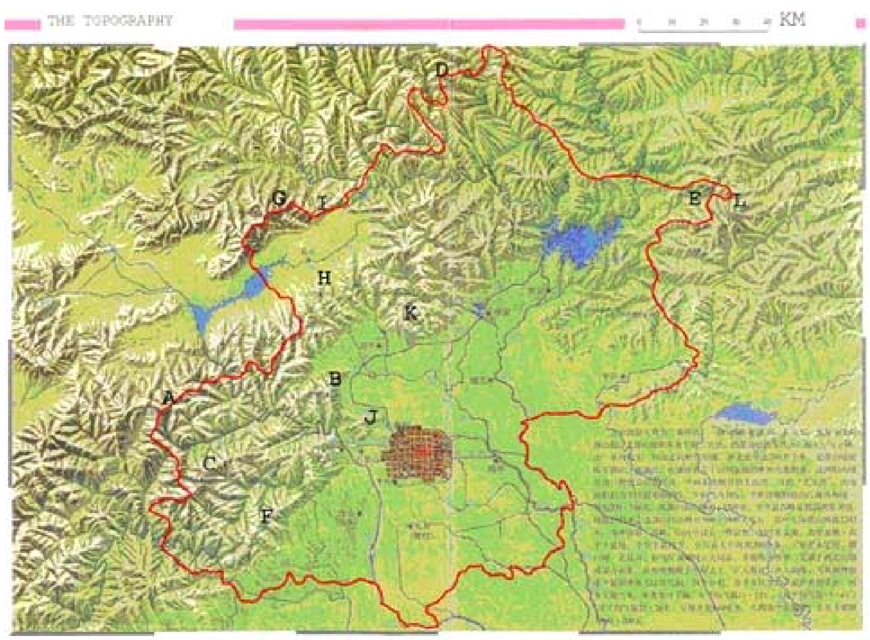
Cortusa matthioli

Table 3: Distribution of Native Vascular Plants in Beijing by Group and Area

	Total	Ferns	Gymnosperms	Angiosperms
Total species	1,677	92	14	1,571
Central city	122	5	3	114
Inner suburbs	462	19	4	439
Outer suburbs	1,093	68	7	1,018

From these data, it is clear that most of the native plants are found in the suburbs, especially the outer suburbs. A significant number of vascular plants are found only in the remote mountainous areas of the outer suburbs. About one third of the total native flora (455 of 1,502 species) are found in these areas. In contrast, in the central city, as in most highly urbanized areas around the world, there are few native plants. See Map 2 for a breakdown of numbers of species and percentages of total native flora by district and county.

Map 2: Topography of Beijing and Key Areas of Plant Distribution*



* Adapted from *The Handbook of Beijing Maps*, by China Map Press (2001, with permission).

Key Areas of Plant Distribution
A. Donglingshan (highest peak), Mentougou District
B. Miaofengshan, Mentougou District
C. Baihuashan, Mentougou District
D. Labagoumen–Sunsanzhi Forest Conservation Area, Huarou County
E. Potou, Miyun County
F. Shangfangshan, Fangshan District
G. Haitoushan, Yanqing County
H. Badaling, Yanqing County
I. Songshan, Yanqing County
J. Jinshan, Xishan, and Xiangshan, Haidian District
K. Nankou and Xiaotangshan, Changping District
L. Wulingshan, Hebei Province

Number of Plants by District or County

Mentougou District (A. Donglingshan; B. Miaofengshan; C. Baihuashan, near Hebei Province to the west): 292 species, or more than 19.4% of the native flora.

Miyun County (E. Potou, bordering Hebei Province to the northeast; L. Wulingshan, eastern Hebei Province): 193 species, or more than 12.8% of native flora.

Huarou County (D. Labagoumen–Sunsanzhi Forest Conservation Area, in northern mountains near border with Hebei Province): 117 species, or about 7.8% of native flora.

Fangshan District (F. Shanfangshan): 68 species, or about 4.5% of native flora.

Yanqing County (G. Haitoushan; H. Badaling; I. Songshan): 63 species, or about 4.2% of native flora.

Haidian District (J. Jinshan, Xishan, and Xiangshan): 53 species, or about 3.5% of native flora.

Changping District (K. Nankou and Xiaotangshan): 19 species, or 1.3% of native flora.

Endemic Plants

About 20 species in *Flora of Beijing* are endemic to Beijing or semiendemic (shared only with neighboring Hebei Province). The endemic and semiendemic species are listed in Table 4.

Table 4: Endemic and Semiendemic Plants of Beijing and Their Distributions*

Aconitum leucostomum (Ranunculaceae) in Yanqing, Hairou, and Miyun Counties (also in Hebei Province)

Adenophora wulingshanica (Campanulaceae) in Potou, Miyun County (also in Hebei Province)

Arenaria formosa (Caryophyllaceae) in Miyun County (also in Hebei Province)

Asplenium miyunense (Aspleniaceae) in Potou, Miyun County

Asplenium pseudo-varians (Aspleniaceae) in eastern Beijing (also in Hebei Province)

Astragalus hancockii (Leguminosae) in Donglingshan and Baishuashan, Mengtougou District (also in Hebei Province)

Batrachium pekinense (Ranunculaceae) in valleys and along stream banks from Nankou to Juyongguan in northwestern Changping District

Clematis acerifolia (Ranunculaceae) in Shangfangshan, Fangshan District; and Baihuanshan and Donglingshan, Mentougou District (also in Hebei Province)

Clematis pinnata in Jinshan and Baihuanshan, Mentougou District, and Pinggu County

Gentiana tenuicaulis (Gentianaceae) (rarely found) in Huairou County (also in Hebei Province)

Gypsophila acutifolia (Caryophyllaceae) in Baihuashan, Mengtougou District (also in Hebei Province)

Hypodematium laxum (Aspleniaceae) in Shangfangshan, Fangshan District (also in Hebei Province)

Ligusticum filisectum (Umbelliferae) in Pinggu, Yanqing, Huairou and Miyun Counties (also in Hebei Province)

Pimpinella cnidioides (Umbelliferae) (record only, no specimen)

Peucedanum hirsutiusculum (Umbelliferae) in Shangfangshan, Fangshan District, and Xishan, Haidian District (also in Hebei Province)

Peucedanum trinioides (Umbelliferae) in Baihuashan and Donglingshan, Mengtougou District (also in Hebei Province)

Phlomis jeholensis (Labiatae) in Huairou, Pinggu County (also in Hebei Province)

Poa longiglumis (Gramineae) in Baihuashan, Haidian District (also in Hebei Province)

Poa lepta in Baihuashan, Haidian District (also in Hebei Province)

Poa schoenites in Jinshan and Baihuashan, Haidian District (also in Hebei Province)

Quercus fangshanensis (Fagaceae) in Shangfangshan, Fangshan District (known only from the Type specimen; perhaps a hybrid between *Q mongolica* and *Q aliena* var. *pekingensis*).

Rhamnus bungeana (Rhamnaceae) in Shangfangshan, Fangshan District and Miaofengshan, Mentougou District only

Saussurea scleroplepis (Compositae) in Potou, Miyun County (also in Hebei Province)

Scirpus schansiensis (Cyperaceae) in Changping District, Huairou and Miyun Counties (also in Hebei Province)

Cultivated Species

Of the 2,206 vascular plants found in Beijing, 704 (about one third) are nonnative species (i.e., introduced, escaped, naturalized, and/or cultivated). Of these, 257 species are widely cultivated, 152 species are occasionally cultivated, and 295 species are found only in gardens and parks, including in greenhouses (see Figure 2). Six hundred one species were introduced intentionally; 96 escaped or naturalized without cultivation; 7 are hybrids. Two hundred fifty species originated in other parts of China; 107 species are from Central and South America; 86 species are from North America; 72 species came from Europe; 65 species are from Africa; 63 species originated in other parts of Asia; 16 species are from the Mediterranean; and seven species came from Australia. The origin of the remaining species is unknown (see Figure 3).

See Table 5 for a list of cultivated species treated in *Flora of Beijing*, grouped by use.

See Table 6 for a list of the street trees of central Beijing.

Figure 2: Native Status of Plant Species in Beijing

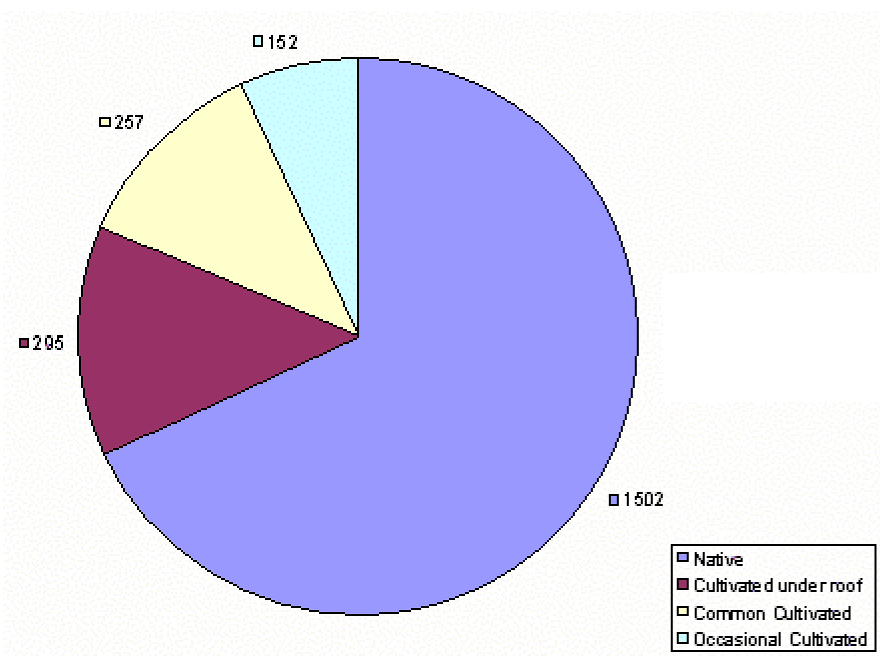


Figure 3: Origin of Nonnative Plant Species in Beijing

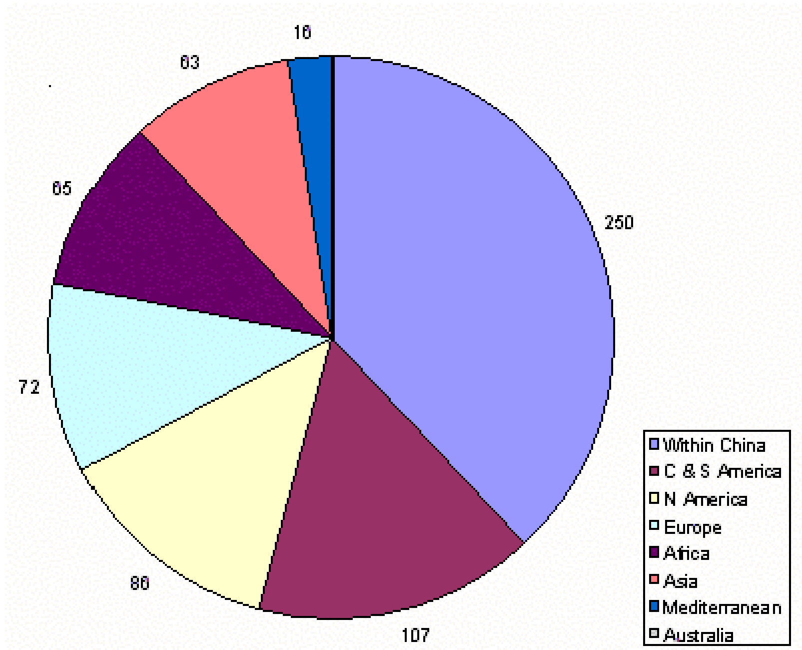


Table 5: Cultivated Plants in *Flora of Beijing*, Grouped by Use

Economic Plants
Common tobacco (*Nicotiana tabacum*)
Eucommia (*Eucommia ulmoides*)
Flatspine pricklyash (*Zanthoxylum bungeanum*)

Oil Crops
Castor bean (*Ricinus communis*)
Common sunflower (*Helianthus annuus*)
Peanut (*Arachis hypogaea*)
Soybean (*Glycine max*)

Crops
Barley (*Hordeum vulgare*)
Common buckwheat (*Fagopyrum esculentum*)
Faxtail millet (*Setaria italica*)
Indian corn (*Zea mays*)
Proso millet (*Panicum miliaceum*)
Rice (*Oryza sativa*)
Sorghum (*Sorghum vulgare*)
Wheat (*Triticum aestivum*)

Fruits
Apple (*Malus pumila*)
Apricot (*Prunus armeniaca*)
Bretschneider pear (*Pyrus bretschneideri*)
Chinese hawthorn (*Crataegus pinnatifida*)
Chinese pearleaf crabapple (*Malus asiatica*)
Chinese waxgourd (*Benincasa hispida*)
Cucumber (*Cucumis sativus*)
Cushaw (*Cucurbita moschata*)
Grape (*Vitis vinifera*)
Muskmelon (*Cucumis melo*)
Peach (*Prunus persica*)
Plum (*Prunus salicina*)
Pumpkin (*Cucurbita pepo*)
Watermelon (*Citrullus vulgaris*)

Nuts
Chinese chestnut (*Castanea mollissima*)
Chinese date (*Ziziphus jujuba*)
Persian walnut (*Juglans regia*)

Legumes
Pea (*Pisum sativum*)
Bean (*Phaseolus vulgaris*)
Broad bean (*Vicia faba*)
Cowpea (*Vigna sinensis*)
Hyacinth bean (*Dolichos lablab*)

Vegetables
Beet (*Beta vulgaris*)

Cabbage (*Brassica oleracea* var. *capitata*)
Carrot (*Daucus carota*)
Cauliflower (*Brassica oleracea* var. *botrytis*)
Celery (*Apium graveolens*)
Chinese cabbage (*Brassica chinensis*)
Eggplant (*Solanum melongena*)
Fennel (*Foeniculum vulgare*)
Fragrant onion (*Allium odorum*)
Garlic (*Allium sativum*)
Lettuce (*Lactuca sativa*)
Onion (*Allium cepa*)
Peking cabbage (*Brassica pekinensis*)
Potato (*Solanum tuberosum*)
Radish (*Raphanus sativus*)
Red pepper (*Capsicum annuum*)
Spinach (*Spinacia oleracea*)
Sweet potato (*Ipomoea batatas)*
Welsh onion (*Allium fistulosum*)

Table 6: Street Trees of Beijing*

More than 50% of total species
Aspen (*Populus* spp.)
Juniper (*Sabina* spp.)
Japanese pagoda tree (*Sophora japonica*)
Locust (*Robinia* spp.)

About 25% of total species
Siberian elm (*Ulmus pumila*)
Maidenhair tree (*Ginkgo biloba*)
Maple (*Acer truncatum*)
Tree of heaven (*Ailanthus altissima*)
Ash (*Fraxinus* spp.)
Paulownia (*Paulownia* spp.)
Pine (*Pinus* spp.)
Silk tree (*Albizzia julibrissin*)
Sycamore (*Platanus* spp.)

Fruit trees, about 15% of total species
Apple (*Malus pumila*)
Apricot (*Prunus persica*)
Chinese date (*Zizyphus jujuba*)
Chinese hawthorn (*Crataegus pinnatifolia*)
Chinese toona (*Toona sinensis*)
Mulberry (*Morus* spp.)
Pomegranate (*Punica granatum*)
Persian walnut (*Juglans regia*)
Wild kaki persimmon (*Diospyros kaki*)

Old and historic trees found mainly around palaces and temples and in parks, about 10% of total species
Chinese arborvitae (*Platycladus orientalis*)
Chinese juniper (*Sabina chinensis*)
Chinese pine (*Pinus tabulaeformis*)

*From "Urban Forestry in Beijing," (Dembner, 1993).

Invasive Species

Although invasion by nonnative species is accepted as a serious threat to natural environments as well as to human health and welfare worldwide (Boufford, 2001), there are little data on invasive species in *Flora of Beijing.* Research in this area is hampered by the lack of data and plant collections, and by the fact that no papers on this subject have yet been published. However, it is possible to extrapolate a few examples of invasive species from *Flora of Beijing:*

Common ragweed (*Ambrosia artemisiifolia*): Widespread from the Yangtze River valley to northern China in the eastern part of the country, this species was very recently found in Beijing. Originally from North America, it has naturalized widely in China since 1970, although it was found as early as the 1930s (Zhu, Sha & Zhou, 1998) and was present in Europe and Russia well before that (Esipenko, 1991; Dimitriev, 1994; Nedoluzhko, 1984). This is a very harmful weed, both to crops and natural vegetation.

Cow soapwort (*Vaccaria segetalis*): Originally from Europe, the species naturalized in China around the 1950s, especially on farmland. It has been become an increasingly serious weed plant since the 1980s. It has also been cultivated and used as a medicinal plant in China.

Giant ragweed (*Ambrosia trifida*): Also from North America, this species was not found in Beijing before 1987, although it was present in the neighboring province of Hebei. However, when *Flora of Beijing* was reprinted in 1992, it was already found in more than five districts and counties in

Beijing. This highly invasive weed has the potential to spread widely and quickly.

Johnsongrass (*Sorghum halepense*): This species was first found in Fengtai District in 1988. Now on the National Quarantine List of China, it is believed to have been introduced via seed-exchange stocks.

Spine cocklebur (*Xanthium spinosum*), smooth cocklebur (*X. glabrum*), and Italian cocklebur (*X. italicum*): All three of these species were found very recently (1988 and 1991). The first, from Europe and Asia, was introduced via seed-exchange stocks; the latter two came from North and South America and southern Europe. The fact that both these plants were found on farmland in Changping District at the same time suggests that they were introduced by chance with imported seed in seed-exchange stocks.

Toothed spurge (*Euphorbia dentata*): The first specimen of this North American native was collected in the Medical Plant Garden, Institute of Medical Plant Development, Chinese Academy of Medical Sciences in the suburbs of Beijing around the 1960s. By the 1990s it had spread throughout the Botanic Garden, Institute of Botany, Chinese Academy of Sciences in Xiangshan, Haidian District. The status of the plant has not been updated since the first report in China (Ma & Wu, 1993). This species may have been introduced to China along with seed-exchange stocks.

The following species are the most commonly found weeds in Beijing: Chinese goosefoot (*Chenopodium acuminatum*); Japanese hop (*Humulus scandens*); common lagopsis (*Lagopsis supine*); barnyard grass (*Echinochloa crusgallii*); and crab grass/digitaria (*Digitaria chrysoblephara*).

Floristics

The flora of Beijing is a typical flora of the Northern Hemisphere with strong continental characteristics. Families with the highest number of species are listed in Table 7.

Table 7: Families With the Highest Number of Species

Compositae (Asteraceae, aster family): 98 genera, 238 species, and 7 varieties, including 78 cultivated species

Gramineae (Poaceae, grass family): 78 genera, 151 species, and 15 varieties, including 32 cultivated species

Leguminosae (Fabaceae, legume family): 44 genera, 113 species, and 6 varieties, including several introduced and naturalized species

Rosaceae (rose family): 25 genera, 99 species, and 11 varieties

Cyperaceae (sedge family): 11 genera, 69 species, and 2 varieties

Liliaceae (lily family): 39 genera, 86 species, and 18 varieties

Labiatae (Lamiaceae, mint family): 25 genera, 63 species, and 70 varieties

Cruciferae (Brassicaceae, mustard family): 26 genera, 29 species, and 4 varieties

Umbelliferae (Apiaceae, carrot family): 28 genera, 40 species, and 2 varieties

Caryophyllaceae (pink family): 15 genera, 49 species, and 1 variety

Polygonaceae (smartweed family): 6 genera and 40 species

Scruphulariaceae (figwort family): 23 genera, 40 species, and 5 varieties

Collections and Research

Several herbaria in Beijing include collections from the city as well as surrounding areas. Table 8 lists the major herbaria in Beijing, the years they were established, the number of specimens, and the focus of the collections.

As Table 8 indicates, herbarium collections of the flora around Beijing are quite extensive. This made it possible to revise *Flora of Beijing* in a short time (1975–1987); Beijing's was also the first revised edition among the local floras of China (Ma & Liu, 1998).

Most of the local flora research is done at the Herbarium of Beijing Normal University (BNU), led by Professor He Shi-Yuan with his students, as well as staff from other institutions who have joined the team. However, for various reasons, the floristic work has not been as extensive as urban floras in western countries. The BNU collections are still limited, and voucher specimens no longer exist for some taxa described in *Flora of Beijing.* Even in the revised edition (1987), there are still at least 24 species without voucher specimens; these have been described from previous records only. Nonnative species have not been emphasized—a subject of increasing importance now that China has opened its markets to the outside; more and more plants, introduced intentionally or unintentionally, will become invasive in coming years. Furthermore, the older generation of botanists is retiring, and there are few young scientists focused on local floristics. This is of particular concern in view of the work yet to be done in China to meet modern standards in Western countries.

Though there are a number of herbarium collections in Beijing, as Table 8 shows, most of them were established fairly recently. The earliest herbaria in Beijing date to around the beginning of the last century. However, this does not mean that no research was done before that time: European botanists did a great deal of collecting in the area, and their research was published outside China. These works can be found in *A Bibliography of Eastern Asiatic Botany* (Merrill & Walker, 1938), in its supplement (Walker, 1960), and in *History of European Botanical Discoveries in China* (Bretschneider, 1898). In addition, important early collections from Beijing are deposited at major gardens and botanical institutions in Europe. These herbaria are crucial for tracking early records of the flora of Beijing.

Table 8: Major Herbaria of Beijing

Abbreviation*	Year Established	No. Specimens	Focus of Collection
BAU	**1949**	**40,000**	**Weeds from north China**
BCMM	1960	30,000	Traditional Chinese medicine
BJFC	1943	50,000	Woody plants of China
BJM	1959	36,000	North China
BJTC	1956	38,000	Local collection
BNU	1912	65,000	Basis of Flora of Beijing
CAF	**1953**	**120,000**	**Woody plants of China**
CMMI	1955	100,000	Traditional Chinese medicine
CPB	1950	20,000	Medicinal plants
IMD	1949	50,000	Medicinal plants
IMM	1956	45,000	Traditional Chinese medicine
PE	1928	2,000,000	Largest national herbarium
PEM	1943	15,000	Medicinal plants
PEY	1905	50,000	Oldest herbarium in China**

* From *Index Herbariorum (*Holmgren, Holmgren & Barnett, 1990) and *Index Herbariorum Sinicorum* (Fu, Zhang, Qin & Ma, 1993).
** Excluding Hong Kong and Taiwan.

Suggestions for Further Research

If *Flora of Beijing* is to meet the standards for modern urban floras, the following issues should be addressed in future revisions, especially if it is to serve as an example for future urban floras in China.

Description

Native and Nonnative Status

The origin of each species should be included in future editions of Flora of Beijing. "Native" indicates that the plant originates in the area where it was first encountered and described. "Nonnative" includes all plants other than native species, including those introduced, escaped, naturalized, and/or cultivated at parks and gardens, in greenhouses, and in yards. Special attention should be given to invasive species, a subject neglected in the past by both local and national floras.

Scale and Scope of Distribution

The distribution information by genus and species should be described in detail, from large to small scale: worldwide, Northern Hemisphere, Eurasia, East Asia, countrywide, region (northwest, north, northeast, etc.), province, county, district-town, etc., with as much local detail as possible. Latitude and longitude should also be recorded, and if feasible, Geographic Positioning Systems (GPS) data should be recorded and uploaded into Geographic Referencing Systems software; these technologies are among the fastest and best new tools for floristics fieldwork and collection management.

Conservation

The population abundance of the species—rated as widespread, common, occasional, rare, or only restricted in distribution (for example, found only on mountain summits)—should be recorded in as much detail as possible. In addition, every species should be classified by IUCN (World Conservation Union) global category: EX (extinct) EW (extinct in the wild), CR (critically endangered), VU (vulnerable), NT (near threatened), LC (least concern), DD (data deficient), and NE (not evaluated) (see http://www.redlist.org/). *The China Plant Red Data Book* (Fu, 1992), a reference for rare and endangered species in China, provides another option for classification. Such information is essential for surveying and protecting regional biodiversity.

Habitat

The habitat of each species should be described fully. Simply noting that it is found in the forest or on farmland is not sufficient. For example, the kind of forest should be described (i.e., whether it is native, secondary, or artificial). If a species is located on a mountain, the altitude, slope, and direction in which it is found should be noted. Similarly, the habitats of wetland plants should be specifically recorded (i.e., river, lake, reservoir, creek, mudflat, or bog). Other elements of description that should be incorporated include soils, surrounding human activities, and original vegetation.

Utilization

Human use of plants should also be noted in as much detail as possible. For example, it is not sufficient to say simply that a species has medical or horticultural uses in China; information on specific medicinal or horticultural uses should be supplied. This information plays a very important part in the Chinese history of botany.

Taxonomy

Name Stability—Nomenclature

Detailed information about the status of each species should be provided. If there is any disagreement about its nomenclature, this should be discussed at length. If there is any change in nomenclature, this should also be addressed. This kind of information has yet to be provided in detail. Taxonomic issues should be treated seriously, since in the long term, it is useful not only for current readers but also for future work.

Description

In classical floras like the current *Flora of Beijing*, description is complex—full descriptions are provided for both genera and species. Future revisions should treat the genera in detail; species and infraspecific taxa should be treated by their diagnostic characteristics only, combined with illustrations that can be easily understood and used by both professional botanists and amateurs. In cases of more than two species, there should be detailed keys, without ambiguous choices. Anything peculiar about a taxon, especially about its use, should also be highlighted.

Herbarium Specimens

Specimens provide the basic foundation for floras and are valuable vouchers for research. The current situation in Beijing is slightly better than most local areas in China. However, this does not mean the collections are adequate. Compared with western institutions, these collections are still of low quality, and there is much room for improvement. The quality of the collections needs to be improved, and the number of specimens needs to be increased to ensure that the collections represent an accurate sampling of the flora under investigation.

Information on Cultivated Plants

Cultivated plants should be treated like native species, and information on their origin and natural history should be included in their description. Although the description should be simple, the information should be detailed and include, for example, whether the plants are widely cultivated like crops, occasionally cultivated in parks and gardens, or grown only in greenhouses or residential yards. Cultivated varieties should be listed and their distribution treated like that of other plants in the flora if possible. If a specimen is unavailable, its absence should be explained. The introduction and development of cultivated species should be discussed to better understand their potential effects on society and environment.

Illustrations

Illustrations are extremely useful in local floras, not only for professionals but also for the public. Each genus should be represented by at least one illustration. Also very helpful are illustrations of the diagnostic parts of each species. The simple black-and-white line drawings of the current *Flora of China* are insufficient, and in future revisions, color digital photos would be ideal, especially for online databases. Detailed maps may also be of great help to readers.

Acknowledgments

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The Nonnative Flora of the Kiev (Kyiv) Urban Area, Ukraine: A Checklist and Brief Analysis*

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Abstract

In this paper, an annotated checklist of the nonnative flora of the city and suburbs of Kiev (Kyiv in Ukrainian transliteration), Ukraine, is presented in tabular form. For each taxon, the following data are provided: occurrence, generalized distribution in the area, degree of naturalization, time of immigration, mode of immigration, and geographical origin. The total nonnative flora (past and present) of the Kiev Urban Area (KUA) consists of 536 species of vascular plants belonging to 297 genera and 71 families. It is the most diverse nonnative flora of any urban region in Ukraine. The modern nonnative flora includes 356 species of 207 genera and 62 families. The stable component of the flora consists of 198 species of 147 genera and 51 families. Ephemerophytes (175 species, or 49.2%) and epoecophytes (99 species, or 28.2%) clearly prevail among Kiev's modern nonnative flora. The percentage of species introduced before the end of the 19th century, including archaeophytes (19.6%) and kenophytes (31%), equals that of the eukenophytes (49.4%), the species that were introduced during the 20th century. Leading roles are played by species native to Mediterranean (254 species, or 50.3%) and North American (99 species or 16.3%) floristic regions. Interestingly, North American taxa form the largest portion of the group of species that successfully naturalized in the 20th century; they are followed by plants from eastern Asia. The nonnative plants in the modern urban flora of Kiev continue to gain in importance. This is evident from the high numbers of newcomers that arrived during the last 20 years of the 20th century.

Introduction

The Kiev City Agglomeration (Kiev Urban Area, KUA) is situated in the central part of the eastern European plains, at the border of the forest and forest-steppe physiographic and vegetation zones. Ukraine's capital, the city of Kiev (Kyiv in the Ukrainian-based transliteration), is the natural center of this urbanized area. It is surrounded by several satellite towns and smaller settlements, including Irpin, Brovary, Boryspil, Vyshgorod, and Boyarka. Kiev and its satellites are located on both banks of the Dnipro (Dnieper) River. The area of Kiev within its official administrative borders is 824 square

* Published Online December 24, 2002

kilometers; its population is currently about 2,616,000 people (according to the 2001 census; other estimates that consider recent migration patterns place it at close to 3 million).

Seminatural and man-made habitats are well represented in KUA, and the region's altered or disturbed plant communities are formed mostly by synanthropic plant species. During their long history in central Ukraine, and the Kiev area in particular, humans have greatly promoted the immigration of nonnative plants through migration, war, trade, agriculture, urbanization, and other activities. The oldest fossil human remains in Kiev date to the late Paleolithic era. In Neolithic times, the area was already home to well-developed agriculture, cattle breeding, and various trade crafts.

By the ninth century A.D., Kiev had become an important political and economic center of eastern Europe, with extensive political and trade contacts in the Baltic and Mediterranean regions, in central and western Europe, western and central Asia, and the Caucasus, as well as in other adjacent and distant areas. In the 18th century, Kiev began to develop as an industrial city. Continued development resulted in the formation of a large urbanized area with a dramatically transformed flora and vegetation.

Nonnative plants are an important component of any modern urban flora. The present checklist of Kiev's nonnative flora was compiled using literature data (Bortnyak, 1978a, 1978b; Bortnyak, et al., 1992; Kotov, 1979; Mosyakin, 1990, 1991a, 1991b, 1995, 1996; Protopopova, 1973, 1991; Yavorska & Mosyakin, 2001; and many others), herbarium collections (mainly the collection of the National Herbarium of Ukraine), and data from our recent field studies (in particular, Mosyakin's collections and observations made in 1985–2002 and Yavorska's collections and studies of 1998–2001). However, because of the dynamics of the process of synanthropization of the flora in the Kiev region, the list cannot be regarded as the final one. It only generalizes the most recent stage of nonnative plant study and remains open for further additions and corrections. The number of nonnative species will grow not only as a result of their casual dispersal and immigration but also due to the deliberate introduction into cultivation of new plants, some of which undoubtedly will be able to adapt to, or naturalize in, the man-altered habitats of KUA.

Families, genera within families, and species within genera are arranged in our table alphabetically. The nomenclature mainly follows the checklist of vascular plants of Ukraine (Mosyakin & Fedoronchuk, 1999). The terminology on synanthropic floras and nonnative plants used in the article follows that of European publications. Please note that this terminology is not commonly used in English-speaking countries. However, explanations and discussion of it can be found in many useful publications (Thellung, 1918; Jäger, 1988; di Castri, 1989; Kornas, 1968, 1990; Protopopova, 1973, 1991; and many others). C. Lambelet-Haueter (1990, 1991) presents especially detailed historical overviews. A good North American introduction to traditional European-style studies of nonnative floras can be found in V. Muhlenbach's classic article (1979) on nonnative plants inhabiting the railroads of St. Louis, Missouri. G. Nesom (2000) provides a more recent discussion on categories of alien plants.

The central and eastern European sources on urban floristics are too numerous to be listed here extensively; therefore we cite only selected publications directly related to the nonnative flora of Kiev or to the methods used in this study. Additional references can be found in the cited books and articles.

Categories and Abbreviations

For the checklist of nonnative species, the following categories and abbreviations were used:

Occurrence of species in the modern nonnative flora of KUA (column 1)

C—Common: plants that are widespread and abundant in the territory of the city and/or in adjacent towns and villages.

D—Disappeared: plants that were reported in early surveys but are now considered extirpated (or in some cases eradicated) in the territory.

E—Ephemera-ergasiophytes: plants introduced by man that occasionally escape beyond cultivation but usually do not persist except in the immediate vicinity of their area of cultivation. These plants do not show pronounced trends toward naturalization, and their occurrence depends on a reliable (stable) source of dissemination (e.g., deriving from plants that are extensively and/or permanently cultivated in the area concerned).

L—Local: plants that only occur in some parts of the city but may be locally abundant.

R—Rare: plants that occur in three to five (sometimes up to seven) localities.

S—Sporadic: plants that occur almost everywhere in the city but not in abundance.

U—Unicates: plants collected in one to three localities in KUA during recent decades but not registered during our 1996–2001 floristic survey of the area.

Distribution of species (column 2)

B—Plants found within the town of Boryspil.

Bo—Plants found within the town of Boyarka.

Br—Plants found within the suburb Brovary.

Ir—Plants found within the town of Irpin.

K—Plants found within the city of Kiev only.

KUA—Plants found within the territory of the city of Kiev and its suburbs.

Degree of naturalization (column 3)

Agr—Agriophytes: naturalized in natural and seminatural habitats.

Col—Colonophytes: epoecophytes that occur in the area in one to several stable colonies but which show little or no trend toward further expansion.

Eph—Ephemerophytes: nonnaturalized species, occasional immigrants, or waifs.

Epo—Epoecophytes: naturalized in man-made and disturbed habitats.

Hagr—Hemiagriophytes: naturalized mostly in seminatural or disturbed habitats.

Note: For extinct species, the degree of naturalization is not indicated.

Time of immigration to KUA (column 4)

arch—Archaeophytes: plants that immigrated before the end of the 15th century.

eu-A—Eukenophytes-A: plants that immigrated in the first half of the 20th century.

eu-B—Eukenophytes-B: plants that immigrated after World War II to the end of the 1970s.

eu-C—Eukenophytes-C: plants that immigrated during the last 20 years.

ken—Kenophytes: plants that immigrated between the 16th century and the end of the 19th century.

Mode of immigration (column 5)

The above groups are segregated according to the traditional classification (see Lambelet-Haueter, 1990, 1991; Protopopova, 1991, et al.), modified by N.A. Vyukova (1985). For archaeophytes, the mode of immigration to KUA is not specified due to the lack of scientifically reliable data. However, we specify the immigration status for a few archaeophytes (14 species of cultivated plants and some specialized weeds of crops) in those rare cases when it is reliably known from archaeobotanical and historical sources. Those species whose nonnative status in the territory of research is questionable (especially when it is unclear whether borders of the native range of a species probably cover, or at least closely approach, our territory) are also provisionally listed below, but their names in column 1 are preceded by a question mark (?).

Erg—Ergasiophytes: plants that were intentionally introduced and cultivated by man, and then spread from places of their cultivation.
Xen—Xenophytes: plants introduced unintentionally.
X-Erg—Xeno-ergasiophytes: plants cultivated outside of the studied area but unintentionally introduced to Kiev.

Initial (original, native) ranges of nonnative species (column 6)

Afr—African; **Afr-Sas**—African–south Asian; **anthr**—of anthropogenic origin (taxa that emerged and evolved in man-made habitats); **As**—Asian; **AsM**—Asia Minor; **CAm**—Central American; **CaAs**—central Asian; **Cauc**—Caucasian; **CEu**—central European; **EAs**—eastern Asian; **EMed**—eastern Mediterranean; **hybr**—species of hybrid origin; **Ir-An**—Irano-Anatolian; **Ir-Tr**—Irano-Turanian; **Med**—Mediterranean; **Med-Cas**—Mediterranean–Irano-Turanian (or Mediterranean–central Asian); **Med-Ir-An**—Mediterranean–Irano-Anatolian; **n/a**—initial range uncertain (34 species); **NAm**—North American; **NMed**—North Mediterranean; **Pon**—Pontic; **S-Eas**—southeastern Asian; **SAm**—South American; **SAs**—south Asian; **SEu**—southern European; **Sib**—Siberian; **WEu**—western European; **WMed**—western Mediterranean.

Checklist of Nonnative Plants of the Kiev Urban Area

Families and Species	**1**	**2**	**3**	**4**	**5**	**6**
ACERACEAE						
Acer negundo L.	C	KUA	Agr	eu-A	Erg	NAm
Acer pseudoplatanus L.	S	KUA	Epo	eu-B	Erg	WEu
Acer saccharinum L.	S	KV	Hagr	eu-B	Erg	NAm
AMARANTHACEAE						
Amaranthus albus L.	C	KUA	Epo	eu-A	Xen	NAm
Amaranthus blitoides S. Watson	C	KUA	Epo	eu-B	Xen	NAm
Amaranthus blitum L. (= *A. lividus* L.)	R	K	Eph	ken	Erg	S-EAs
Amaranthus caudatus L.	R	KUA	Eph	ken	Erg	SAm
Amaranthus cruentus L. (incl. *A. paniculatus* L.)	E	KUA	Eph	eu-A	Erg	CAm
Amaranthus hybridus L. s. str.	R	K	Eph	eu-C	Xen	CAm
Amaranthus hypochondriacus L.	E	K	Eph	eu-C	Erg	NAm

Amaranthus palmeri S. Watson	U	K	Eph	eu-C	Xen	NAm
Amaranthus powellii S. Watson	L	KUA	Epo	eu-C	Xen	CAm
Amaranthus retroflexus L.	C	KUA	Epo	ken	Xen	NAm
Amaranthus rudis Sauer	U	K	Eph	eu-C	Xen	NAm
Amaranthus spinosus L.	U	K	Eph	eu-C	Erg	SAm
Amaranthus tuberculatus (Moq.) Sauer	U	K	Eph	eu-C	Xen	NAm
ANACARDIACEAE						
Cotinus coggygria Scop.	L	K	Hagr	eu-B	Erg	Med
Toxicodendron radicans (L.) O. Kuntze	E	K	Eph	eu-C	Erg	NAm
APIACEAE						
? *Aethusa cynapium* L.	C	KUA	Epo	arch		WEu
Anethum graveolens L.	L	KUA	Epo	ken	Erg	Med-CAs
Anthriscus cerefolium (L.) Hoffm.	R	K	Eph	eu-B	Xen	Med
Bifora radians M. Bieb.	R	K	Eph	eu-C	Xen	Med
Bupleurum rotundifolium L.	R	KUA	Eph	eu-A		Med-Ir-An
Carum carvi L.	E	KUA	Eph	ken	Erg	n/a
Caucalis platycarpos L.	D	K	Eph	eu-A	Xen	Med
? *Conium maculatum* L.	C	KUA	Epo	n/a	Xen	Med-CAs
Coriandrum sativum L.	E	KUA	Eph	ken	Erg	Med
Foeniculum vulgare Mill.	E	KUA	Eph	ken	Erg	Med
Heracleum mantegazzianum Sommier & Levier	L	K	Col	eu-C	Erg	Cauc
Levisticum officinale Koch	E	KUA	Col	ken	Erg	Med-CAs
Pastinaca sativa L.	E	KUA	Eph	ken	Erg	Med-CAs
Pastinaca umbrosa Steven ex DC.	S	K	Epo	ken	Xen	Med-CAs
Petroselinum crispum (Mill.) A.W. Hill	E	KUA	Eph	ken	Erg	Med
Turgenia latifolia (L.) Hoffm.	U	K	Eph	eu-C	Xen	Med
APOCYNACEAE						
Apocynum cannabinum L.	L	KUA	Col	eu-C	Erg	n/a
Vinca minor L.	L	KUA	Hagr	ken	Erg	n/a
ARACEAE (incl. **ACORACEAE**)						
Acorus calamus L.	S	KUA	Agr	arch		S-EAs
ASCLEPIADACEAE						
Asclepias syriaca L.	S	K,Ir	Epo	ken	Erg	NAm
ASPHODELACEAE						
Anthericum liliago L.	E	K	Eph	ken	Erg	Med
ASTERACCAE						
Achillea micrantha Willd.	D	K	Eph?	eu-A	Xen	Pon
Acroptilon repens (L.) DC.	R	K	Col	eu-C	Xen	Ir-Tr
Ageratum houstonianum Mill.	R	KUA	Eph	eu-B	Erg	CAm
Ambrosia artemisiifolia L.	S	KUA	Epo	eu-B	Xen	NAm
Ambrosia trifida L.	U	K	Eph	eu-C	Xen	NAm
Anthemis arvensis L.	S	KUA	Epo	arch		NMed
Anthemis cotula L.	S	KUA	Eph	arch		EMed
? *Artemisia absinthium* L.	S	KUA	Epo	arch		Med-CAs

Artemisia annua L.	C	KUA	Hagr	eu-A	Xen	EAs
Artemisia argyi Levéillé & Vaniot	R	K	Col	eu-C	Xen	EAs
Artemisia dracunculus L.	R	K	Eph	eu-C	Xen	Sub
Artemisia glauca Pallas ex Willd.	R	K	Eph	eu-C	Xen	Sub
Artemisia rubripes Nakai	D	K	Eph	eu-C	Xen	EAs
Artemisia selengensis Turcz. ex Besser	D	KUA	?	eu-C	Xen	CAs
Artemisia sieversiana Willd.	L	KUA	Epo	eu-C	Xen	Med-CAs
Artemisia tournefortiana Reichb.	L	K	Col	eu-C	Xen	Ir-Tr
Artemisia umbrosa (Turcz. ex Besser) Pamp.	R	K	Eph	eu-C	Xen	EAs
Aster lanceolatus Willd.	S	KUA	Eph	ken	Erg	NAm
Aster novae-angliae L.	E	KUA	Eph	ken	Erg	NAm
Aster novi-belgii L.	E	KUA	Eph	ken	Erg	NAm
Aster x salignus Willd.	E	KUA	Eph	ken	Erg	NAm
Bellis perennis L.	E	K	Eph	ken	Erg	n/a
Bidens connata Muehl. ex Willd.	L	K	Hagr	eu-C	Xen	NAm
Bidens frondosa L.	S	K	Agr	eu-B	Xen	NAm
Calendula officinalis L.	E	KUA	Eph	ken	Erg	Med
Carduus acanthoides L.	L	KUA	Epo	arch		NMed
Carduus nutans L.	L	KUA	Epo	arch		NMed
Centaurea cyanus L.	S	KUA	Epo	arch		Med
Centaurea depressa M.Bieb.	R	K	Eph	eu-C	Xen	Ir-Tr
Centaurea diffusa Lam.	R	K	Epo	eu-A	Xen	Med-CAs
Cichorium endivia L.	D	K	?	ken	Erg	Med-CAs
? *Cichorium intybus* L.	C	KUA	Hagr	arch		Med-CAs
Cirsium ciliatum (Murr.) Moench	U	K	Eph	eu-C	Xen	Kv
Conyza canadensis (L.) Cronq. (= *Erigeron canadensis* L.)	C	KUA	Hagr	ken	Xen	NAm
Coreopsis grandiflora Hogg ex Sweet	E	K	Eph	eu-C	Erg	NAm
Cosmos bipinnatus Cav.	E	KUA	Eph	eu-C	Erg	CAm
Galinsoga parviflora Cav.	C	KUA	Epo	ken	Erg	SAm
Galinsoga urticifolia (Kunth) Benth. (*G. ciliata* auct.)	R	K	Eph	eu-C	Xen	SAm
Grindelia squarrosa (Pursh) Dunal	L	KUA	Col	eu-B	Xen	NAm
Helianthus annuus L.	R	KUA	Eph	ken	Erg	NAm
Helianthus decapetalus L.	S	KUA	Col	eu-C	Erg	NAm
Helianthus rigidus (Cass.) Desf.	E	K	Eph	eu-C	Erg	NAm
Helianthus subcanescens (A.Gray) E. Watson	S	KUA	Col	eu-C	Erg	NAm
Helianthus tuberosus L.	L	KUA	Col	ken	Erg	SAm
Helianthus x *laetiflorus* Pers.	S	KUA	Col	eu-C	Erg	NAm
Inula helenium L.	E	KUA	Eph	eu-A	Erg	n/a
Iva xanthiifolia Nutt.	C	KUA	Epo	ken	Erg	NAm
Lactuca sativa L.	E	KUA	Eph	ken	Erg	n/a
? *Lactuca serriola* L.	S	KUA	Epo	arch		Med-CAs
Lactuca tatarica (L.) C.A.Mey.	L	KUA	Col	eu-B	Xen	Ir-Tr
Lepidotheca suaveolens (Pursh) Nutt.	C	KUA	Epo	ken	Xen	NAm
Matricaria recutita L.	C	KUA	Epo	ken	Erg	WEu

Onopordon acanthium L.	C	KUA	Epo	arch		Med-CAs
Phalacroloma annuum (L.) Dumort.	C	KUA	Epo	ken	Xen	NAm
Phalacroloma septentrionale (Fern. et Wieg.) Tzvelev	C	KUA	Epo	eu-B	Xen	NAm
Pyrethrum partheniifolium Willd.	E	K	Eph	eu-B	Erg	Med
Pyrethrum parthenium (L.) Smith	E	K	Col	eu-A	Erg	WEu
Rudbeckia hirta L. (incl. *R. bicolor* Nutt.)	L	KUA	Eph	ken	Erg	NAm
Rudbeckia laciniata L.	R	KUA	Col	ken	Erg	NAm
Senecio viscosus L.	S	KUA	Epo	eu-B	Xen	CEv
? *Senecio vulgaris* L.	S	KUA	Epo	arch		Med
Silphium perfoliatum L.	L	KV	Col	eu-C	Erg	NAm
Solidago canadensis L.	L	KUA	Hagr	ken	Erg	NAm
Solidago serotinoides A.Löve & D.Löve (*S. gigantea* auct.)	L	KUA	Col	eu-B	Erg	NAm
Sonchus arvensis L.	L	KUA	Epo	arch		Med
Sonchus asper (L.) Hill	S	KUA	Epo	arch		Med
Sonchus oleraceus L.	S	KUA	Epo	arch		Med
Tagetes erecta L.	E	KUA	Eph	ken	Erg	CAm
Tagetes patula L.	E	KUA	Eph	ken	Erg	CAm
Tripleurospermum inodorum (L.) Sch.Bip.	R	KUA	Epo	arch		EMed
Xanthium albinum (Widder) H.Scholz	C	KUA	Agr	eu-B	Xen	WEu
Xanthium ripicola Holub	L	KUA	Epo	eu-B	Xen	CEv
Xanthium spinosum L.	U	KUA	Eph	ken	Xen	SAm
Xanthium strumarium L. s. str.	R	KUA	Epo	arch		Ir-Tr
BALSAMINACEAE						
Impatiens glandulifera Royle (*I. roylei* Walp.)	S	K	Hagr	eu-B	Erg	S-EAs
Impatiens parviflora DC.	C	KUA	Agr	ken	Erg	Med-CAs
BERBERIDACEAE						
Berberis thunbergii DC.	E	KUA	Col	eu-C	Erg	EAs
Berberis vulgaris L.	S	KUA	Col	ken	Erg	n/a
Mahonia aquifolium (Pursh) Nutt.	L	KV	Agr	eu-B	Erg	NAm
BORAGINACEAE						
Anchusa officinalis L.	C	KUA	Epo	arch		Med
Argusia sibirica (L.) Dandy	R	K,Ir	Eph	eu-A	Xen	Med-CAs
Borago officinalis L.	R	K	Epo	ken	X-Erg	Med
Buglossoides arvensis (L.) I.M.Johnst.	L	KUA	Epo	arch		Med-CAs
Cynoglosum officinale L.	L	KUA	Epo	arch		Med
Echium plantagineum L.	D	KUA	?	eu-A	Xen	Med
Lappula patula (Lehm.) Menyh.	R	K	Epo	eu-A	Xen	Med-CAs
Lappula squarrosa (Retz.) Dumort.	L	KUA	Epo	arch		Med-CAs
? *Myosotis arvensis* (L.) Hill	C	KUA	Epo	arch		Med-CAs
Symphytum asperum Lepechin	E	K	Col	ken	Erg	WMed
BRASSICACEAE						
Armoracia rusticana P.Gaertn., B.Mey. & Scherb.	L	KUA	Agr	arch	X-Erg	Ir-Tr
Brassica campestris L.	C	KUA	Epo	arch	X-Erg	Med-CAs
Brassica juncea (L.) Gzern.	L	KUA	Eph	eu-B	Xen	Ir-Tr

Brassica napus L.	R	KUA	Eph	ken	Erg	SEu
Brassica nigra (L.) W.D.J.Koch	S	KUA	Epo	eu-A	X-Erg	Med
Brassica rapa L.	R	KUA	Eph	ken	Erg	Med
Bunias orientalis L.	S	KUA	Epo	ken	Xen	EMed
Camelina alyssum (Mill.) Thell.	D	KUA	?	arch		ant
Camelina microcarpa Andrz.	L	K	Epo	arch		Med-CAs
Camelina sativa (L.) Crantz	L	KUA	Eph	arch		ant
? *Capsella bursa-pastoris (*L.) Medik.	C	KUA	Agr	arch		n/a
Capsella orientalis Klokov (*C. bursa-pastoris*) aggr.)	U	K	Eph	eu-B	Xen	Pon
Capsella rubella Reut. (*C. bursa-pastoris* aggr.)	D	K	?	eu-B	Xen	Med
Cardaria draba (L.) Desv.	C	KUA	Epo	ken	Xen	Med
Cardaria pubescens (C.A.Mey.) Jarm.	R	K	Eph	eu-C	Xen	n/a
Chorispora tenella (Pall.) DC.	L	KUA	Epo	ken	Xen	Med-CAs
? *Descurainia sophia* (L.) Webb. ex Prantl	C	KUA	Epo	arch		Med-CAs
Diplotaxis muralis (L.) DC.	L	KUA	Eph	eu-A	Xen	SEu
Diplotaxis tenuifolia (L.) DC.	C	KUA	Epo	ken	Xen	Med
Eruca vesicaria (L.) Cav. (= *E. sativa* Mill.)	R	KUA	Eph	arch	X-Erg	Med
Erucastrum armoracioides (Czern. ex Turcz.) Cruchet	D	KUA	?	eu-A	Xen	Ir-Tr
Erysimum cheiranthoides L.	L	KUA	Epo	arch		Med-CAs
Erysimum repandum L.	S	KUA	Epo	arch		Med-CAs
Euclidium syriacum (L.) R.Br.	U	K	Eph	eu-C	Xen	Ir-Tr
Goldbachia laevigata (M.Bieb.) DC.	U	K	Eph	eu-C	Xen	CAs
Hesperis matronalis L.	E	KUA	Eph	ken	Erg	Ir-Tr
Hirschfeldia incana (L.) Lagr.-Foss.	L	K	Col	eu-C	Xen	EMed
Iberis amara L.	E	KUA	Eph	ken	Erg	Med
Iberis umbellata L.	E	KUA	Eph	ken	Erg	Med
Isatis tinctoria L.	D	K	?	ken	Xen	Med-CAs
Lepidium campestre (L.) R.Br.	R	K	Eph	arch		Med
Lepidium densiflorum Schrad.	C	KUA	Epo	ken	Xen	NAm
Lepidium latifolium L. s.l. (incl. *L. affine* Ledeb.)	L	KUA	Col	ken	Xen	Ir-Tr
Lepidium perfoliatum L.	L	KUA	Epo	ken	Xen	Med-CAs
Lepidium ruderale L.	S	KUA	Epo	arch		Med-CAs
Lobularia maritima (L.) Desv.	E	KUA	Eph	ken	Erg	Med
Matthiola bicornis (Sibth. & Sm.) DC.	E	KUA	Eph	ken	Erg	Med
Matthiola incana (L.) R. Br.	E	KUA	Eph	ken	Erg	Med
Matthiola longipetala (Vent.) DC.	E	KUA	Eph	ken	Erg	Med
Myagrum perfoliatum L.	R	K	Eph	eu-C	Xen	Med
Neslia paniculata (L.) Desv.	R	K	Eph	arch		ant
? *Raphanus candidus* Worosch.	R	KUA	Epo	eu-B	Xen	hybr
Raphanus raphanistrum L.	S	KUA	Epo	arch		Med
Raphanus sativus L.	R	KUA	Eph	ken	Erg	Med
Rapistrum perenne (L.) All.	R	KUA	Col	eu-A	Xen	Med
Rapistrum rugosum (L.) Bergeret	R	KUA	Eph	eu-A	Xen	Med
Sinapis alba L.	S	KUA	Eph	arch	X-Erg	Med

Sinapis arvensis L.	S	KUA	Eph	arch		Med
Sinapis dissecta Lag.	R	K	Eph	eu-A	Xen	Med
Sisymbrium altissimum L.	C	KUA	Epo	ken	Xen	Med-CAs
Sisymbrium loeselii L.	C	KUA	Epo	ken	Xen	Med-CAs
? *Sisymbrium officinale* (L.) Scop.	C	KUA	Epo	arch		Med
Sisymbrium orientale L.	R	K	Eph	eu-C	Xen	Med
Sisymbrium volgense M.Bieb. ex Fourn.	S	KUA	Epo	eu-A	Xen	Pon
Thlaspi arvense L.	C	KUA	Epo	arch		Ir-Tr
CAESALPINIACEAE						
Gleditsia triacanthos L.	R	KUA	Col	ken	Erg	NAm
CAMPANULACEAE						
Campanula medium L.	E	KUA	Eph	eu-C	Erg	n/a
CANNABACEAE						
Cannabis sativa L. s.l. (incl. *C. ruderalis* Janisch.)	C	KUA	Epo	arch		Ir-Tr
CAPRIFOLIACEAE						
Lonicera caprifolium L.	L	K	Col	eu-A	Erg	Med
Lonicera tatarica L.	L	KUA	Col	eu-A	Erg	Sub
Symphoricarpos albus (L.) S.F.Blake	L	KUA	Col	eu-B	Erg	NAm
Viburnum lantana L.	L	K	Col	eu-A	Erg	Med
CARYOPHYLLACEAE						
Agrostemma githago L.	U	K	Eph	arch		ant
Dianthus barbatus L.	E	KUA	Eph	eu-B	Erg	Med
Dianthus euponticus Zapał.	E	K,Ir	Eph	eu-B	Xen	EMed
Gypsophila perfoliata L.	L	K	Eph	eu-B	Xen	Ir-Tr
Lychnis chalcedonica L.	S	KUA	Epo	ken	Erg	As
Oberna cserei (Baumg.) Ikonn.	D	K	?	eu-A	Xen	Med
Petrorhagia saxifraga (L.) Link	E	K	Eph	ken	Erg	Med
Saponaria officinalis L.	S	KUA	HAgr	ken	X-Erg	Med
Scleranthus annuus L.	S	KUA	Epo	arch		WMed
Silene armeria L.	R	K	Eph	?		n/a
Silene dichotoma Ehrh.	R	K	Eph	eu-A	Xen	WEu
Silene gallica L.	S	KUA	Epo	eu-B	Xen	WMed
Silene pendula L.	S	KUA	Epo	ken	Erg	Med
Spergula arvensis L.	S	KUA	Epo	ken	Xen	Med
Spergula maxima Weihe	D	KUA	?	arch		ant
Spergula morisonii Boreau	R	K,Br	Eph	eu-B	Xen	WEu
Vaccaria hispanica (Mill.) Rauschert	U	KUA	Eph	arch		S-EAs
CHENOPODIACEAE						
Atriplex hortensis L.	L	KUA	Epo	ken	Erg	Ir-Tr
Atriplex micrantha C.A. Mey.(= *A. heterosperma* Bunge)	R	K	Eph	ken	Xen	Ir-Tr
Atriplex rosea L.	R	KUA	Eph	eu-B	Xen	Med
Atriplex sagittata Borkh. (= *A. nitens* Schkuhr)	C	KUA	Epo	arch		Ir-Tr
? *Atriplex tatarica* L.	C	KUA	Hagr	arch		Med-CAs
Ceratocarpus arenarius L.	O	K	Eph	eu-C	Xen	Med-CAs

Chenopodium berlandieri Moq.	R	K	Eph	eu-C	Xen	NAm
Chenopodium botrys L.	R	KUA	Eph	eu-A	X-Erg	Med-CAs
Chenopodium chenopodioides (L.) Aellen	R	K	Eph	eu-C	Xen	Med-CAs
Chenopodium ficifolium Smith	S	KUA	Epo	eu-A	Xen	EAs
Chenopodium foliosum Asch.	U	K	Eph	eu-C	Erg	Med
Chenopodium glaucophyllum Aellen	U	K	Eph	eu-C	Xen	NAm
Chenopodium hybridum L.	S	KUA	Epo	n/a		Res
Chenopodium missouriense Aellen	U	K	Eph	eu-C	Xen	NAm
Chenopodium murale L.	U	K	Eph	arch		Med
Chenopodium opulifolium Schrader ex DC.	S	KUA	Epo	arch		Med
? *Chenopodium polyspermum* L.	S	KUA	Epo	arch		n/a
Chenopodium pratericola Rydb.	U	K	Eph	eu-C	Xen	NAm
Chenopodium probstii Aellen	R	K	Eph	eu-C	Xen	n/a
Chenopodium reticulatum Aellen	U	K	Eph	eu-C	Xen	n/a
Chenopodium schraderianum Schultes	R	K	Eph	eu-C	Xen	Afr
Chenopodium striatiforme J. Murr	S	KUA	Epo	n/a	Xen	Med
Chenopodium strictum Roth	C	KUA	Epo	n/a	Xen	NAm
Chenopodium urbicum L.	R	K	Eph	n/a	Xen	Med-CAs
Chenopodium vulvaria L.	D	K	?	ken	Xen	Med-CAs
Corispermum declinatum Steph. ex Iljin	R	K	Eph	eu-C	Xen	EAs
Corispermum pallasii Steven (C. leptopterum auct.)	S	K	Epo	eu-C	Xen	Sub
Corispermum redowskii Fisch. ex Steven	R	K,Br	Eph	eu-B	Xen	Sub
Kochia scoparia (L.) Schrader s.l.	S	KUA	Epo	ken	Erg	Ir-Tr
Polycnemum arvense L.	R	K	Eph	ken	Xen	Med-CAs
Salsola collina Pallas	L	K,Ir	Epo	eu-C	Xen	Med-CAs
Salsola tragus L. s. str. (= *S. ruthenica* Iljin)	C	KUA	Epo	ken	Xen	Ir-Tr
Spinacia oleracea L.	S	KUA	Eph	ken	Erg	Med-CAs
COMMELINACEAE						
Commelina communis L.	S	KUA	Epo	eu-A	Erg	S-EAs
Tradescantia virginiana L.	E	K	Eph	eu-C	Erg	NAm
CONVOLVULACEAE						
Calystegia spectabilis (Brummitt) Tzvelev (*C. inflata* auct.)	E	K	Eph	eu-C	Erg	NAm
Ipomoea hederacea (L.) Jacq.	E	K	Eph	eu-C	Xen	CAm
Ipomoea purpurea (L.) Roth	S	KUA	Eph	eu-B	Erg	SAm
CRASSULACEAE						
Sedum rupestre L. (incl. *S. reflexum* L.)	R	K	Col	eu-B	Erg	Kv
Sedum spurium M. Bieb.	R	K	Col	eu-A	Erg	Kv
CUCURBITACEAE						
Bryonia alba L.	S	KUA	Epo	ken	Erg	Med-Cas
Citrulus lanatus (Thunb.) Matsum. & Nakai	E	KUA	Eph	ken	Erg	NAm
Cucurbita pepo L.	E	KUA	Eph	ken	Erg	NAm
Echinocystis lobata (Michx.) Torr. & A.Gray	S	KUA	Agr	eu-B	Erg	NAm
Sicyos angulata L.	E	K	Col	ken	Erg	NAm
Thladiantha dubia Bunge	E	K	Col	eu-A	Erg	EAs

CUSCUTACEAE						
Cuscuta campestris Yunck.	S	KUA	Epo	eu-B	Xen	NAm
Cuscuta gronovii Willd. ex Roemer & Schultes	R	K	Eph	eu-B	Xen	NAm
EQUISETACEAE						
Equisetum ramosissimum Desf.	R	KUA	Col	eu-B	Xen	n/a
EUPHORBIACEAE						
Euphorbia dentata Michx.	L	K	Epo	eu-C	Xen	NAm
Euphorbia falcata L.	L	K	Epo	arch		Med-CAs
Euphorbia helioscopia L.	S	KUA	Epo	arch		Med
Euphorbia marginata Pursh	R	KUA	Eph	eu-C	Erg	NAm
Euphorbia peplus L.	S	KUA	Epo	arch		Med
Flueggea suffruticosa (Pallas) Baillon	L	K	Col	eu-C	Erg	EAs
FABACEAE						
Amorpha fruticosa L.	L	KUA	Agr	eu-B	Erg	NAm
Astragalus onobrychis L.	R	KUA	Col	ken	Erg	Med-CAs
Caragana arborescens Lam.	L	KUA	Hagr	eu-B	Erg	Sub
Caragana frutex (L.) K.Koch	E	KUA	Col	eu-B	Erg	Ir-Tr
Lathyrus odoratus L.	R	KUA	Eph	ken	Erg	Med
Lathyrus sativus L.	E	KUA	Eph	eu-C	Erg	Med
Lathyrus tuberosus L.	L	KUA	Hagr	ken	Erg	Med-CAs
Lens culinaris Medik.	E	KUA	Eph	ken	Erg	Med
Lupinus polyphyllus Lindl.	L	KUA	Hagr	eu-C	Erg	NAm
Medicago minima (L.) Bartal.	U	KUA	Eph	ken	Xen	n/a
Medicago sativa L.	C	KUA	Epo	ken	Erg	AsM
Onobrychis viciifolia Scop.	R	KUA	Eph	ken	Erg	SEu
Ornithopus sativus Brot.	R	KUA	Eph	eu-C	Erg	WMed
Phaseolus vulgaris L.	E	KUA	Eph	ken	Erg	SAm
Pisum sativum L.	E	KUA	Eph	ken	Erg	Ir-Tr
Robinia pseudoacacia L.	C	KUA	Hagr	eu-A	Erg	NAm
? *Trifolium hybridum* L.	S	KUA	Epo	eu-A	Erg	Med
Trifolium incarnatum L.	E	KUA	Eph	eu-A	Erg	EMed
Trifolium resupinatum L.	R	K	Eph	eu-C	Xen	Med-CAs
Trifolium sativum (Schreber) Crome	R	KUA	Eph	eu-A	Erg	WEu
Trigonella caerulea (L.) Sér.	L	KUA	Eph	ken	Erg	Med
Vicia angustifolia Reichard	L	KUA	Eph	ken	Xen	Med-CAs
Vicia faba L.	E	KUA	Eph	ken	Erg	Ir-Tr
Vicia hirsuta (L.) S.F.Gray	L	KUA	Eph	arch		WMed
Vicia sativa L.	L	KUA	Eph	ken	Erg	hybr
Vicia tetrasperma (L.) Schreber	S	KUA	Eph	arch		Med
Vicia villosa Roth s.l. (incl. *V.sordida* Waldst. & Kit.)	R	KUA	HAgr	arch		Med
FAGACEAE						
Quercus palustris Moench	E	K	Col	eu-C	Erg	NAm
Quercus rubra L. (= *Q. borealis* Michx.)	S	KV	Hagr	eu-B	Erg	NAm
FUMARIACEAE						

Fumaria officinalis L.	S	KUA	Epo	arch		Med
Fumaria schleicheri Soy.-Willem.	L	KUA	Epo	arch		Ir-Tr
Fumaria vaillantii Loisel.	L	KUA	Epo	eu-A	Xen	Med-CAs
GERANIACEAE						
*Erodium cicutarium (*L.) L'Hér.	C	KUA	Eph	arch		Med-CAs
Geranium dissectum L.	L	KUA	Epo	arch		Med
Geranium molle L.	D	K	?	ken	Xen	Med
Geranium pusillum L.	S	KUA	Epo	arch		Ir-An
Geranium pyrenaicum Burm. f.	L	K	Epo	ken	Xen	Med
Geranium sibiricum L.	C	KUA	Epo	ken	Erg	Ir-Tr
HEMEROCALLIDACEAE						
Hemerocallis fulva (L.) L.	E	KUA	Eph	eu-B	Erg	EAs
Hemerocallis lilioasphodelus L.	E	KUA	Eph	eu-B	Erg	EAs
HYDROCHARITACEAE						
Elodea canadensis Michx.	C	KUA	Agr	ken	Xen	NAm
HYDROPHYLLACEAE						
Phacelia tanacetifolia Benth.	E	K	Eph	ken	Erg	NAm
IRIDACEAE						
Iris florentina L.	E	KUA	Eph	ken	Erg	Med
Iris germanica L.	E	KUA	Eph	ken	Erg	WEu
Limoniun meyeri (Boiss.) O.Kuntze	R	K	Col	eu-C	Xen	Med
Sisyrinchium septentrionale Bicknell	R	K	Eph	ken	Erg	NAm
JUGLANDACEAE						
Juglans mandshurica Maxim.	L	KUA	Col	eu-C	Erg	EAs
Juglans regia L.	S	KUA	Eph	eu-C	Erg	EAs
JUNCACEAE						
Juncus tenuis Willd. (= *J. macer* S.F.Gray)	C	KUA	Hagr	ken	Xen	NAm
LAMIACEAE						
? *Ballota nigra* L. s.l.	C	KUA	Hagr	arch		Med
Dracocephalum thymiflorum L.	D	K	?	ken	Erg	EAs
Elsholtzia ciliata (Thunb.) Hyl.	S	K	Epo	eu-A	Xen	EAs
Galeopsis ladanum L.	L	KUA	Epo	arch		NMed
Lamium album L. s.l.	L	KUA	Epo	arch		CAs
Lamium amplexicaule L.	L	KUA	Epo	arch		Med-CAs
? *Lamium purpureum* L.	C	KUA	Hagr	arch		Med
Marrubium vulgare L.	R	KUA	Eph	arch		Med-CAs
Melissa officinalis L.	E	KUA	Eph	ken	Erg	n/a
Mentha arvensis L.	E	KUA	Eph	ken	Erg	n/a
Mentha spicata L.	E	KUA	Epo	ken	X-Erg	Med
Mentha x *piperita* L.	E	KUA	Eph	ken	Erg	n/a
Nepeta cataria L.	L	KUA	Epo	arch		EMed
Salvia reflexa Hornem.	R	K	Eph	eu-C	Xen	NAm
Sideritis montana L.	R	K	Epo	ken	Xen	Med
Stachys annua (L.) L.	S	KUA	Epo	arch		WMed

LINACEAE						
Linum ustitatissimum L.	E	KUA	Eph	arch	Erg	As
MALVACEAE						
Abutilon theophrastii Medik.	L	K	Epo	ken	Erg	EAs
Alcea rosea L.	E	KUA	Col	ken	Erg	n/a
Hibiscus syriacus L.	E	K	Eph	eu-C	Erg	n/a
Hibiscus trionum L.	D	K	?	eu-B	Xen	Med
Malva crispa (L.) L.	L	KUA	Epo	ken	Erg	EAs
Malva excisa Reichenb.	L	KUA	Eph	arch	X-Erg	Pon
Malva mauritiana L.	E	KUA	Eph	ken	Erg	Med
Malva neglecta Wallr.	C	KUA	Epo	arch	X-Erg	Ir-Tr
Malva pusilla Smith.	C	KUA	Epo	arch	X-Erg	Res
Malva sylvestris L.	L	K	Hagr	arch	X-Erg	Med
Sida rhombifolia L.	U	K	Eph	eu-C	Xen	S-EAs
MORACEAE						
Morus alba L.	S	KUA	Epo	ken	Erg	EAs
NYCTAGINACEAE						
Oxybaphus nyctagineus (Michx.) Sweet	S	KUA	Epo	ken	X-Erg	NAm
OLEACEAE						
Fraxinus lanceolata Borkh.	R	K	Col	eu-B	Erg	NAm
Fraxinus pennsylvanica Marshall	S	K	Epo	eu-B	Erg	NAm
Ligustrum vulgare L.	E	KUA	Col	eu-C	Erg	n/a
Syringa vulgaris L.	E	K	Col	ken	Erg	EMed
ONAGRACEAE						
Epilobium ciliatum Raf. s.l. (=*E. adenocaulon* Hausskn.)	C	K	Agr	eu-B	Xen	NAm
Oenothera biennis L. s.l.	L	KUA	Epo	ken	Xen	NAm
Oenothera laciniata Hill	O	K	Eph	eu-C	Xen	NAm
Oenothera rubricaulis Klebahn	C	KUA	Hagr	eu-A	Xen	WEu
Oenothera oakesiana (A. Gray) S. Watson & Coulter	R	K	Eph	ken	Xen	NAm
Oenothera villosa Thunb. s.l.	C	K	Epo	eu-B	Erg	NAm
OROBANCHACEAE						
Orobanche cernua Loefl.	R	KUA	Eph	ken	Xen	ant
Phelipanche ramosa (L.) Pomel (*Orobanche ramosa* L.)	L	K	Eph	ken	Xen	Med-CAs
OXALIDACEAE						
Xanthoxalis dillenii (Jacq.) Holub	L	KUA	Epo	eu-B	Xen	NAm
Xanthoxalis stricta (L.) Small	C	KUA	Hagr	ken	Xen	NAm
PAPAVERACEAE						
Glaucium corniculatum (L.) J. Rudolph	R	B	Eph	ken	Xen	Med
Papaver dubium L.	S	KUA	Eph	arch		Med-CAs
Papaver ocellatum Woronow	U	K	Eph	eu-C	Xen	Ir-Tr
Papaver rhoeas L.	C	KUA	Epo	arch		Med-CAs
Papaver somniferum L.	D	KUA	?	ken	ErgMed	EMed
POACEAE (= GRAMINEAE)						
Agropyron cristatum (L.) P.Beauv. s. str.	R	K	Eph	eu-C	Xen	Ir-Tr

Agropyron pectinatum (M.Bieb.) P.Beauv.	R	KUA	Eph	arch		Ir-Tr
Alopecurus myosuroides Huds.	L	K	Eph	eu-C	Xen	Med-Ir-An
Anisantha sterilis (L.) Nevski (= *Bromus sterilis* L.)	R	K	Eph	eu-B	Xen	Med-Ir-An
Anisantha tectorum (L.) Nevski (= *Bromus tectorum* L.)	S	KUA	Epo	arch		Med-CAs
*Apera spica-venti (*L.) P.Beauv.	C	KUA	Agr	arch		n/a
Arrhenatherum elatius (L.) J.Presl & C.Presl	R	KUA	Eph	ken	Erg	WEu
Avena fatua L.	U	KUA	Eph	arch	Xen	Ir-Tr
Avena nuda L.	D	KUA	?	ken	Erg	WEu
Avena sativa L.	L	KUA	Eph	arch	Erg	SEu
Avena strigosa Schreb.	D	K	?	eu-A	Xen	ant
Beckmannia syzigachne (Steud.) Fern.	U	K	Eph	eu-C	Xen	NAm
Bromus arvensis L.	C	KUA	Epo	arch		NMed
Bromus commutatus Schrad.	D	KUA	?	ken	Xen	WEu
Bromus hordeaceus L.	C	KUA	Hagr	arch		NMed
Bromus japonicus Thunb.	S	KUA	Epo	ken	Xen	Med
Bromus secalinus L.	D	KUA	?	arch		ant
Bromus squarrosus L.	S	KUA	Epo	ken	Xen	Med-CAs
Cenchrus longispinus (Hack.) Fern.	S	K	Epo	eu-C	Xen	NAm
Ceratochloa carinata (Hook. & Arn.) Tutin	L	K	Col	eu-C	X-Erg	NAm
Ceratochloa cathartica (M.Vahl.) Herter	R	K	Eph	eu-C	X-Erg	SAm
Cynodon dactylon (L.) Pers.	R	K	Col	eu-B	Xen	Med-CAs
Digitaria ciliaris (Retz.) Koeler	U	K	Eph	eu-C	Xen	Med
Digitaria pectiniformis (Henrard) Tzvelev	R	K	Eph	ken	Xen	Med
Digitaria sanguinalis (L.)Scop.	C	KUA	Agr	arch		S-EAs
Echinochloa colona (L.) Link	U	K	Eph	eu-C	X-Erg	SAs
? *Echinochloa crusgalli* (L.) P.Beauv. s.l.	C	KUA	Hagr	arch		S-EAs
Echinochloa esculenta (A.Br.) H.Scholz	U	K	Eph	eu-C	X-Erg	EAs
Echinochloa frumentacea Link	U	K	Eph	eu-C	Xen	S-EAs
Echinochloa microstachya (Wiegand) Rydb.	L	K	Col	eu-C	Xen	NAm
Echinochloa oryzicola (Vasing.) Vasing.	U	K	Eph	eu-C	Xen	EAs
Echinochloa oryzoides (Ard.) Fritsch	U	K	Eph	eu-C	Xen	S-EAs
Echinochloa wiegandii (Fassett) McNeill & Dore	U	K	Eph	eu-C	Xen	NAm
Eleusine indica (L.) Gaertn.	U	K	Eph	eu-C	Xen	Afr-SAs
Elymus sibiricus L.	U	K	Eph	eu-C	Xen	EAs
Elymus trachycaulus (Link) Gould & Schinners	R	K	Eph	eu-C	X-Erg	NAm
Eragrostis cilianensis (All.) Vign. ex Janchen	R	K	Eph	eu-C	Xen	Med
Eragrostis minor Host	C	K	Hagr	ken	Xen	Med-CAs
Eragrostis *multiflora* Steudel	R	K	Eph	eu-C	Xen	S-EAs
Eragrostis pectinacea (Michx.) Nees	S	KUA	Epo	eu-C	Xen	NAm
Eragrostis pilosa (L.) P.Beauv.	C	KUA	Hagr	ken	Xen	EAs
Eremopyrum orientale (L.) Jaub. & Spach	R	K	Eph	eu-C	Xen	Ir-Tr
Hordeum distichon L.	R	KUA	Eph	ken	Erg	Ir-Tr
Hordeum jubatum L.	L	K	Col	eu-C	Xen	NAm

Hordeum leporinum Link	R	K	Eph	eu-A	Xen	Med
Hordeum murinum L.	L	K	Col	eu-A	Xen	Med-CAs
Hordeum vulgare L.	E	KUA	Eph	ken	Erg	Ir-Tr
Lolium multiflorum Lam.	S	KUA	Eph	ken	Erg	Med-CAs
Lolium persicum Boiss. & Hohen.	R	K	Eph	eu-C	Xen	Ir-Tr
Lolium remotum Schrank	D	KUA	?	arch		ant
Lolium temulentum L.	R	KUA	?	arch		NMed
Panicum capillare L. s.l.	L	K	Eph	eu-C	Xen	NAm
Panicum dichotomiflorum Michx.	R	K	Eph	eu-C	Xen	NAm
Panicum miliaceum L. s.l.	E	KUA	Eph	ken	Erg	EAs
Phalaris canariensis L.	E	K	Eph	ken	Erg	Med
Puccinellia hauptiana V.Krecz.	U	K	Eph	eu-C	Xen	CAs
Puccinellia nuttalliana (Schult.) A.Hitchc.	U	K	Eph	eu-C	Xen	NAm
Puccinellia poecilantha (K.Koch) Grossh.	R	K	Eph	eu-C	Xen	Ir-Tr
Puccinellia tenuissima Litv. ex V.Krecz.	R	K	Eph	eu-C	Xen	Med-CAs
Sclerochloa dura (L.) P.Beauv.	L	K	Eph	arch		Med-CAs
Secale cereale L.	E	KUA	Eph	arch	Erg	AsM
Secale sylvestre Host	R	K	Eph	eu-B	Xen	n/a
Setaria adhaerens (Forssk.) Chiov.	R	K	Eph	eu-C	Xen	Afr-SAs
Setaria faberi F.Herrmann s.l.	U	K	Eph	eu-C	Xen	EAs
? *Setaria glauca* (L.) P.Beauv. (*S. pumila* auct.)	C	KUA	Hagr	arch		S-EAs
Setaria italica (L.) P.Beauv.	S	KUA	Eph	ken	Erg	EAs
Setaria pycnocoma (Steud.) Henrard ex Nakai	L	KUA	Epo	eu-C	Xen	EAs
Setaria verticilliformis Dumort.	R	K	Eph	arch		Med
? *Setaria viridis* (L.) P.Beauv.	S	KUA	Hagr	arch		Med-CAs
Sorghum bicolor (L.) Moench s. str.	U	K	Eph	eu-C	X-Erg	SAs
Sorghum cernuum (Ard.) Host	U	K	Eph	eu-C	X-Erg	SAs
Sorghum halepense (L.) Pers.	L	K	Col	eu-C	X-Erg	Med
Sorghum saccharatum (L.) Moench	R	K	Eph	ken	X-Erg	SAs
Sorghum sudanense (Piper) Stapf	E	K	Eph	eu-C	Xen	Afr
Trisetum sibiricum Rupr.	R	K	Eph	n/a		n/a
Triticum aestivum L.	R	KUA	Eph	ken	Erg	Ir-Tr
Triticum durum Desf.	R	KUA	Eph	ken	Erg	Ir-Tr
Zea mays L.	E	KUA	Eph	ken	Erg	CAm
POLEMONIACEAE						
Phlox paniculata L.	E	KUA	Col	eu-B	Erg	NAm
Phlox subulata L.	E	KUA	Col	eu-B	Erg	NAm
POLYGONACEAE						
Fagopyrum esculentum Moench	S	KUA	Eph	ken	Erg	EAs
Fagopyrum tataricum (L.) P. Gaertn.	R	KUA	Eph	ken	Xen	EAs
? *Fallopia convolvulus* (L.) A. Löve.	C	KUA	Epo	arch		As
*Persicaria orientali (*L.) Spach	E	K	Eph	eu-C	Erg	S-EAs
Polygonum ramosissimum Michx.	U	K	Eph	eu-C	Xen	NAm
Reynoutria japonica Houtt.	S	K	Epo	eu-C	Erg	EAs

R. sachalinensis (F.Schmidt ex Maxim.) Nakai	R	K	Epo	eu-C	Erg	EAs
Rumex longifolius DC.	R	KUA	Epo	ken	X-Erg	n/a
Rumex patientia L.	R	KUA	Eph	ken	Erg	Med
Rumex stenophyllus Ledeb.	S	K	Epo	eu-B	Xen	Med-CAs
Rumex triangulivalvis (Danser) Rech.f.	L	K	Col	eu-C	Xen	NAm
PORTULACACEAE						
Portulaca grandiflora Hook.	E	KUA	Eph	eu-C	Erg	hybr
Portulaca oleracea L.	S	K	Epo	arch		Med-CAs
PRIMULACEAE						
Anagallis arvensis L.	C	KUA	Epo	arch		Med-CAs
RANUNCULACEAE						
Adonis aestivalis L.	U	K	Eph	eu-A	Xen	Med-CAs
Adonis annua L.	D	K	?	ken	Xen	Med
Adonis flammeus Jacq.	D	K	?	ken	Xen	Med-CAs
Aquilegia vulgaris L.	E	KUA	Col	ken	Erg	WEu
Clematis jackmannii Moore	E	K	Col	eu-C	Erg	hybr
Clematis viticella L.	E	K	Col	eu-C	Erg	Kv
Consolida ajacis (L.) Schur	E	KUA	Eph	ken	Erg	n/a
Consolida orientalis (J.Gay) Schroedinger	U	K	Eph	eu-C	Xen	Med
Consolida paniculata (Host) Schur	U	K	Eph	eu-C	Xen	Med
Consolida regalis S.F.Gray	S	KUA	Epo	arch		Med-CAs
Nigella arvensis L.	E	KUA	Eph	eu-B	Xen	EMed
Nigella damascena L.	E	KUA	Eph	ken	Erg	Med
Nigella sativa L.	E	K	Eph	ken	Erg	Med-CAs
Nigella segetalis M.Bieb.	U	K	Eph	eu-C	Xen	EMed
Ranunculus arvensis L.	U	K	Eph	eu-C	Xen	Med-CAs
RESEDACEAE						
Reseda lutea L.	S	KUA	Epo	eu-A	Xen	Med
Reseda luteola L.	D	KUA	?	arch	X-Erg	Med
ROSACEAE						
Amelanchier ovalis Medik.	E	KUA	Col	eu-B	Erg	Med
Armeniaca vulgaris Lam.	E	KUA	Col	ken	Erg	EAs
Aronia melanocarpa (Michx.) Elliot s.l.	R	KUA	Col	eu-C	Erg	NAm
Cerasus mahaleb (L.) Mill.	E	KUA	Col	eu-B	Erg	EMed
Cerasus vulgaris Mill.	E	KUA	Col	eu-B	Erg	EMed
Cotoneaster melanocarpus Fisch. ex Blytt	R	KUA	Col	eu-B	Erg	Ir-Tr
Fragaria x ananassa (Duchesne) Duchesne	E	KUA	Col	ken	Erg	hybr
Malus baccata (L.) Borkh.	E	KUA	Col	ken	Erg	Sub
Malus domestica Borkh.	E	KUA	Col	ken	Erg	n/a
Padus serotina (Ehrh.) Ag. (= *Prunus serotina* Ehrh.)	L	KUA	Agr	eu-B	Erg	NAm
Physocarpus opulifolius (L.) Maxim.	L	K	Col	eu-B	Erg	NAm
Potentilla longifolia Willd. ex Schlecht.	R	K	Col	eu-C	Xen	As
Potentilla paradoxa Nutt. ex Torr. & A.Gray	S	K	Epo	eu-C	Xen	As
Potentilla tergemina Soják	D	K	?	eu-C	Xen	EAs

Poterium polygamum Waldst. & Kit.	L	KUA	Epo	eu-B	Xen	Med-CAs
Poterium sanguisorba L.	S	KUA	Epo	eu-B	Xen	Med-CAs
Rosa rugosa Thunb.	E	KUA	Col	ken	Erg	EAs
Sorbaria sorbifolia (L.) A.Braun	E	KUA	Col	ken	Erg	n/a
Spiraea chamaedryfolia L.	E	K	Col	ken	Erg	n/a
Spiraea douglasii Hook. s.l.	L	K	Col	eu-C	Erg	NAm
Spiraea salicifolia L.	L	KUA	Epo	eu-C	Erg	Sub
RUBIACEAE						
? *Galium exoletum* Klokov	U	K	Eph	eu-B	Xen	WEu
? *Galium spurium* L.	R	K	Eph	eu-A	Xen	ant
Sherardia arvensis L.	R	KUA	Eph	arch		WMed
RUTACEAE						
Ptelea trifoliata L.	L	K	Hagr	eu-B	Erg	NAm
SALICACEAE						
Populus balsamifera L.	L	K	Col	eu-C	Erg	NAm
Populus bolleana Lauche	L	K	Col	eu-C	Erg	Med-CAs
Populus deltoides Marshall	L	K	Col	eu-C	Erg	Med-CAs
Salix fragilis L.	C	KUA	Agr	arch		Med-CAs
SCROPHULARIACEAE						
Antirrhinum majus L.	E	KUA	Eph	ken	Erg	Med
Veronica cardiocarpa (Kar. & Kir.) Walp.	L	K	Epo	eu-C	Xen	Ir-Tr
Veronica filiformis Smith	L	K	Eph	eu-C	Erg	Kv
Veronica hederifolia L.	S	KUA	Epo	eu-A	Xen	Med
Veronica persica Poir.	L	KUA	Epo	ken	Xen	Ir-Tr
Veronica polita Fr.	S	KUA	Epo	arch		Med-CAs
SIMAROUBACEAE						
Ailanthus altissima (Mill.) Swingle	R	K	Epo	eu-C	Erg	EAs
SOLANACEAE						
Datura stramonium L.	L	KUA	Epo	ken	Xen	As
Hyoscyamus niger L.	S	KUA	Epo	ken	Xen	Ir-An
Lycium barbarum L.	S	K,Bo	Hagr	arch	Erg	EAs
Lycopersicon esculentum Mill. (Solanum lycopersicum L.)	E	KUA	Eph	ken	Erg	SAm
Nicandra physalodes (L.) P.Gaertn.	E	K	Epo	ken	Erg	SAm
Nicotiana alata Link & Otto	E	KUA	Eph	ken	Erg	Cam
Petunia x atkinsiana D. Don. ex Loudon	E	KUA	Eph	ken	Erg	hybr
Physalis alkekengi L.	E	K	Eph	eu-C	Erg	Med
Physalis ixocarpa Brot. ex Hornem.	E	KUA	Eph	eu-C	Erg	CAm
Solanum alatum Moench	L	KUA	Epo	ken	Xen	WEu
Solanum carolinense L.	R	K	Eph	eu-C	Xen	NAm
Solanum schultesii Opiz	R	K	Eph	ken	Xen	Med
Solanum tuberosum L.	E	KUA	Eph	ken	Erg	SAm
THYMELAEACEAE						
Thymelaea passerina (L.) Coss. & Germ.	D	KUA	?	arch		Med-CAs
TYPHACEAE						

Typha laxmannii Lepech.	L	K	Col	eu-B	Xen	Med-CAs
ULMACEAE						
Celtis occidentalis L.	E	K	Col	eu-C	Erg	EAs
Ulmus pumila L.	S	K	Hagr	eu-C	Erg	EAs
URTICACEAE						
Parietaria officinalis L.	E	K	Eph	?	Erg	Med
Urtica urens L.	S	KUA	Epo	arch		Med
VERBENACEAE						
Verbena officinalis L.	S	KUA	Epo	arch		Med-Ir-An
VITACEAE						
Parthenocissus inserta (A.Kerner) Fritsch	C	KUA	Hagr	eu-B	Erg	NAm
Parthenocissus quinquefolia (L.) Planch.	L	K	Col	eu-B	Erg	NAm
Vitis labrusca L.	L	KUA	Eph	eu-C	Erg	n/a
Vitis vinifera L.	L	KUA	Eph	eu-C	Erg	n/a
ZYGOPHYLLACEAE						
Tribulus terrestris L.	L	K	Eph	eu-A	Xen	Med

Results and Analysis

According to the data, the total nonnative flora (past and present) of KUA consists of 536 species of vascular plants belonging to 297 genera and 71 families. The flora has the highest degree of diversity of any urban nonnative flora in Ukraine. The modern nonnative flora, confirmed for the area in 1997–2001, consists of 356 species belonging to 207 genera and 62 families. We did not include in this group plants that are now considered extinct in the territory of research (28 species), recent unstable introductions (occasionally introduced during the last 20 years), plants not confirmed with new collections during the 1997–2001 study (48 species), and Ephemero-ergasiophytes (104 species). The stable component of the modern nonnative flora includes only effectively naturalized species (agriophytes, hemiagriophytes, and epoecophytes). This component is represented by 198 species belonging to 147 genera and 51 families.

The observations indicate that 63 species (17.7% of the total number of modern nonnative plants) are widespread over practically the whole territory of KUA, and that they are stable and abundant components of disturbed habitats. The majority of the nonnative species analyzed (108 species, or 30.3%) occur infrequently, 99 species (27.8%) occur locally, 86 species (24.2%) are sporadic, and at least 37 species from these groups display pronounced trends toward further dispersal and invasions within the studied area.

In examining the taxonomic structure of the nonnative flora, we found that, unlike the native regional flora, just a few families contain a considerable portion of the species (Asteraceae, Poaceae, and Brassicaceae comprise 38.8% of species; 6 leading families comprise 54.1%; and 15 leading families, 76.7%). This is typical of other nonnative floras (Protopopova, 1991; Vyukova, 1985; Mosyakin & Yavorska, 2001, etc.). In its taxonomic spectrum, the studied flora proved to be more similar to other nonnative floras of the Palaearctics than to the native flora of the Kiev region, where it is physically located. In contrast to the native flora of KUA, the role of the families Brassicaceae, Chenopodiaceae, and Polygonaceae is somewhat elevated, as is the role of Poaceae, Asteraceae, and Rosaceae. The families Asteraceae, Onagraceae, Rosaceae, and Polygonaceae play leading roles in forming the stable component of the alien flora.

Our analysis of nonnative plants by their degree of naturalization has shown that ephemerophytes (175 species, or 49.2%) and epoecophytes (99 species, or 28.2%) clearly prevail in the structure of the modern nonnative flora of Kiev. Smaller numbers of species are represented by colonophytes (42 species, or 11.7%) and agriophytes (21 species, or 5.7%). The group of typical agriophytes is smallest (19 species, or 5.2%). Thus, ephemerophytes and epoecophytes are over three times more numerous than agriophytes, hemiagriophytes, and colonophytes combined, which again is rather typical of nonnative floras. These data testify to instability in the present nonnative component of KUA's flora as it goes through an intensive period of formation. The nonnative fraction of the Kiev flora is characterized by a much higher level of instability in species composition compared to floras of satellite cities. This is due to increased numbers of recently introduced ephemerophytes and ergasiophytes in KUA. Nevertheless, there is some degree of stabilization in the species composition. The ratio of stable to unstable components in the structure of the modern nonnative flora is 54% to 46%, respectively.

The percentage of species introduced before the end of the 19th century, which includes archaeophytes (19.6%) and kenophytes (31%), is roughly equal to that of eukenophytes (49.4%), species that were introduced during the 20th century. According to the obtained data, the last century saw the number of nonnative species swell at an ever-increasing rate. Though eukenophytes-C immigrated to our territory within the shortest time span (20 years) of the three eukenophyte subgroups, they constitute 55.8% of the total number of eukenophytes (subgroups A and B constitute 17.3% and 26.9%, respectively).

In mode of immigration, xenophytes (47.8%) and ergasiophytes (46.5%) dominate. Xeno-ergasiophytes constitute only 5.7% of the whole nonnative flora. Taking into account the increased role (both in the number of species and their growing participation in plant communities) of ergasiophytes in the structure of our nonnative flora and vegetation, it would be wise to pay more attention to the naturalization ability of newly introduced cultivated plants. There are numerous cases of uncontrollable invasions by some of these plants in our city and adjacent areas.

In the formation of the total nonnative flora of KUA, the leading role is played by species native to the ancient Mediterranean (254 species; or 50.3%) and North American (99 species, or 16.3%) floristic regions. The American group (122 species, or 21.5%) includes taxa native to both North and South America. Much fewer of our nonnative species immigrated from Asia (81 species, or 19%), Europe (22 species, or 4.7%), Caucasus (6 species, 1.3%), and other regions (3.2%). Interestingly, North American taxa form the largest portion of the group of species that successfully naturalized in the 20th century (36% of all eukenophytes). They are followed in that group by eastern Asian plants (26% of all eukenophytes).

Nonnative plants are gaining in importance in the modern urban flora of Kiev. In general, in the second half of the 20th century, the number of new nonnative plants increased tenfold compared with the number of taxa registered from the end of the 19th to the middle of the 20th century. The number of completely naturalized species at least doubled. Finally, since more than half of the century's nonnative species immigrated only within the last two decades, we can expect further growth in the number of new nonnative plants.

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Glossary

Agriophytes: Naturalized in natural and seminatural habitats.

Archaeophytes: Plants that immigrated before the end of the 15th century.

Colonophytes: Epoecophytes that occur in the area in one to several stable colonies but which show little or no trend toward further expansion.

Ephemerophytes: Nonnaturalized, occasional immigrants, or waifs.

Epoecophytes: Naturalized in man-made and disturbed habitats

Ergasiophytes: Plants that were intentionally introduced and cultivated by man, and then spread from places of their cultivation.

Eukenophytes: Plants that immigrated in the 20th century.

Hemiagriophytes: Naturalized mostly in seminatural or disturbed habitats.

Kenophytes: Plants that immigrated between the 16th century and the end of the 19th century.

Palaearctic: Found in the arctic regions of the Old World.

Xenophytes: Plants introduced unintentionally.

Xeno-ergasiophytes: Plants cultivated outside of the studied area but unintentionally introduced.

Synanthropic: Living in close association with humans.

The Effects of Climate Change on the Vegetation of Central European Cities*

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Abstract

Since the 1850s the effects of global warming have been anticipated by the rise of temperature in many big cities. In addition, vegetation changes in central European cities have been well documented. This paper explores the changing urban distribution of some ruderal herbaceous species and discusses changes in distribution and physiological changes in tree and shrub species in response to this rise in temperature. Examples of affected species covered here include *Acer negundo, Ailanthus altissima, Amelanchier spicata, Berberis julianae, Buddleia davidii, Colutea arborescens, Cornus alba, C. stolonifera, Cotoneaster bullatus, Cytisus multiflorus, C. striatus, Juglans regia, Laburnum anagyroides, Ligustrum vulgare, Mahonia aquifolium, Paulownia tomentosa, Philadelphus coronarius, Platanus* × *hispanica, Populus* × *canadensis, Prunus armeniaca, P. laurocerasus, P. mahaleb, P. persica, P. serotina, Pyrus communis, Quercus cerris, Q. rubra, Q. robur, Ribes aureum, Robinia pseudacacia, Sambucus* spp., *Sorbus intermedia* agg., *Symphoricarpos albus,* and *Syringa vulgaris.* The responses of some woody scramblers and creepers are also examined. For many of these species, there was a long lag time between introduction and invasion in the wild. We briefly review phenological investigations, including studies of *Aesculus hippocastanum* and *Tilia euchlora.* Finally, we consider the extent to which cities can act as simulators of global climate change. We conclude that although other ecological and socioeconomic factors are affecting the vegetation in urban areas, many of the nonnative invasive species found colonizing cities (or naturalizing within them) originate in warmer areas and are benefiting from the more favorable climate.

Introduction: Urban Climate in Central Europe

Climatological and environmental research has led scientists to expect global warming and other climate changes to occur within the next few decades. The causes seem to be man-made. One question is what influence, if any, a warmer climate will have on flora and vegetation.

Since the 1850s the effects of global warming have been anticipated by the rise of temperature in

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many big cities. Cities have particular climatic characteristics (Landsberg, 1981; Kuttler, 1993):

- More air pollution: There is from 5 to15 times more gaseous pollution; the concentration of condensation nuclei (carbon particles and other particles) is about 10 times higher than in outlying areas. Air pollution is caused by traffic, heating of buildings, power stations, and industry. Trace gases, with the exception of low-level ozone, occur at concentrations 5 to50 times higher than usual.
- Altered solar radiation: There are 5% to 15% fewer hours of sunshine, 22% to 25% less direct solar radiation, about 10% less surface albedo, and 12% more energy reflected back to the earth due to atmospheric pollution, leading to an increased net radiation of 11% at noon and 47% in the evening.
- Wind speeds are reduced by 10% to 20% due to the roughness of the city surface. There are 5% to 20% more calm days.
- The relative humidity is between 2% (winter) and 10% (summer) lower; on clear days this difference can reach 30%.
- The annual mean precipitation is up to 20% higher; however, for a variety of reasons, water generally does not percolate down through the soil but rather runs off very quickly. In other words, the vegetation in cities must contend with higher aridity than that in surrounding terrain.

The most important ecological result of these effects is higher temperature. Cities are "heat islands" or "hot spots" on the surface of the earth. How much higher the temperature is depends on the size of the city; the difference can reach 12°C on clear days, or 1°C to 2°C in yearly mean temperature.

Climatic conditions within a city can vary considerably, depending on such factors as an area's location within the city; its type of construction and paving; its density of buildings and the emanation of heat from them; and especially, its distance from large tracts of vegetation. Different climate zones, usually more or less concentric, can be distinguished within a city. A city's internal heat islands usually coincide with its built-up areas, but changes in wind direction can temporarily heat other areas as well.

The warmer climate in cities is associated with the following:

- a shorter nongrowing season (time between the first and last frosts) and less severe frosts
- a reduction in the number of frost days (to nearly half the normal amount) and snow days.

This warmer climate has the following effects on the vegetation in cities:

- a longer growing season (e.g., in Vienna, by about 10 to 20 days yearly)
- a shift in phenological phases.

Vegetation Changes in Central European Cities

Vegetation changes in central Europe have well been documented (e.g., Haeupler & Schönfelder, 1989). The interrelationships between species ranges and climate have also been investigated (Jäger, 1968). The flora and vegetation of cities have been described and mapped for a long time (Sukopp & Wittig, 1993). From this information it is possible to draw conclusions about environmental changes, including climate changes, by comparing historical data with present conditions (Sukopp, 1973).

Lists of urban plants have been published by the working group Methodik der Biotopkartierung im besiedelten Bereich (1993) and by Frank and Klotz

(1990). Some examples of spontaneously growing nonnative urban plants are presented in Table 1. The cosmopolitan character of many urban plants is a tribute to the ubiquity of humanity's modification of environmental conditions and to our efficiency as agents of dispersal (Salisbury, 1961).

Many of the ruderal species in cities are short-lived plants that react quickly to climate changes. The percentage of heat-resistant plants among ruderals is high, as indicated by their origin in warmer regions. Only in favorable conditions such as those in cities are they able to build up stable populations in central Europe. The prevailing influence of climate on ruderal plants and their ability to react quickly to climatic changes make them suitable indicators. Climate changes will thus be seen in the distribution of ruderals in cities as well as in changes of their northern boundaries and their altitude tolerances in mountainous areas (Hügin, 1992, 1995).

A summary of the ecological demands of the urban spontaneous flora can be attained by using indicator indices such as those of Ellenberg (1979, 1991). Kunick (1982b) used these to compare many cities with each other; the results for certain indices are shown in Figure 1. For details in Zürich, compare Landolt (2001).

Establishment of Plants Sensitive to Frost and Cold

Distribution and dispersal of nonnative plants in central Europe has changed during the past two centuries, resulting in a higher percentage of plants sensitive to frost and cold today.

Chenopodium botrys, of south-Eurasian-Mediterranean origin, has spread over large areas of central and western Europe as a consequence of increased transportation and trade and changes in land use (Figure 2). It was introduced in Berlin in 1889 (Sukopp, 1971). The original habitats of this species are sandy and stony places along riversides and in rocky debris, very specialized habitats in which there is little competition. The plant's secondary habitats in its naturalized range in central Europe are roadsides, fields, and rubble sites. Under natural conditions there are few such sites in central Europe; only under the influence of humans has the establishment of open calcareous sites with sand and gravel increased. *Chenopodium botrys* has only one of the typical characteristics of weed species—high seed production under favorable environmental conditions. What is more, for germination to occur, very specialized conditions involving the quality and intensity of light, photoperiod, and storage of seeds must be met.

In central European cities, *Hordeum murinum* is an indicator of dry and warm sites on permeable soils. According to Wittig (1991), it has been found in cities in the northern part of central Europe since Roman times. By mapping this species at Osnabrück, Germany, in 1978 and 1989–90, Hard and Kruckemeyer (1990) showed clear expansion of its range without corresponding climate changes. They suggested that this was due to the intensification of land use and a changing concept of what constitutes a clean and well-kept city rather than climate change.

Robinia pseudoacacia has been planted in Europe since 1623 and has spread spontaneously on the rubble of bombed cities, but only in areas with relatively continental climates with warm summers (Kohler & Sukopp, 1964). In central Europe the invasion of *Robinia pseudoacacia* (Figure 3) has been more successful in areas with a subcontinental or sub-Mediterranean climate than in areas under oceanic influence.

The same is true for *Ailanthus altissima*: In the Mediterranean or subcontinental regions, *Ailanthus* has spread abundantly through a broad range of sites. In central Europe, however, it is virtually confined to warmer regions or to urban-industrial sites with a more favorable microclimate. It is reasonable to assume that the spread of *Robinia pseudoacacia* has been promoted by the climate warming that began in the 19th century. The invasion was first observed in 1924, but only in the second part of the 19th century did this species become frequent. Similarly, the initial spread of *Ailanthus* was observed only at the beginning of the 20th century. Actually, in Germany it is more frequent in the warm zones of metropolitan Berlin (Figure 4, Table 3) than on the urban fringe, and in surrounding areas of Brandenburg it has been reported mainly in cities (Kowarik & Böcker, 1984; Kowarik, 1992b).

Prunus laurocerasus exemplifies how low winter temperatures may limit invasions (Adolphi, 1995). The species has been cultivated in Berlin since 1663, but the first seedlings were not observed until 1982. In regions with mild winter temperatures it obviously does better: It is common in London and in cities in the west of Germany (Table 2), and it has become a permanent member of natural forests in the sub-Mediterranean region of Italy (Gianoni et al., 1988). In Zurich, it has begun to invade forests only in recent years.

Buddleia has been invasive in Berlin since 1952, but it is actually less common there than in regions with mild winters.

Other species that are considered thermophilous, or heat-loving, with an indicator value for temperature > 7 (Ellenberg et al., 1991), include *Laburnum anagyroides* (with a time lag of 198 years between the plant's introduction and the onset of spreading; see also Table 3), *Quercus cerris* (161 years), and the sub-Mediterranean *Colutea arborescens*, which is native to the warmest sites in southwest Germany. In Brandenburg, 265 years elapsed before *Colutea* began to spread, in 1859. An even longer time lag is associated with *Vitis vinifera* and *Juglans regia*. Both have been cultivated in Brandenburg since 1200, but they were first reported as invading in 1860 and 1968, respectively. A warmer climate may also have encouraged the spread of the commonly occurring *Prunus persica* and of the rarer *Prunus armeniaca*, both of which spread 300 to 400 years after they were first cultivated (Kowarik, 1995).

An analysis of *Syringa vulgaris* indicates that the mode of spread also needs to be considered. This species was reported as being invasive early on, but it usually spreads by clonal growth and the enlargement of existing plantings. Even on rocky outcrops in the Rhine Valley with a favorable microclimate, fruits of *Syringa* do not ripen regularly (Lohmeyer & Sukopp, 1992). In Brandenburg, *Syringa* spreads mainly by root suckers, but recently some established shrubs were discovered fruiting along abandoned railway areas in Berlin. It is logical to assume that the fruit ripening on these sites has been promoted by the warmer urban climate. In other words, climate change has enabled the species to increase its repertoire of spreading strategies (Kowarik, 1995).

While many woody species are still in the process of establishment, one species has become a characteristic component of *Robinia* stands, *Mahonia aquifolium.* And not only does it thrive in older *Robinia* stands, it is also present in nearly every old *Sambucus* group. *Ribes aureum* may be another companion as well, although it cannot tolerate shade as well as *Mahonia* (Lohmeyer & Sukopp, 1992;

Kowarik & Langer, 1994). During research in Germany's Leipzig-Bitterfeld region, Auge (1997) found several reasons why *Mahonia aquifolium* is such a successful invader: It can adapt easily to disturbed and even contaminated soils; it profits from clonal growth; and it is also quite fertile. See Figure 5, which shows the spontaneous distribution of *Mahonia aquifolium* in Brandenburg and Berlin (after Kowarik, 1992b).

Erkamo (1956) analyzed the capability of woody species to regenerate by seeds. He found that from the beginning to the middle of the 20th century, a number of species were extending their ranges, for example *Quercus robur*, which is native to the south of Finland, and nonnative species such as the North American *Amelanchier spicata* (Figure 6).

To estimate the effect of local or global warming, it is necessary to develop models that take into account the time lags between a plant's introduction and its spread. Davis (1986) found big differences in both the magnitude and the timing of species' responses to the same climatic trend. She referred mainly to changes in abundance, demography, and distribution of native species. Different response patterns to climate changes may also be a key factor in the variation in lag times preceding biological invasions.

The examples mentioned above show that many factors have influenced the distribution of spontaneously growing flora in cities: Land use, land management, and substrate have played an important role as well as the urban climate. The plant-distribution patterns mirror building patterns and the economic structure of the city (Sukopp, 1969; Kunick, 1982a) as well as its social structure (Hard & Otto,1985). The meso- and macro-climate of the city overlies the distribution patterns of single biotopes.

Phenological Investigations in Cities

The various temperature zones in urban areas can be illustrated by systematic phenological investigations. It is possible to create maps showing when and where a species begins a particular phase of its life cycle: budding, leafing, flowering, fruiting. The different starting points of the various phases indicate different temperature regimes in the city. It is possible to map these heat islands and cooler areas with relatively little technical difficulty.

In many cases these phenological phases start several days earlier in the center of the city than at its edge or in large parks. An analysis of the flowering phase of *Tilia euchlora* in West Berlin is shown in Figure 7 (Zacharias, 1972). *Tilia euchlora* was chosen because of the genetic homogeneity of the cultivated plants, which are offsprings of one individual. In the inner city the first flowers are seen eight days earlier than at the edge of the city. The difference in temperature between the day of flowering and one day earlier is 1°C. This accords with the distribution of phenological phases in Europe in general. In cool valleys and bogs, flowering can start two days later than at the base station for macroclimate observation. The steepest gradient is found at the boundary between forests and built-up areas.

The relationship between mean air temperature and leafing of *Aesculus hippocastanum* in Geneva is shown in Figure 8 (Kuttler, 1987). The air temperature in Geneva has been regularly measured since 1808. From that year to the present, the date of emergence of young leaves has also been recorded (in days after the beginning of the year). Between 1808 and 1980, the date of leafing shifted from April

5 to March 5. Because this phenomenon depends on temperature, one would expect that during this time the air temperature was also changing. This proved to be the reality. After some fluctuation, the air temperature increased from 9.6°C and 9.3°C (years 1831 and 1860) to 10.4°C in 1964. Both curves show a high degree of correspondence. This example shows that plants can be indicators of climate changes in cities, provided that records have been kept long enough to make such comparisons.

Specificity of Urban Flora and Vegetation

In a study of the ruderal vegetation of Saxony, Gutte (1972) noted that urban areas are quite different biologically from surrounding areas. The urban regions of Leipzig, Chemnitz, and Dresden were differentiated on the basis of the occurrences of thermophilous plants. In his map showing the degree of occurrence of natural vegetation, Schlüter (1992) found that the flora of these big cities is unique too.

Urban flora is remarkably different from the flora of the rural hinterland. Yet a comparison of the flora of big urban agglomerations in central Europe shows little differentiation among them. The differences that do exist are caused solely by large-scale climate variations, and they increase with the distance between the urban areas. Still, the differences are astonishingly minor, even between cities as distant as Warsaw and Brussels (Kunick, 1982b).

The vegetation of disturbed places—rubble fields, railway and port areas, ruins, walls, and waste areas—is "urban" in a narrow sense. The occurrence of new nonnatives on sites under human influence (Thellung, 1915) inspired many early investigations of adventive flora. The newcomers were recorded and categorized according to the time of introduction, the way they were introduced, and their degree of naturalization. Figure 9 shows the close correlation between human population growth and the number of nonnative plants. Of particular interest are the studies of the rapid colonization of bombed-out areas of London and Stuttgart, and of the climate changes of the last decade (Lousley, 1944; Salisbury, 1943). Changes associated with the urbanization of flora and vegetation, measured by time and scale, are shown in Figure 10.

Conclusions

The warmer climate is not the only factor leading to changes in the flora and vegetation of urban areas. Other ecological and socioeconomic factors also affect the vegetation.

The introduction of nonnative species via transportation and trade or for horticulture is a prerequisite for the dispersal of thermophilous plants. In many cases, these plants have crossed formerly insurmountable barriers. In cities, native plants now grow alongside those that would never have reached the new area without human help. A high percentage of nonnative species is a characteristic feature of urban floras.

Erkamo (1956) demonstrated that the rise in temperature during the first half of the 20th century caused changes in the occurrence of single plant species as well as at the community level. Over the last decade it has become evident that ecological theories on changes at the population or community level are inadequate when the climate is considered to be constant. Climate changes over time, and such change may affect plant communities, even over periods as short as decades or a few centuries (Davis, 1986).

Urban areas of central Europe are experiencing a retreat of native species and archaeophytes; at the same time they are—and will continue to be—centers of introduction and abundance of newcomers. The origin of these new species is primarily warmer regions of Europe, Asia, and the Americas.

Many native plants are also capable of colonizing new urban sites. These are called apophytes (Rikli, 1903/04). Kowarik (1992a) found 32% of Berlin's native plants established on urban sites. J.B. Falinski (personal communication, June 19, 1994) even estimated that all native plants of the Bialowieza Forest in Poland could also live as apophytes.

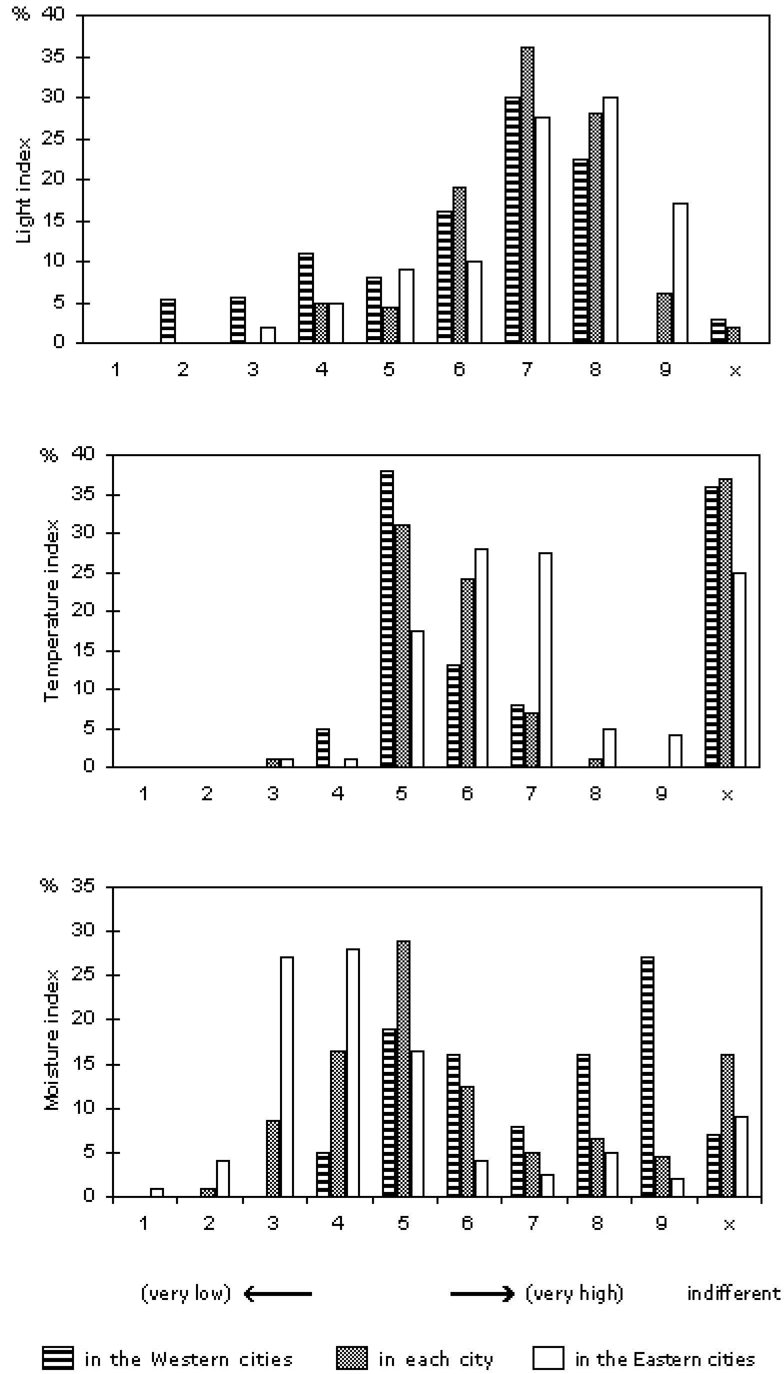
Plant species found in urban environments disperse relatively slowly into surrounding areas. This process can take several decades to centuries (Davis, 1986, Kowarik, 1992b). The introduced plants have quite uneven chances for dispersal.

Ten percent of all introduced species in central Europe are able to spread; 2% become permanent members of the flora; and only 1% is able to survive in natural vegetation. *Robinia pseudoacacia, Acer negundo,* and *Ailanthus altissima* were introduced in the 18th and 19th centuries. It took 100 to 180 years for these adaptable and very fertile plants to spread, although suitable sites were available before the devastation of World War II (Figure 11).

In big cities, the effects of global climate warming since the 1850s have been exacerbated by the heat-island effect. Berlin grew from a city of about 170,000 inhabitants in 1800 to a metropolitan area with 3.7 million inhabitants in 1910. Calculations of the increased warming effect of the urban climate are 0.2°C for 1798–1804, 0.7°C for 1831 to 1837, and 1.4°C for 1886 to 1898 (annual mean temperatures). For the period 1961 to 1980, there was a difference in the annual mean air temperature of more than 2°C between the center of Berlin and the surrounding areas. This warming correlates with a significant reduction of frost days: < 64 days in the center of the city; > 102 days in the surrounding areas (von Stülpnagel et al., 1990). Consequently, in Berlin, an accelerated invasion of nonnative species that tolerate higher temperatures could be expected. This hypothesis is supported by Figure 12, which shows an obvious increase in woody species that began to invade Berlin by the middle of the 19th century, coinciding with the changes in temperature: In the period 1756 to 1847, the winters were colder by –0.7°C than they were in 1848 to 1907, and before 1846, extremely cold winters were much more common.

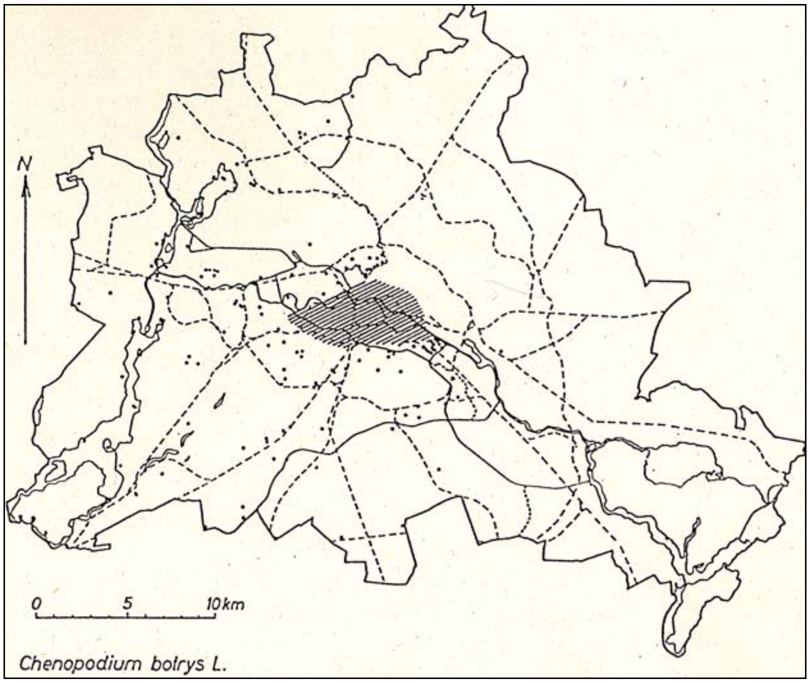
Similar trends have been observed for annual and perennial herbs in Berlin and for all established nonnative plant species in Germany. At first these trends were explained only by the huge increase in introductions and subsequent dispersal, promoted both by new transportation systems and the increasing commercial exchange of goods, which coincided with the diversification of habitats in the urban environment. But many of the nonnative invaders are native to warmer areas, and they are believed to benefit from a more favorable local climate, even on the small spatial scale of cities (Kowarik, 1995).

Figure 1: Light, Temperature, and Moisture Requirements of Spontaneous Flora in Central European Cities (Kunick, 1982b)



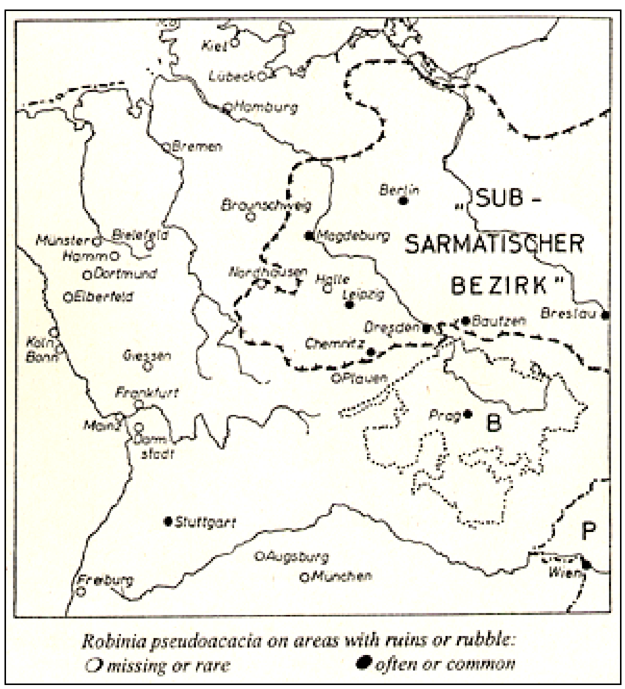
Geographical differences existing between the oceanic and the continental regions of central Europe are reflected in the composition of the urban flora. The graph demonstrates an increasing proportion of plants of moist and wet habitat toward the west and, in contrast, an increase of dry-grassland species toward the east. The transition area between both regions lies between the rivers Elbe and Oder.

Figure 2: Distribution of *Chenopodium botry* L. in Berlin, 1947 to 1971



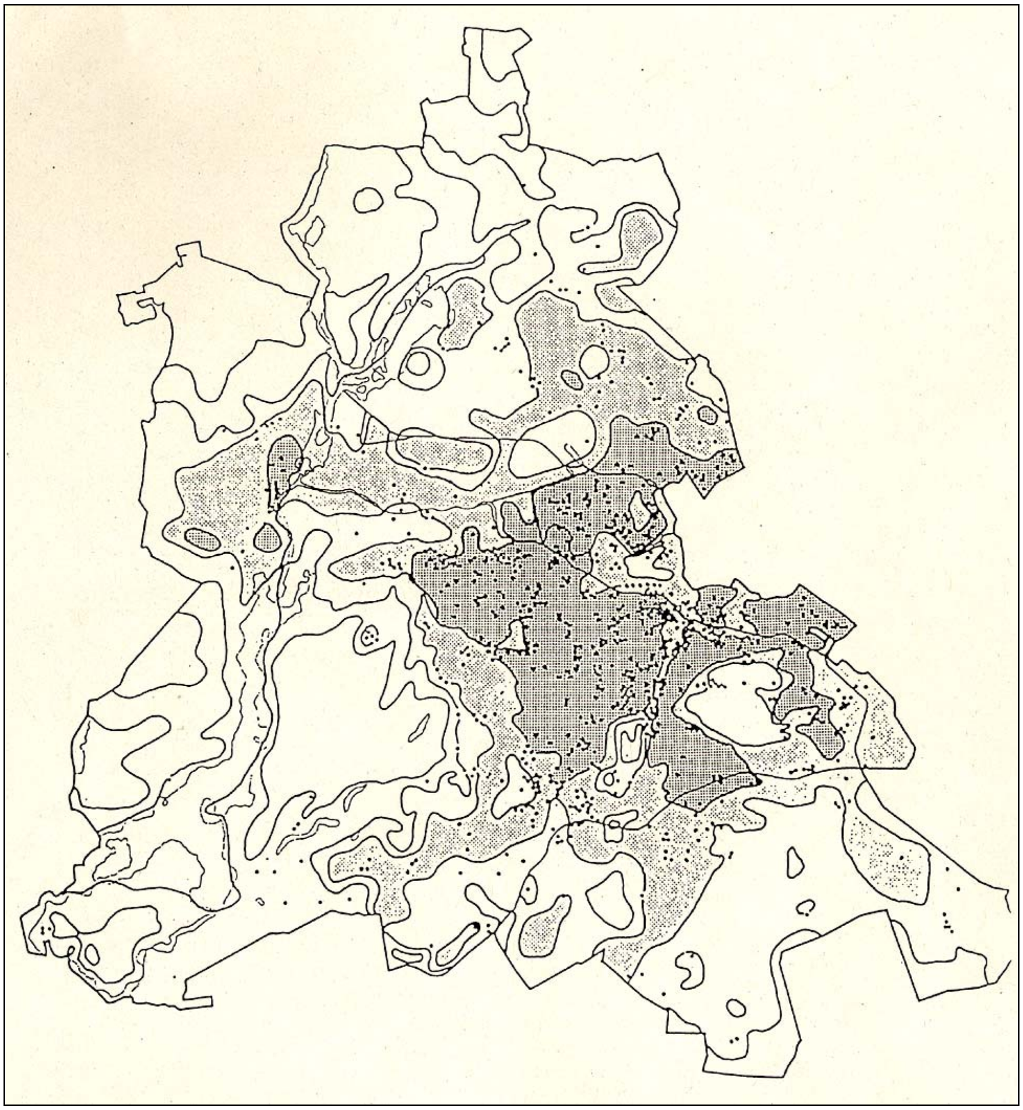
The area with the highest density is shaded (Sukopp, 1971).

Figure 3: *Robinia pseudoacacia* L. in Areas With Ruins or Rubble Fields



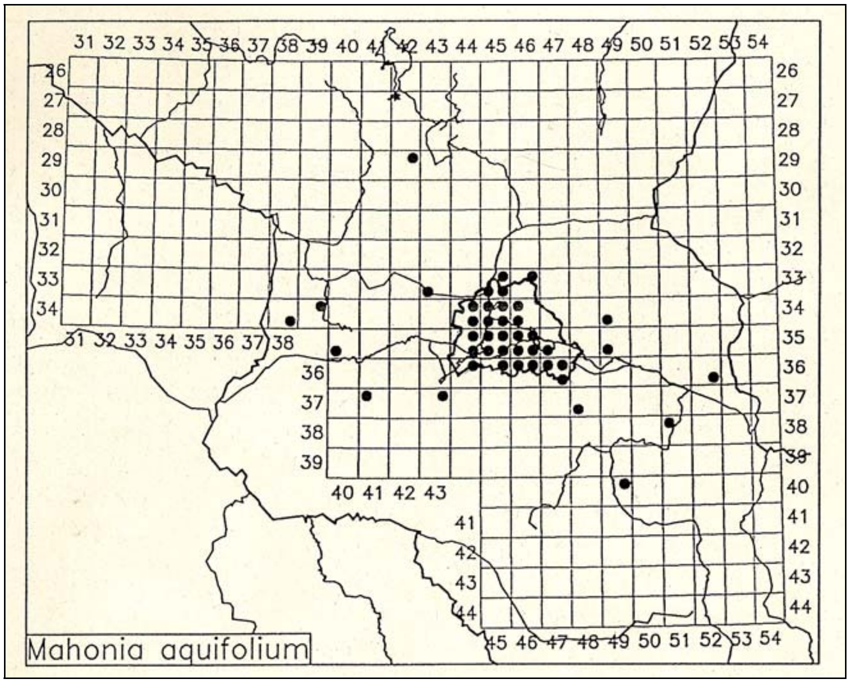
Robinia pseudoacacia L., native to North America, is one of the nonnative species that have become established in parts of middle and southern Europe (Kohler & Sukopp, 1964).

Figure 4: Distribution of *Ailanthus altissima* (Miller) Swingle in West Berlin



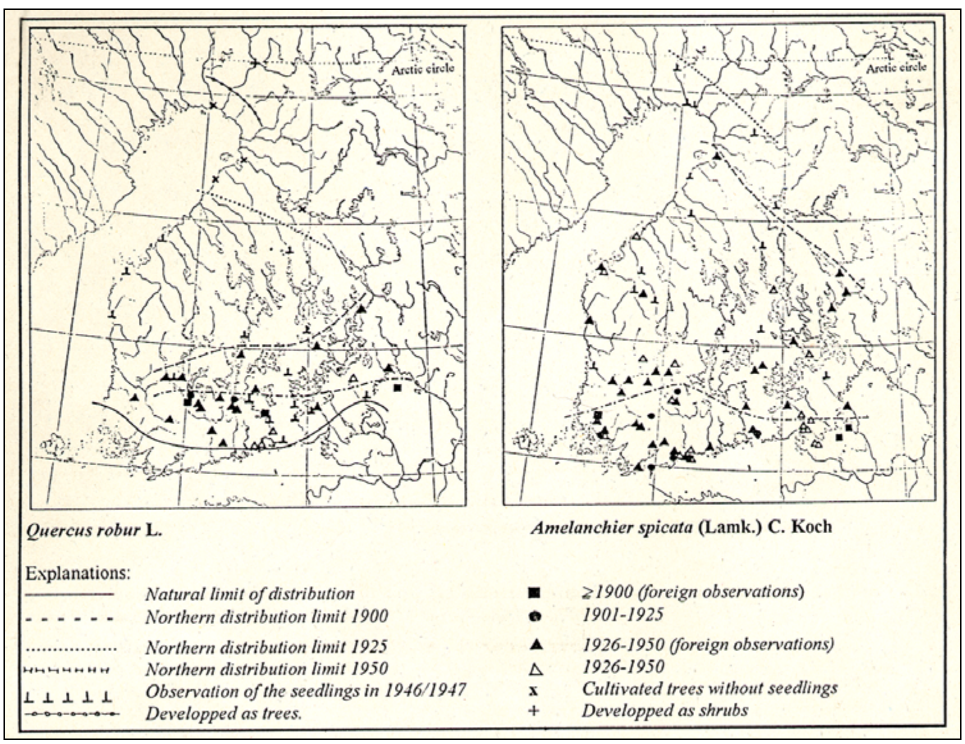
The map shows the location of trees (dots) and the different temperature zones of the area (shaded areas); the warmest zone is in darkest shade (Kowarik & Böcker, 1984).

Figure 5: Spontaneous Distribution of *Mahonia aquifolium* (Pursh.) Nutt. in Brandenburg and Berlin



The border of Berlin is outlined in bold (Kowarik, 1992b).

Figure 6: Changing Distribution of *Quercus robur* L. and *Amelanchier spicata* (Lamk.) C. Koch in Finland

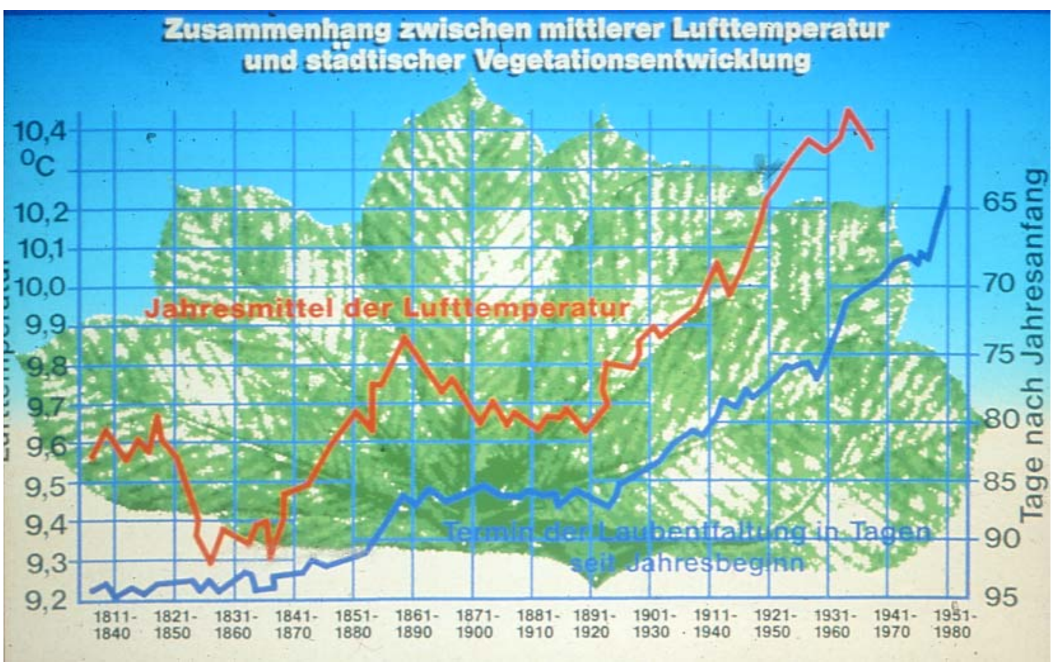


Changing distribution of native and spontaneously growing shrubs (1900, 1925, and 1950) and observations (1946, 1947) of seedlings near the mother plants of Q*uercus robur* L. and *Amelanchier spicata* (Lamk.) C. Koch in Finland (Erkamo, 1956).

Figure 7: Differences in the Flowering Phases of *Tilia* x *euchlora* at the Edge of West Berlin and at Stations Inside the City

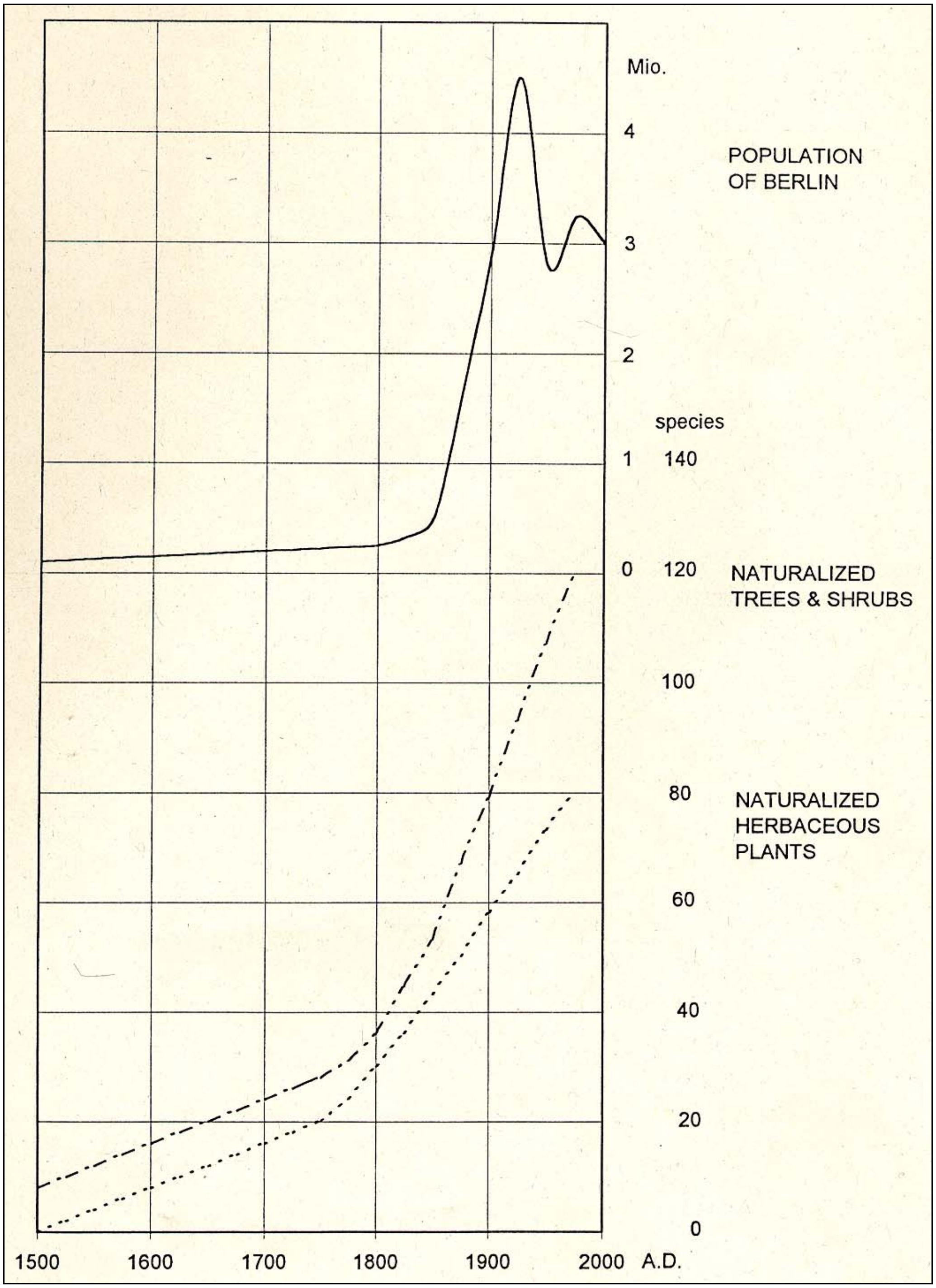
K. Koch mapped the differences in the flowering phases of *Tilia* x *euchlora* during spring 1967. The numbers indicate days before (or after) flowering at the base station for macroclimate observation (Zacharias, 1972).

Figure 8: Relationship Between Mean Annual Air Temperature and Leafing of *Aesculus hippocastanum* L. in Geneva



From Kuttler, 1987; slide: Landesbildstelle Nordrhein-Westfalen.

Figure 9: Correspondence Between Human Population Growth and Number of Two Groups of Nonnative Plants



Naturalized neophytic ruderal plants excluding trees and shrubs according to Scholz (1960) and nonnative trees and shrubs according to Kowarik (1985).

Figure 10: Changes in Flora and Vegetation Due to Urbanization, Measured by Time and Scale

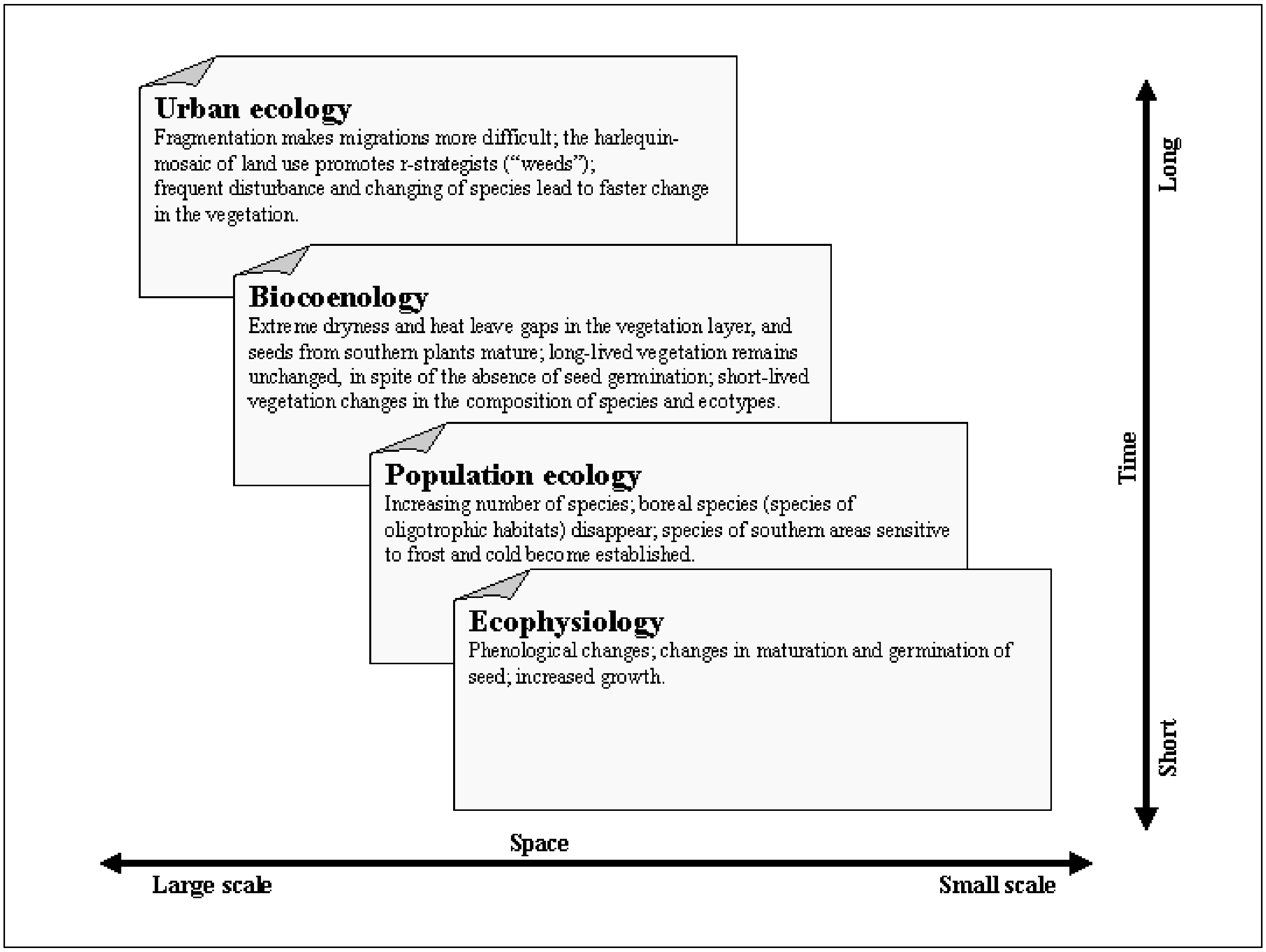
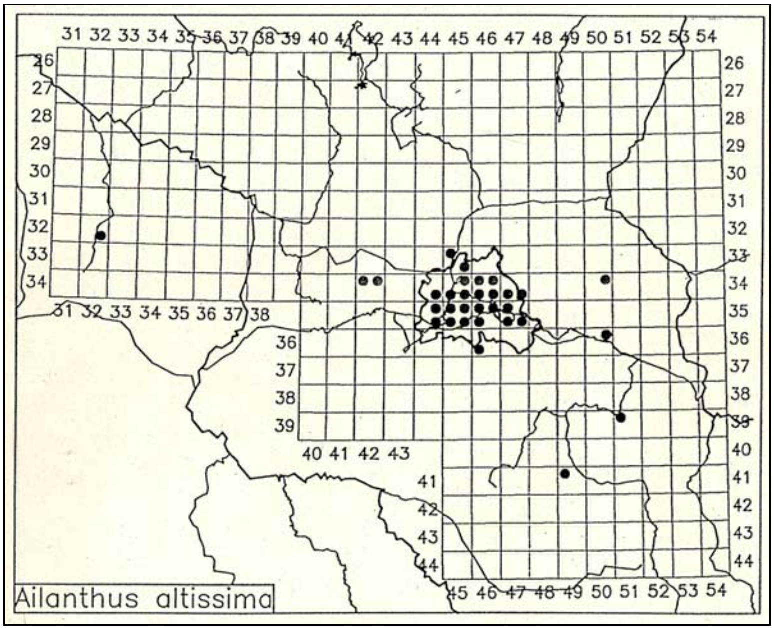
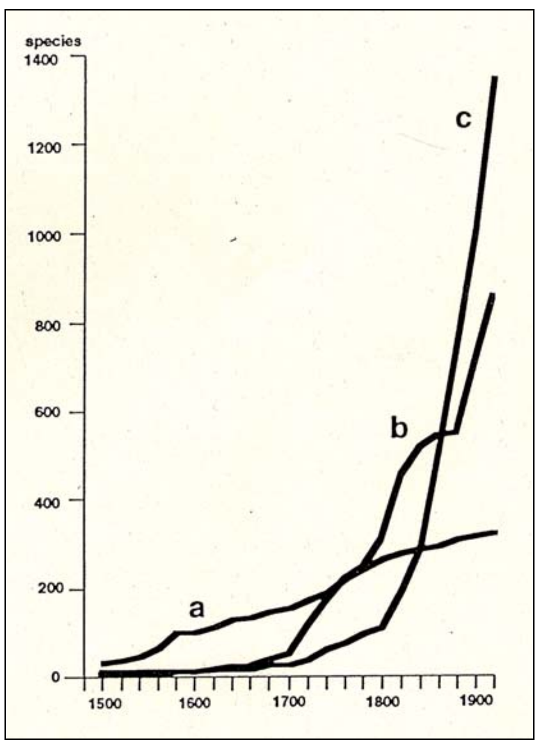


Figure 11: Spontaeneous Distribution of *Ailanthus altissima* (Miller) Swingle in Brandenburg and Berlin



The border of Berlin is outlined in bold (Kowarik, 1992b)

Figure 12: Introduction of Woody Species to Nemoral Europe During the Period Between 1500 and 1916



The species are grouped according to their origin from (a) other parts of Europe, including the Mediterranean (n=309); (b) North America (n=857); and (c) central and eastern Asia (n=1,351). These are cumulative curves; an additional 128 species introduced from western Asia and of cultural or unknown origin are not shown (Kowarik, 1995).

Table 1: Distribution of Some Nonnative Plant Species in Central Europe (From Sukopp & Wurzel, 1995)

	Temperature value (Ellenberg 1991)[1]	**Moisture value** (Ellenberg 1991)	**Remarks** (Haeupler & Schönfelder 1989)[2]	**Examples**	**References**
Ailanthus altissima (Miller) Swingle	8	5		Berlin Münster, Essen, Düsseldorf	Kunick, 1982b Kowarik & Böcker, 1984 Wittig et al., 1985
Amaranthus retro-flexus L.	7	4	Neophyte, possibly of North American origin, cultivated since 1794 in Germany, mapped growing spontaneously in 1815. Today found fully integrated in many regions.	Braunschweig	Brandes, 1977
Artemisia absinthium L.	7	4		Braunschweig	Brandes, 1977
Buddleia davidii L.	7	4		Berlin Münster, Essen, Düsseldorf Berlin Halle, Leipzig Ruhr area	Kunick, 1982 Wittig et al., 1985 Kunick, 1982 Frank & Klotz, 1990 Dettmar & Sukopp, 1991
Chenopodium botrys L.	7	4	In Berlin fully naturalized, building special communities; at other places inconstant. Mainly in cities, naturalized.	Leipzig Berlin Halle, Leipzig	Gutte, 1971 Sukopp, 1971 Kunick, 1982b Frank & Klotz, 1990
Colutea arborescens L.	8	3	Mainly along railway lines	Berlin	Kunick, 1982b
Corydalis lutea (L.) DC.	7	6	Since Middle Ages has fully naturalized at many places, especially on old walls.	Halle, Leipzig	Frank & Klotz, 1990
Cotoneaster Bullatus Bois *and C. moupinensis* Franch.			"Garden escapees"	Rhinelands	Adolphi in litt.
Cynodon dactylon (L.) Pers.	7	4		Leipzig	Gutte, 1971
Eragrostis minor Host	7	3		Braunschweig Leipzig Halle, Leipzig Münster, Essen, Düsseldorf	Brandes, 1977 Gutte, 1971 Frank & Klotz, 1990 Wittig et al., 1985
Ficus carica L.			Fig trees appear occasionally, especially in wine regions, where they were planted. They are inconstant and synanthropic. In some	Berlin	Kunick, 1982

			places, for example at the port of Neuss, they are able to fruit.		
Hordeum murinum L. (Critesion Raf.)	7	4		Essen, Düsseldorf Münster Köln Bremerhaven	Wittig et al., 1985 Wittig et. al., 1985 Kunick, 1984 Kunick, 1979
Lepidium latifolium L.	6	5		Leipzig Poznan	Gutte, 1971 Zukowski, 1971
Paulownia tomentosa (Thunb.) Steud	*8*	5	Dispersed by wind along railway lines in the same way as *Ailanthus altissima*	Rhein-Neckar-Area	Nowack, 1987a, 1987b
Platanus x *hispanica* Miller ex Münchh			Along canals	Berlin	Kunick, 1982 Kowarik, 1984
Prunus persica (L.) Batsch			On waste heaps	Berlin	Kunick, 1982
Rhus typhina L.			This species is not completely mapped; it occurs partly in a spontaneous and partly in a naturalized manner.	Halle, Leipzig Rhinelands	Frank & Klotz, 1990 Adolphi, 1995

[1] Temperature Values (on a scale from 1 to 9):

Altitude	**Annual Mean Air Temperature**
5 montane to level	6.0°C
6 submontane to level	7.5°C
7 hilly or level (warm lowlands)	9.0°C
8 extremely favored valleys in southwest	10.0°C
9 warmest places (mainly upper Rhine region)	>10.5°C
x indifferent to elevation	

[2] Moisture Values (on a scale from 1 to 12):

2 intermediate between values 1 and 3 (between strong desiccation and desiccation)

3 indicator of desiccation, these plants more often found on dry soils than on moist soils

4 intermediate between values 3 and 5

5 between dry and humid, these plants mainly found on medium wet soils, absent on wet and on often dry soils

6 intermediate between values 5 and 7

7 indicator of moisture, these plants mainly found on moist but not wet soils

8 intermediate between values 7 and 9 (intermediate between moist and wet)

x indifferent to moisture

Table 2: Evergreen Broad-Leaved Plants Recently Often Spontaneously Appearing in the Rhinelands (Adolphia, 1995)

Name	Origin
Berberis julianae L.	Nemoral (broad-leaf deciduous) zone, humid mountain regions of west China with a monsoon climate; summer green deciduous forest
Cytisus multiflorus (L'Her. Ex Aiton) Sweet	Meridional zone, winter-mild nemoral (broad-leaf deciduous) zone of semihumid regions; Mediterranean hardleaf (sclerophyllous) forest, dry with mild summers
Cytisus striatus (Hill) Rothm.	Like *C. multiflorus*; introduced with seeds from Spain and Portugal used for planting along highways.
Lonicera nitida E.	Humid, nemoral (broad-leaf decidous) mountain regions of the meridional zone, summer green deciduous forest; the southwest of China, laurophyllous forest
Lonicera pileata Oliver	Nemoral zone of North America; summer green deciduous forest
Mahonia aquifolium (Pursh.) Nutt.	Nemoral zone of North America; summer green deciduous forest
Prunus laurocerasus L.	Nemoral zone, humid, mild winter regions from southeast Europe to the Caucasus; summer green deciduous forest

Table 3: Time Lag Between the Introduction and the Spontaneous Dispersal for a Number of Nonnative Woody Species of Brandenburg (Kowarik, 1992b)

Trees	Year of first introduction	Year of first observation of spontaneous dispersal	Time lag
Acer negundo L.	1736	1919	183
Aesculus hippocastanum L.	1663	1787	124
Ailanthus altissima (Miller) Swingle	1780	1902	122
Juglans regia L.	<1200	1860	>660
Laburnum anagyroides Medikus	1663	1861	198
Populus x *canadensis* Moench	1787	1952	165
Prunus armeniaca L.	1657	1965	308
Prunus mahaleb L.	1785	1839	54
Prunus serotina Ehrh.	1796	1825	29
Pyrus communes L.	<1594	1787	>193
Quercus cerris L.	1796	1957	161
Quercus rubra L.	1773	1887	114
Robinia pseudoacacia L.	1623	1824	201
Sorbus intermedia agg.	1796	1908	112
Shrubs			
Buddleja davidii L.	1796	1852	56
Colutea arborescens L.	1594	1859	265
Cornus alba L.	1773	1857	84
Cornus stolonifera	1785	1861	76
Ligustrum vulgare L.	1594	1787	193
Lonicera tatarica L.	1770	1864	94
Lycium barbarum L.	1769	1839	70
Mahonia aquifolium (Pursh) Nutt.	1822	1860	38
Philadelphus coronarius L.	1656	1839	183
Prunus persica (L.) Botsch	<1594	1965	>371
Ribes aureum Pursh	1822	1883	61
Symphoricarpos albus (L.) S.F. Blake	1822	1887	65
Syringa vulgaris L.	1663	1787	124
Vitis vinifera L.	<1200	1860	>660

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Ruderalization in a Roman Park as a Result of Changing Management*

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Abstract

Rome has one of the best open-space systems in Europe, and the Parco Regionale Urbano del Pineto is among its crown jewels. The 250-hectare park is among the city's last extensive undeveloped areas and has one of the most diverse floras in Rome. Presented here are the results of comparisons of studies conducted over a ten-year period of the vegetation in one-hectare quadrates situated in the park. We compared these studies in order to examine changes caused by a shift in land management. Once managed primarily as a sheep pasture, the park is now a nature reserve and used for recreation and tourism. This change has subjected the land to less pressure from animals and increasing pressure from humans. The comparison of the vegetation over time shows that natural succession has resumed, and reforestation is occurring in many areas. However, an analysis of Ellenberg's indicator values shows a clear increase in the number of ruderal species from the margins toward the center of the park. Neither trend bodes well for the future: Both reforestation and ruderalization will likely lead to a loss of biodiversity in the years ahead as important habitats and species niches are lost.

Introduction

Despite its rapid urban development, the city of Rome has one of most extensive green-space systems in Europe. Currently the park system, RomaNatura, includes 12 reserves, plus numerous historical villas, archaeological sites, and a number of gardens and uncultivated spaces (Cignini, Massari & Pignatti, 1995; Celesti Grapow & Pignatti, 1993).

Some of these parks are located in a buffer zone between the urban area and the surrounding countryside, forming a sort of greenbelt surrounding the urban area. Others are now completely inside the urbanized zone, and their use ranges from agricultural to recreational, as is the case of Parco del Pineto; these sites now represent a residual biotope, where patches of natural vegetation have somehow been saved from development (Celesti Grapow & Fanelli, 1991; Fanelli, 1995; Fanelli, Pignatti & Tescarollo, 2001; Pignatti, 1995).

Floristic lists are powerful tools in analyzing ecological patterns. Floristic composition can be analyzed qualitatively, but a quantitative analysis of floristic patterns is possible as well by means of Ellenberg's indicator values (Ellenberg, 1985; Pignatti et al., 2001; Thompson et al., 1993). A comparative study of urban biotopes by analysis of

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floristic patterns and historical data provides clues to understanding the effects of shifts in land management (Anzaldi, Celesti Grapow & Pignatti, 1992; Brandes, 1985; Catena, Macigno, Mulder & Pignatti, 1995; Celesti, Minichetti & Petrella, 1989; Kowarik, 1990; Kunick, 1982; Sukopp, Hejny & Kowarik, 1990; Horbert, Blume, Elvers & Sukopp, 1982). The Parco del Pineto is a representative case study because a large amount of historical and recent floristic information is available (Montelucci, 1953–54; Bianco, 1994) and because the biotope, although completely surrounded by intensively urbanized areas, preserves seminatural vegetation and a rich biodiversity.

Area of Study

The Parco Regionale Urbano del Pineto is one of 15 protected areas within the city of Rome (Figure 1). The 247-hectare park is characterized by a remarkable variety of landscapes, including cork oak (*Quercus suber*) forests, species-rich grasslands, ponds, and wetlands; these diverse landscapes provide habitat for 642 plant species, giving the park the richest plant-species density in Rome (Celesti Grapow, Petrella, Fanelli & Lucchese, 1995) (Figure 2). The park is located within the metropolitan area, approximately two kilometers from the walls of the Vatican. Until about 15 years ago it was used primarily as a sheep pasture. Saved from development thanks to the efforts of citizens, it is the last expanse of undeveloped land in a highly urbanized sector of Rome. The park is in fact completely surroundend by heavily built-up areas with few green or open spaces (Figure 3).

Geomorphologically the Parco del Pineto is a tuffaceous plateau that rises above a lowland field (from which came the old place name "Vallis Infera"—Lower Valley). It is composed of small sandy hills (in part attributable to a system of fossil dunes) alternating with modest valleys. The geological substrata consist of four types or layers (Bonadonna, 1968; Carboni et al., 1991):

Mount Vatican (Unità di Monte Vaticano) (Vatican marls formation): clay and sands of the Pliocene–lower Pleistocene (3–1.8 million years ago). The clay increases toward the bottom of this layer and causes water accumulation in the valley bottoms;

Mount Mario (Unità di Monte Mario): silt and clay deposited during the lower Pleistocene (1.7–1.4 million years ago);

Mount Ciocci (Unità di Monte Ciocci): fluvial deltaic deposits of gravel and sand a little later than the Mount Mario substrate (1.3–1.2 million years ago);

Tufi Sabatini: deposits of tufa from the upper-middle Pleistocene.

In the valley bottoms, recent alluvial sediments are found.

The area has a moderate Mediterranean climate, with a mean annual temperature of around 16°C and a mean rainfall of more than 800 millimeters annually. The average January temperature is 7.4°C, the average July temperature is 23.9°C, and frosts are very rare. There is a drought period that extends from June to August (Monte Mario meteorological station) (Figure 4).

The climate, the variety of substrates, and millennia of human activities have resulted in the area's great floristic diversity, making it an object of study since the last century (Montelucci, 1953–54; De Lillis & Testi, 1984, 1989; De Lillis, Testi, Scalfati & Cavendon, 1986; Bianco, 1994). Many rare species are present, in particular species from acidic soils poor in nutrients like *Romulea rolli* and *Crocus suaveolens*.

The vegetation of the area is very diverse, with about 15 vegetation types (Bianco, 1994; Fanelli, 2002). The primeval vegetation was probably a woodland dominated by the deciduous turkey oak (*Quercus cerris*) and Italian oak (*Quercus frainetto)* mixed with the evergreen cork oak (*Quercus suber)*, a rare vegetation type that can still be found in relatively undisturbed sites in a few areas surrounding Rome. Wetlands were probably also present.

Nowadays the vegetation is dominated by Mediterranean species that have spread mainly as a consequence of burning and cutting. The main vegetation types include the following (Figure 5):

***Quercus suber* woodland**: This is an evergreen woodland dominated by cork oak (*Quercus suber*) along with a few deciduous trees like downy oak (*Quercus pubescens*) and Italian oak (*Quercus frainetto)*. The undergrowth is relatively rich with species like *Stachys officinalis, Viola suavis, Smilax aspera,* and the endemic *Crocus suaveolens*. This woodland is often subjected to fire, but due to its thick, corky bark, cork oak is very fire-resistant.

***Corylus avellana* woodland**: This deciduous woodland is present as patches dominated by hazelnut (*Corylus avellana*). Other species are downy oak (*Quercus pubescens*) and poplar (*Populus tremula*). The undergrowth is scarce.

***Dasypyrum villosum* grassland**: This grassland is dominated by tall annual herbs (1–1.5 meters) such as *Dasypyrum villosum, Avena barbata,* and *Phalaris brachystachys*. Perennials are also present, such as *Asphodelus ramosus* and *Carlina corymbosa*. This grassland is species-rich (about 30 species per ten square meters), including in particular annual legumes like *Medicago polymorpha, Trifolium subterraneum,* and *Trifolium campestre*. It has been irregularly subjected either to mowing (closer to the urban areas) or to grazing. Blackberry (*Rubus ulmifolius*), elm (*Ulmus minor*), and broom (*Spartium junceum*) thickets are sparsely present in the grassland.

***Tuberaria guttata* grassland**: This is a low grassland (15–25 centimeters) growing on acidic soils, with a diverse floristic composition rich in rare or interesting species such as *Tuberaria guttata, Crassula tillaea, Ornithopus pinnatus, Romulea rolli,* and *Rumex bucephalophorus*. It is present in very small patches in a mosaic with the *Dasypyrum villosum* grassland and the *Quercus suber* woodland.

Wetlands: A few small springs in the park form ponds and ditches, where wetland vegetation occurs. The main species are *Iris pseudacorus, Sparganium erectum, Lythrum salicaria,* and *Eupatorium cannabinum*.

Perennial ruderal vegetation: This vegetation is present along the paths and on disturbed soils in moderate shade. It is dominated by nitrophilous forbs like *Artemisia vulgaris, Cirsium arvense, Urtica dioica,* and *Melissa romana*.

Annual ruderal vegetation: This vegetation is found as a narrow fringe along the paths that cut through the grassy areas. Main species are *Hordeum murinum* subsp. *leporinum, Echium plantagineum,* and *Malva sylvestris.*

Methodology

For the purposes of this study, the park was divided into quadrates of one hectare. Some of them, chosen randomly, were analyzed floristically in 1991 (Bianco, 1994) and again in 2000.

In most squares a mosaic of different vegetation types is present. *Quercus suber* and *Corylus avellana* woodland is predominant in squares D7, D10, M8, N8, P8, and Q8. *Dasypyrum villosum* grassland predominates in the other squares, often together with small areas of ruderal annual vegetation, in particular in squares C6, C7, and R2. Wetlands are found only in squares P8 and N8. Nitrophilous vegetation is found in particular in squares Q6 and R3, but species typical of this type are found frequently in other quadrates, in particular C3, R2, and S8.

The quadrate floras (two surveys for each square, one in 1991 and one in 2000) were subjected to multivariate analysis, or centered Principal Component Analysis (PCA), using Sin-Tax 5.01 software (Podani, 1994) in order to identify variation. Moreover, each quadrate was analyzed according to Raunkiaer life-forms (1907, 1934) and Ellenberg's indicator values (1985). Differences between years have been tested by means of the paired samples T test. Raunkiaer life-forms have been calculated as percentages, and Ellenberg values as the average value of the species present in the square, without weighting abundance. Taxonomic nomenclature follows Pignatti (1982).

Results

The main floristic trends are represented on the first two axes of the PCA diagram, which indicate a 67% variance. Along the first axis, surveys are shifted to the right from 1991 to 2000 (Figure 6). This shifting can be interpreted in light of the increase in perennial species and a decrease in annuals.

Phanerophytes (trees) and nanophanerophytes (trees and shrubs 0.25–2 meters), in particular *Prunus spinosa*, *Ulmus minor*, *Rubus ulmifolius*, and *Crataegus monogyna*, have increased to the detriment of the therophytes (annuals), which have diminished over time in nearly all the examined quadrates (Figures 7 and 8; Table 1). Differences between years are significant (t statistic –2.367, df 18, P = 0.029 (2-tailed).

Only quadrates C5, L6, R2, and R3 show a reverse trend. The surveys from 1991 are shifted to the left in 2000, and little variation or an increase in therophytes has been observed. These quadrates are near the main entrances to the park, where the growth of trees and shrubs is hindered by strong human pressure, such as trampling or cutting.

The second axis separates quadrates of the outer zones (C5, R2, R3, etc.) from those of the inner part of the park (G7, M8, P8, etc.). From 1991 to 2000 there was a slight shift downward of outer quadrates and upward of inner quadrates. This pattern on the ordination diagram matches Ellenberg's indicator values (Figure 9; Table 2), which fall into three distinct categories: quadrates in which an obvious increment was found (C5, C6, D10, R2, R3, S9, and V7), quadrates in which a moderate increment was found (D4, D7, L6, Q6, and T7), and quadrates in which the average of the indices remained the same (G7, M8, N8, and U7) or decreased (F6, H7, and P8). The distribution of the three categories indicates an increase of nitrogen indicator values toward the marginal areas of the park and a slight decrease in the inner zones. The overall change of nitrogen indicator value is highly significant (t statistic –2.367, df 18, P < 0.0001).

A closer study of the new species and those that disappeared suggests an explanation of the floristic changes. In quadrates where there is a strong increase in the nitrogen indicator values, species appear that are both nitrophilous and intolerant of competition, such as *Arctium minus*, *Picris hieracioides*, *Sonchus* *tenerrimus*, *Urtica membranacea*, and ephemerals such as *Cardamine hirsuta* and *Fumaria officinalis*. At the same time, oligotrophic annuals (those characteristic of areas low in nutrients like nitrogen) such as *Aira cupaniana*, *Briza maxima*, *Petrorhagia prolifera*, *Trifolium arvense*, *Trifolium cherleri*, and *Trifolium echinatum* disappeared. This is a clear indication that ruderalization is under way.

In areas with a moderate increase in nitrogen indicator values, there is an increase in only a few nitrogen-demanding species (*Elymus repens*, *Arctium minus*, *Veronica polita*). The main change associated with this indicator value is the disappearance of oligotrophic species such as *Medicago truncatula*, *Plantago psyllium*, *Rumex bucephalophorus*, and *Tuberaria guttata*.

Discussion

Since the first vegetation studies were done at Parco del Pineto, there has been a drastic change in management. In the past the park was mainly a sheep pasture, with moderate recreational use limited to the park's margins. The area was considered dangerous and "dirty" by the local people (Bonnes, De Rosa, Ardone & Bagnasco, 1989). In 1995, grazing was prohibited, and at the same time there was an increase in the number and frequency of visitors inside the park.

Other possible factors influencing the floristic composition of the Parco del Pineto include the use of certain areas for sewage works, railway tracks, and small public gardens, and the periodic burning of some areas. These are nonetheless limited to spotty areas scattered in the park and don't affect large segments of the landscape.

The most important result of these management changes is a general tendency toward reforestation throughout the park, as shown by the increase in phanaerophytes and nanophanaerophytes and the decrease in therophytes. The cessation of grazing has enabled vegetation succession to resume.

The data on the variation in nitrogen indicator values, as mentioned earlier, allowed us to distinguish three concentric areas in the park (Figure 10):

External Area: This includes areas near the border, which are subject to greater numbers of visitors and affected by construction. In this area, there has been a strong increase in nitrogen indicator values. This is associated with human impact, in particular the removal of shrubs, which favors the growth of nitrophilous forbs.

Intermediate Area: This area includes most of the lawns in the park and corresponds more or less with the zone that was grazed most intensively in the past. Here there has been a moderate increase in nitrogen indicator values, probably associated with the interruption of grazing. It is logical to conclude that with the disappearance of the animals there has been greater mobilization of nitrogen; nitrogen was once partially removed by the animals with grazing and only in part reintroduced in their excrement (Figure 11). All the nitrogen in the decaying vegetation is now available (Schmidt, 1978). The higher levels of nutrients have caused a gradual disappearance of oligotrophic species, which have been replaced by more competitive species.

Inner Area: This area includes most of the middle hill of the park and the less accessible areas; it also includes all those areas that were not heavily grazed. The nitrogen indicator values have remained the same, or in some cases, decreased.

The increase in nitrogen indicator values could also be affected by atmospheric deposits due to air pollution, a widespread phenomenon in recent years (Perakis & Hedin, 2002).

Conclusion

Our study demonstrates that the change in management of the Parco del Pineto from a pasture to a protected area for recreation and tourism has resulted in significant floristic changes. The abolition of grazing, which at first glance might be considered a good conservation measure, has coincided with an increase in nitrogen indicator values. This is possibly due to the fact that when grazing ceased, so did nitrogen removal by the sheep. Moreover, the increased number of human visitors has caused obvious ruderalization, especially in the more frequented outer areas of the park.

The future is not encouraging: We can expect a disappearence of oligotrophic, often rare species throughout the area and a decrease in biodiversity due to reforestation and the resulting reduction in the number of glades, microhabitats, and important species niches.

Acknowledgments

We greatly thank Dr. Andrea Palmeri and the members of the Cooperative Pineto 2000, Doctors Alessandro Serafini Sauli, Andrea Ramello, Diego D'Angeli, Giulia Rinieri, and Michele De Sanctis for their valuable contributions in the floristic surveys of 2000.

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Figure 1. Parco del Pineto: Area of Study

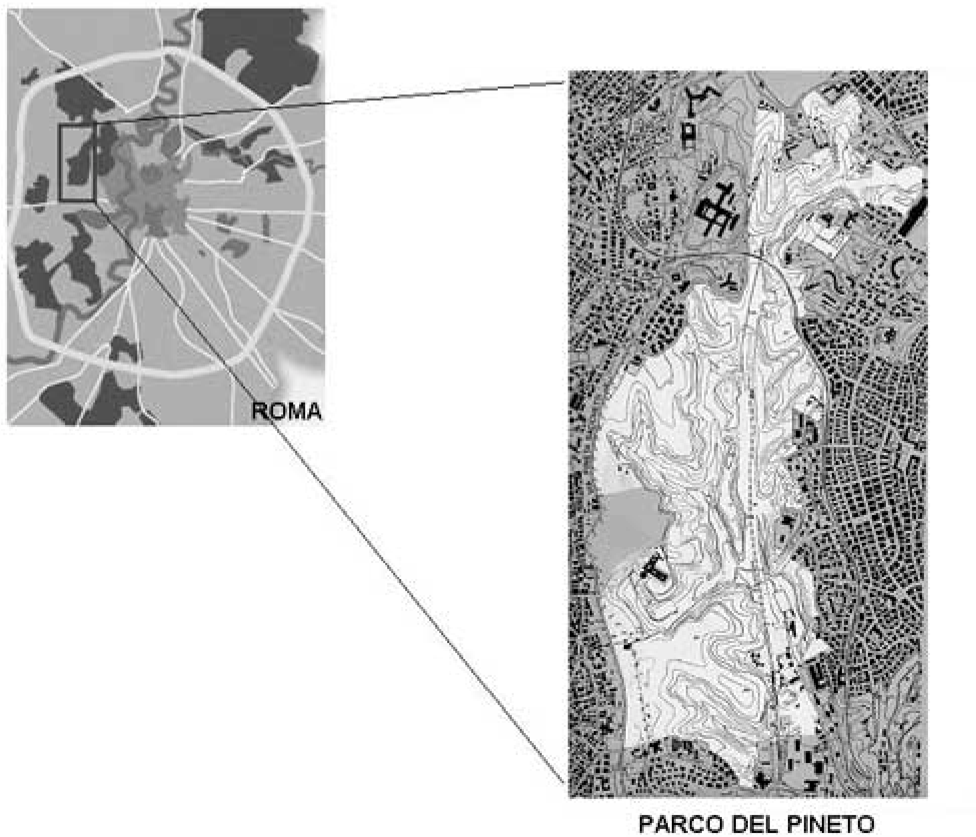


Figure 2. A View of the Park (Quadrate M7)

Figure 3. Aerial Photograph of the Park: a Sector in Northwestern Rome near the Tiber River.

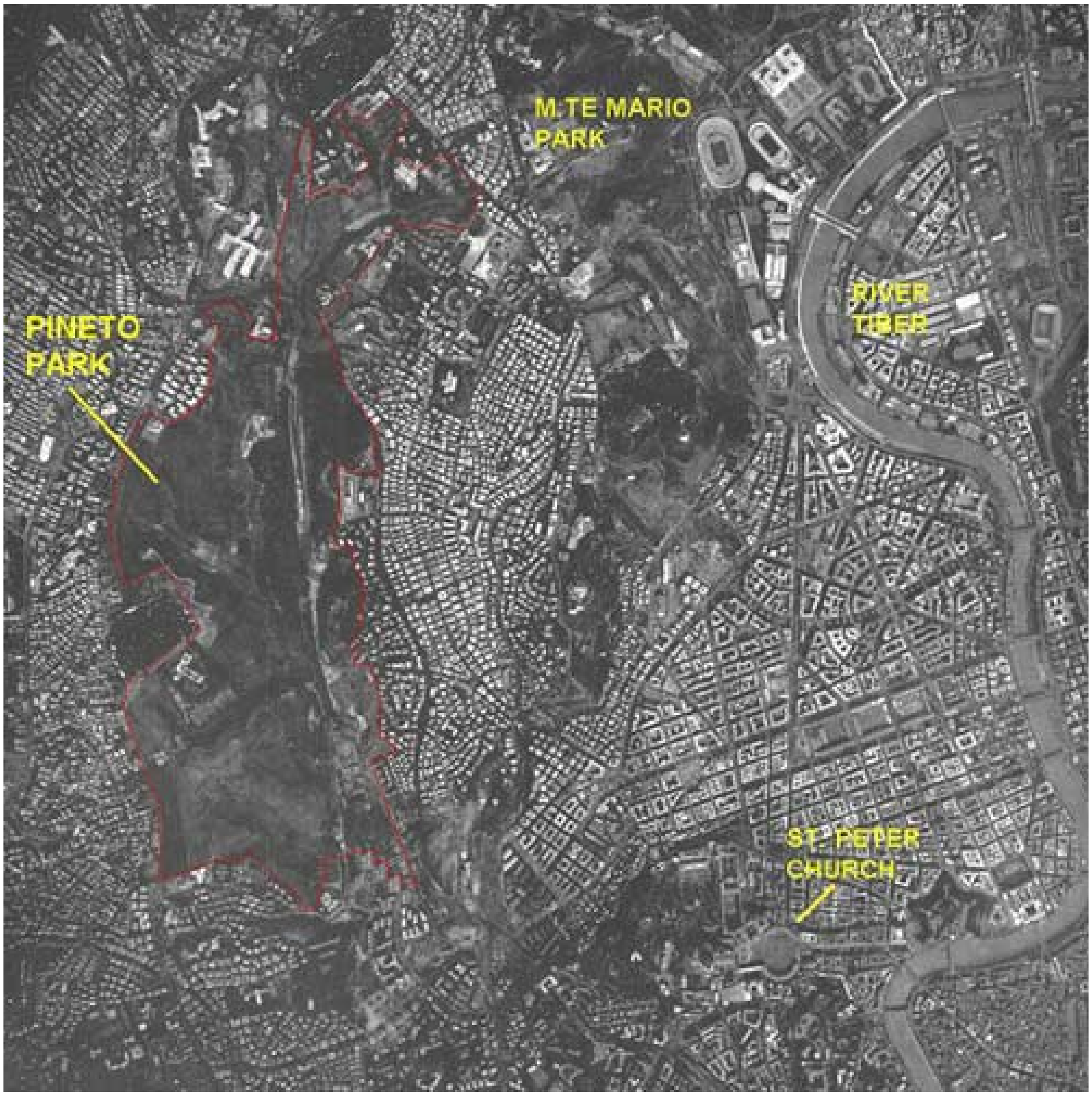


Figure 4. Bagnouls-Gaussen Climatic Diagram of Monte Mario

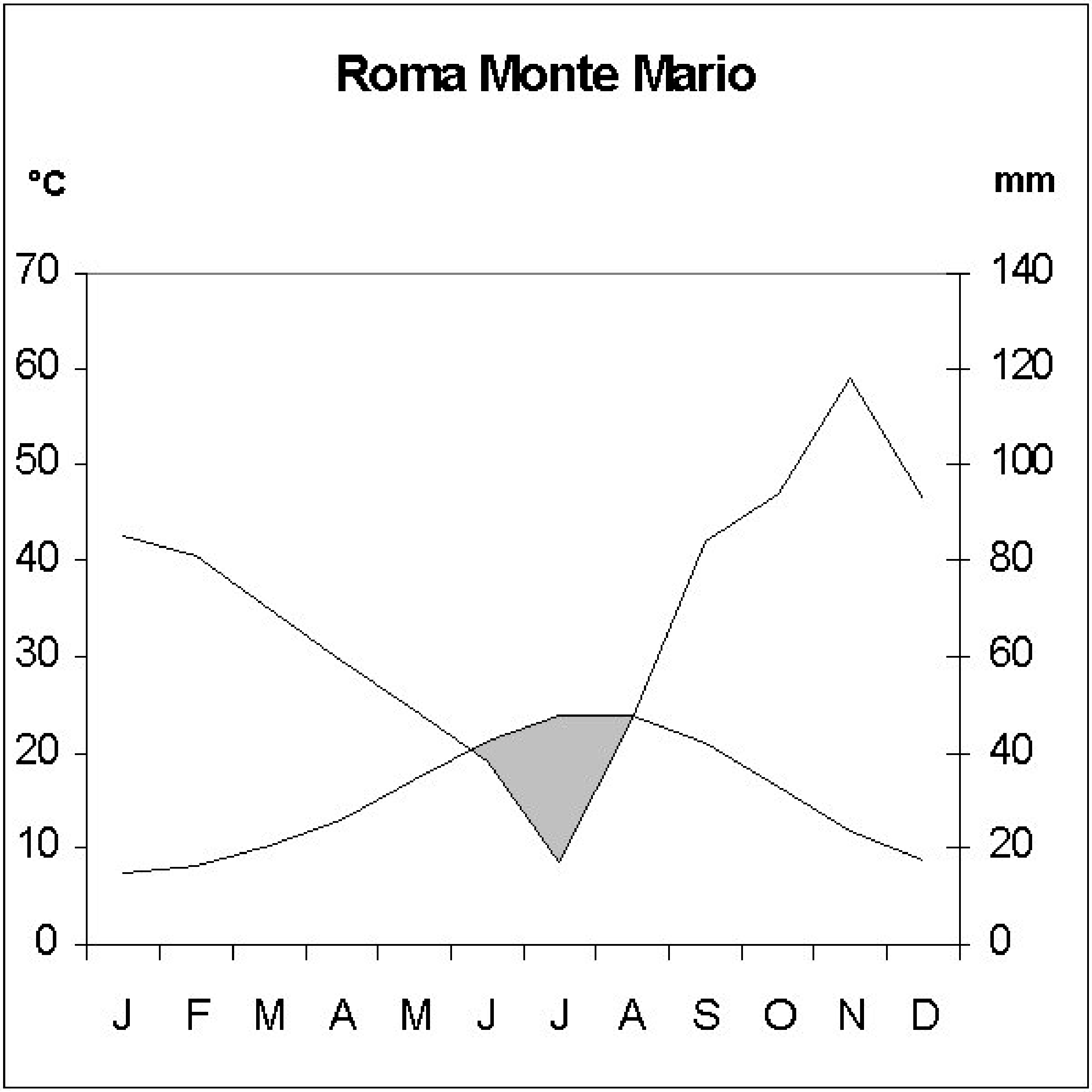
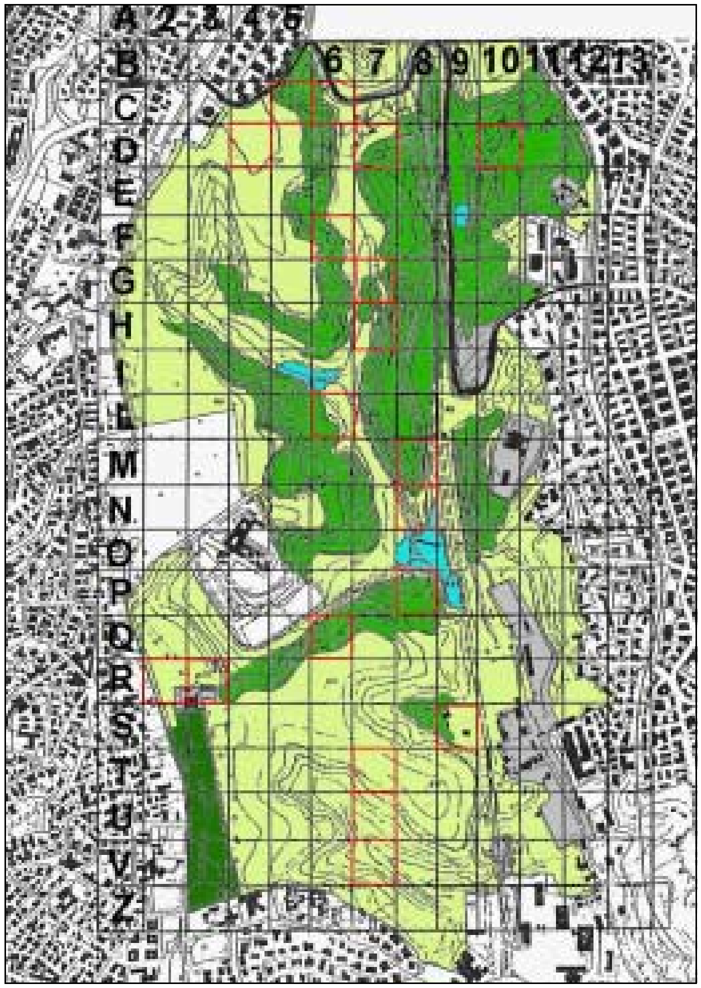
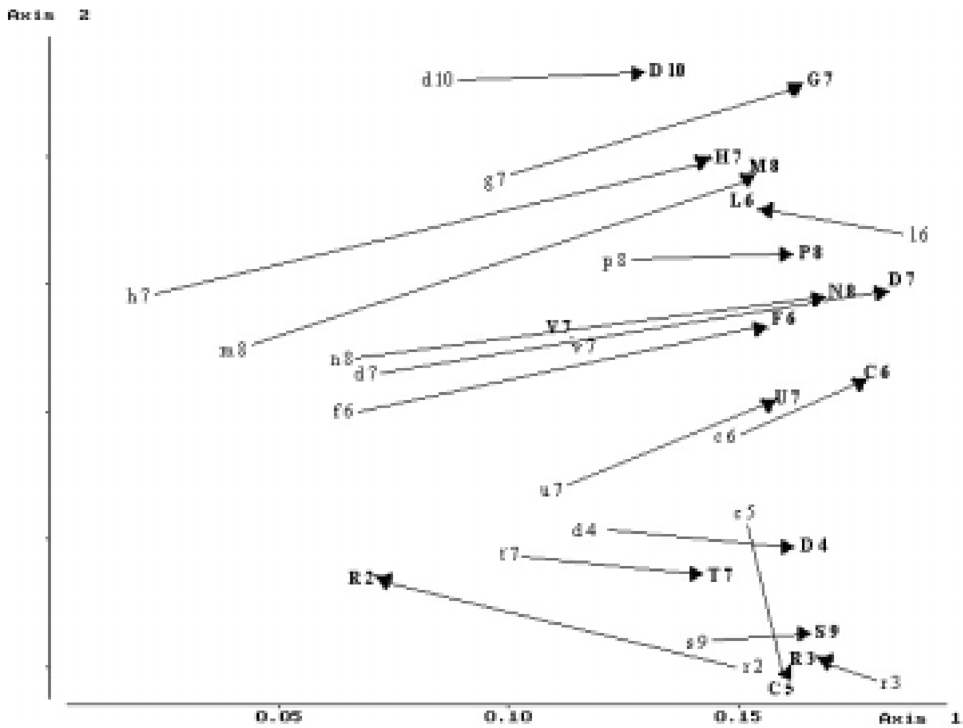


Figure 5. Map of the Main Vegetation Types in the Parco del Pineto



Legend:
Studied quadrates outlined in red.
Dark green = planted pine woods
Light green = woodland, mainly *Quercus suber*
Yellow = lawns and grassland with sparse thickets of small bushes
Blue = wetlands
Gray = built-up areas and wastelands

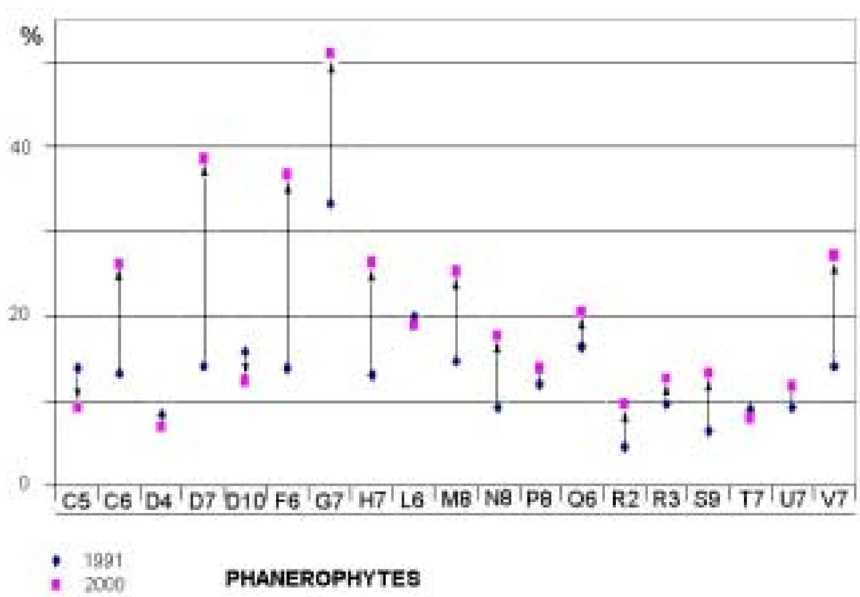
Figure 6. Principal Component Analysis (PCA) of the Quadrates



Legend:

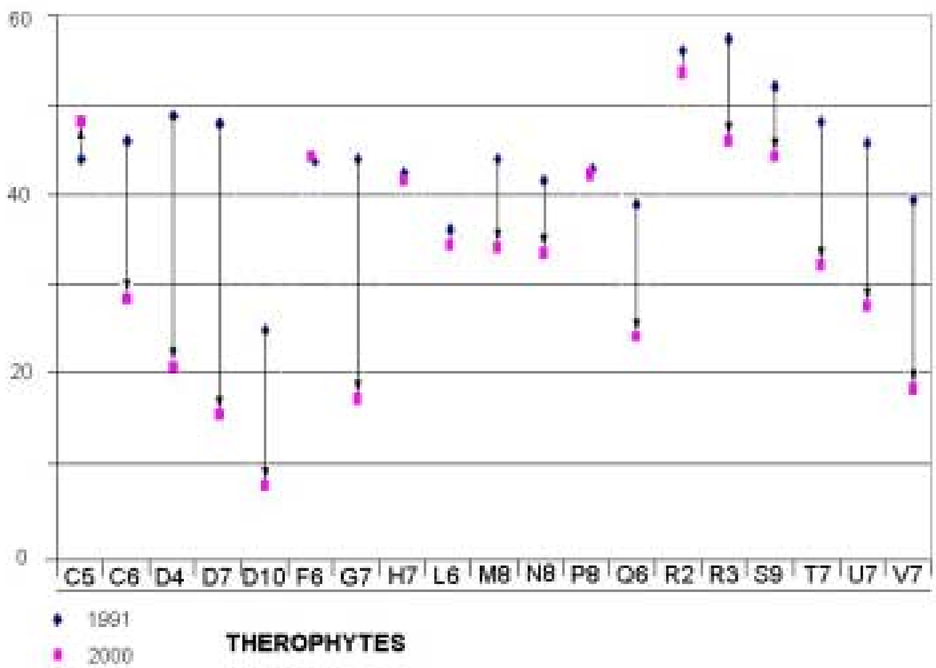
Quadrates are represented by letter/number codes.
Capital letters = 2000 surveys
Lower-case letters = 1991 surveys
Arrows = trend of variation in floristic composition from 1991 to 2000

Figure 7. Variation in Percent of Flora Represented by Phanerophytes



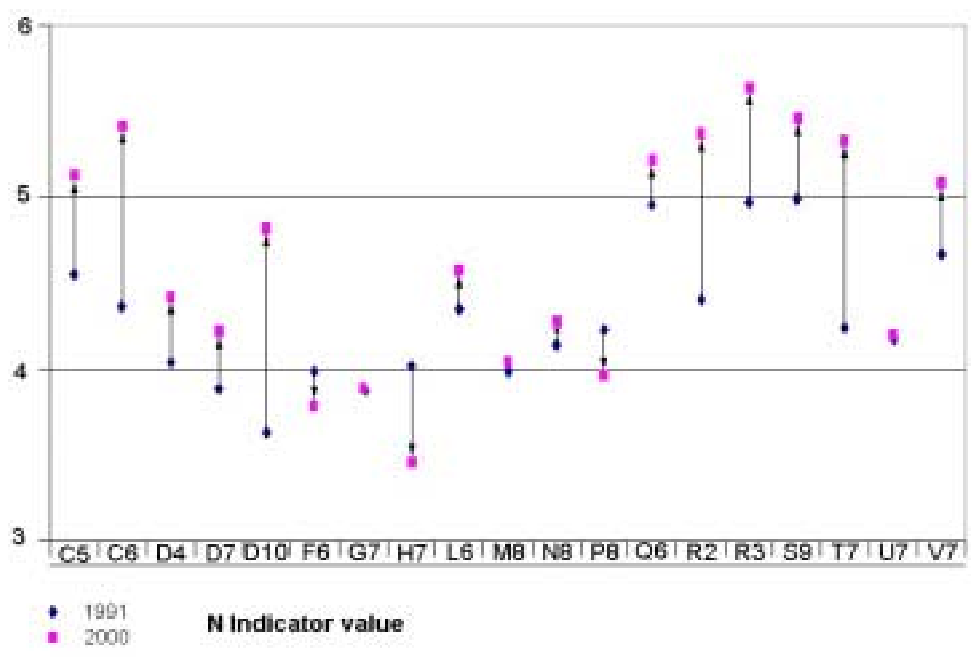
Arrows indicate the direction of variation from 1991 to 2001.

Figure 8: Variation in Percent of Flora Represented by Therophytes



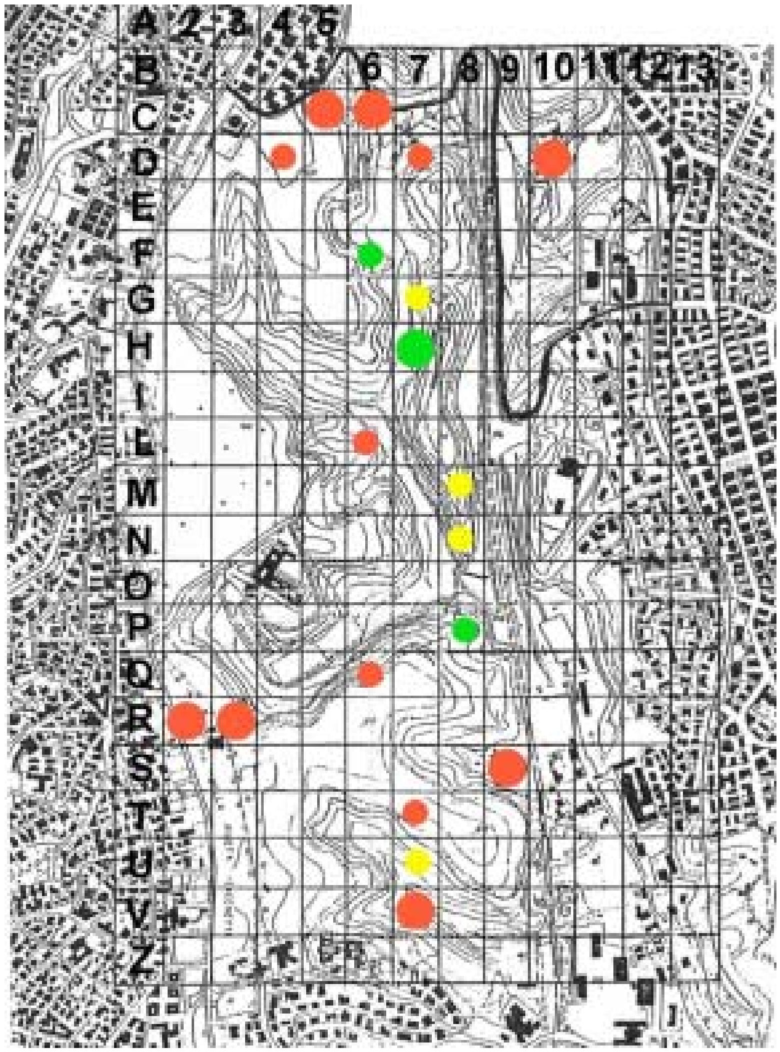
Arrows indicate the direction of variation from 1991 to 2001.

Figure 9. Variation in Ellenberg's Indicator Values



Arrows indicate the direction of variation from 1991 to 2000.

Fig. 10: Map of the Variation in Nitrogen Indicator Values



Legend:

Large red circles = large increase
Small red circles = moderate increase
Yellow circles = no change
Large green circles = large decrease
Small green circles = moderate decrease

Fig. 11. Hypothetical Scheme of Nitrogen Cycling in Quadrates Subject to Grazing (1991) and Five Years After Sheep Removal (2000)

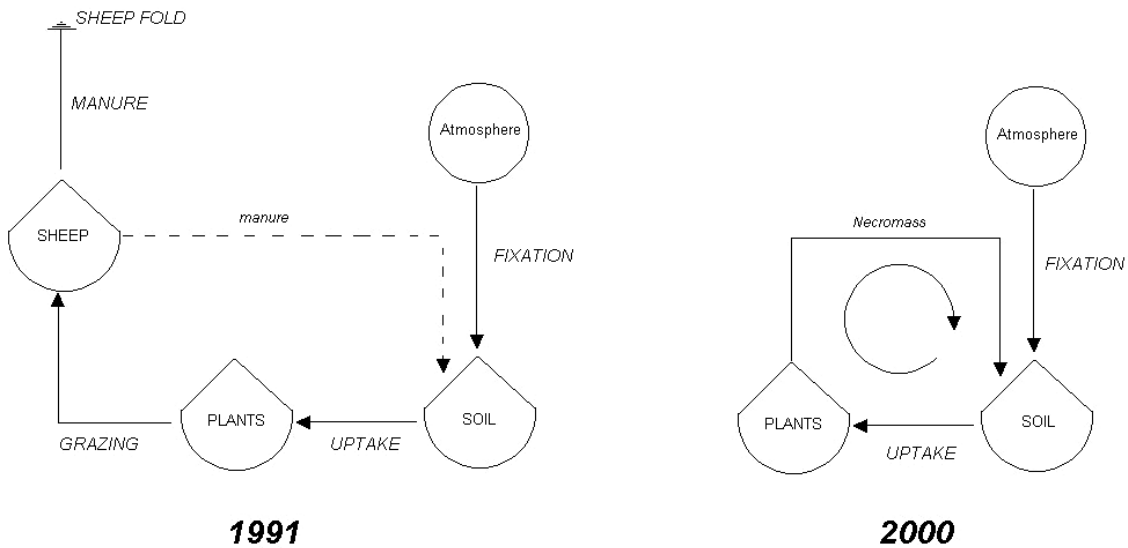


Table 1. Variation in the Life-Forms in Quadrates

	Ch	G	H	P/NP	T	He/I
C5 1991	0	4,7	36,4	14	43,9	0,9
C5 2000	0	1,9	40,7	9,3	48,1	0
C6 1991	0	6,67	34,2	13,3	45,8	0
C6 2000	0	10,9	34,8	26,1	28,3	0
D4 1991	0,84	9,24	31,9	8,4	48,7	0,84
D4 2000	0	6,89	65,5	6,89	20,7	0
D7 1991	0,82	6,61	29,8	14	47,9	0,8
D7 2000	0	9,62	36,5	38,5	15,4	0
D10 1991	2,15	10,8	29	33,3	24,7	0
D10 2000	1,88	13,2	26,4	50,9	7,55	0

F6 1991	1,05	7,37	30,5	15,8	44,2	0
F6 2000	0	8,55	34,2	12,5	44,1	0
G7 1991	0,67	8,67	31,3	14	44	1,3
G7 2000	0	14,6	31,7	36,6	17,1	0
H7 1991	1,01	11,1	31,3	13,1	42,4	1,01
H7 2000	0	11,3	20,8	26,4	41,5	0
L6 1991	0,8	12	31,2	20	36	0
L6 2000	0	8,86	37,3	19	34,2	0,63
M8 1991	1,83	8,26	30,3	14,7	44	0,92
M8 2000	1,59	10,3	28,6	25,4	34,1	0
N8 1991	0	7,57	39,5	9,19	41,6	2,16
N8 2000	1,3	10,5	36	17,7	33,3	1,31
P8 1991	0,8	9,6	33,6	12	42,4	1,6
P8 2000	0,5	10,7	32,7	14	42,1	0
Q6 1991	0	8,26	36,4	16,5	38,8	0
Q6 2000	0	14,8	40,7	20,4	24,1	0
R2 1991	0,93	7,47	30,8	4,67	56,1	0
R2 2000	0	4,87	31,7	9,75	53,7	0
R3 1991	0,8	3,2	29	9,7	57,3	0
R3 2000	0	6,3	34,9	12,7	46	0

S9 1991	0	8,26	33,1	6,61	52,1	0
S9 2000	0	7,35	35,3	13,2	44,1	0
T7 1991	0,9	6,36	35,5	9,09	48,2	0
T7 2000	0	8	52	8	32	0
U7 1991	0	8,47	36,4	9,32	45,8	0
U7 2000	0	15,7	45,1	11,8	27,5	0
V7 1991	1,01	8,08	37,4	14,1	39,4	0
V7 2000	0	13,6	40,9	27,3	18,2	0

Table 2. Variation in Ellenberg's Nitrogen Indicator Index in Quadrates

Ellenberg N index				
	1991	2000		
C5	4,55	5,13		+0,58
C6	4,36	5,41		+1,05
D4	4,04	4,42		+0,38
D7	3,89	4,22		+0,33
D10	3,63	4,81		+1,18
F6	3,99	3,79		-0,2
G7	3,89	3,89		0
H7	4,02	3,45		-0,57
L6	4,35	4,57		+0,22
M8	3,98	4,04		+0,06
N8	4,14	4,27		+0,13
P8	4,23	3,96		-0,27
Q6	4,96	5,21		+0,25

R2	4,41	5,37		+0,96
R3	4,97	5,63		+0,66
S9	4,99	5,46		+0,47
T7	4,29	4,62		+0,33
U7	4,17	4,2		+0,03
V7	4,67	5,23		+0,56

Glossary

Biotope: A region uniform in environmental conditions and in its populations of animals and plants for which it is the habitat.

Ellenberg's Indicator Values: Scales that describe the relationship between the occurrence of plant species and various factors such as nitrogen, light, temperature, soil pH, and moisture. An Ellenberg nitrogen indicator value of 1 is associated with plants on extremely infertile sites, 9 with plants on very rich sites.

Paired Samples T Test: The Paired Samples T Test compares the means of two variables. It computes the difference between the two variables for each case, and tests to see if the average difference is significantly different from zero (see http://www.wellesley.edu/Psychology/Psych205/pairttest.html).

Principal Component Analysis: A statistical procedure for reducing multivariate data in order to detect structure and patterns within data.

Raunkiaer Life-forms: Danish botanist C. Raunkiaer's method of classifying higher plants irrespective of their taxonomy and systematics (see http://worc.ac.uk/departs/envman/courses/bio/L1/bio101/raunkiaer.html).

Ruderal Species: Species characteristic of lands that are highly disturbed but rich in water, nutrients, and other resources.

Tuffaceous: Of or pertaining to tuff, rock made of the finer components of volcanic debris, usually fused by heat.

A Reconstruction of the Flora and Vegetation in the Central Area of Early Medieval Kiev, Ukraine, Based on the Results of Palynological Investigations*

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Abstract

This paper provides a partial reconstruction of the main features of the flora and vegetation of the central area of the city of Kiev (Kyiv in the Ukrainian-based transliteration), Ukraine, in early medieval times. The reconstruction is based on fossil spore and pollen samples. Samples for the spore-pollen analysis were selected in 1998 and 1999 during archaeological investigations on the grounds of St. Michael's Gold-Domed Cathedral and in three adjacent areas in the hilly central part of Kiev. According to archaeological data, the samples were dated to between the 10th and 12th centuries A.D. Analysis of the fossil palynoflora yielded a general list of 102 taxa of different ranks (identified by species, genus, family, or order), 72 of which were herbaceous (62.9% to 82.1% for the four sites). Analysis of the herbaceous pollen on the species level turned up a significant number of weedy flora. The data was used to supplement prior lists of weedy and cultivated plants. A comparison of our species list with diagnostic species of modern syntaxa of ruderal vegetation gives evidence that some synanthropic plant species achieved their community-forming role only during the last millennium. The data collected and analyzed in his paper provide only a fragmentary view of the natural (nonsynanthropic) vegetation that surrounded the ancient city of Kiev. However, it includes new details and paleobotanical information on the anthropic factors influencing the formation of the urban flora and vegetation of ancient Kiev.

Introduction

Understanding the interactions between humans and the natural world is best solved using methods from both the natural sciences and historiography. The reliability of paleobotanical (or archeobotanical) reconstruction is very much enhanced by combining the tools of palynology (especially paleopalynology) and paleoethnobotany, in short, by studying microfossils alongside macrofossils. Use of spore-pollen analysis to study the cultural layers of archeological sites, especially in urbanized areas, provides insight into the anthropic, or human-influenced, components of past vegetation. This is

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especially true when the pollen belongs to plants that are considered indicators of economic activity—namely, crop plants and weedy species associated with human presence, and especially human economic activity, in the natural or man-altered environment.

In paleobotanical terms, the ancient city of Kiev (Kyiv in the Ukrainian-based transliteration), Ukraine's capital and the so-called "Mother of Russian Cities," is a fascinating model for study. Situated along an important historical trade route, it played a leading role in the urban development of eastern Europe, until its devastation in A.D. 1240 by the Mongol and Tatar hordes of Batu Khan (a grandson of Genghis Khan). Between the 10th and 12th centuries, Kiev was among the largest and most densely populated urban areas in Europe. It is safe to assume, then, that Kiev's flora and vegetation were considerably altered by humans during these two centuries.

Material and Methods

In our study, samples for spore-pollen analysis were selected in 1998 and 1999 during archaeological investigations on the grounds of St. Michael's Gold-Domed Cathedral and in adjacent areas in the hilly central part of Kiev. In this article, we present the results of our palynological analysis of the first series of data. The samples were dated to between the 10th and 12th centuries A.D. They came from the following early medieval sites: (1) a 10th-century Slavonic burial site at modern-day Sofia Square; (2) a 10th-century Slavonic burial site on the grounds of the present-day reconstructed St. Michael Gold-Domed Cathedral (trench No. 6); (3) a 10th-century Scandinavian burial site on the grounds of St. Michael's Gold-Domed Cathedral (chamber No. 2, the northern corner at the western side of the cathedral's gate); (4) construction fill from a building dating from the end of the 11th century through the 12th century A.D. on the grounds of St. Michael's Gold-Domed Cathedral (trench No. 15, building No. 2).

The three selected burial sites are from roughly the same era. They can be traced to the formative years of feudal ancient Rus, which included nearly all of present-day Ukraine, Belarus, and parts of northwestern Russia. This powerful medieval Slavonic state is usually called Kievan Rus in the history books, as its capital city was Kiev. In the 10th century and the first half of the 11th century, there were no permanent buildings in the immediate vicinity of the studied burial sites. The last burials to take place there were probably in the first half of the 11th century, and urban development of the area began around this time. This historical part of ancient Kiev is known as Izyaslav City or Izyaslav–Svyatopolk City. Prince Izyaslav (Isiaslav), the son of the Kievan Grand Prince Yaroslav (Iaroslav) the Wise, built St. Dmitry Monastery here in the 1060s. St. Peter's Church was built at the monastery between 1085 and 1087 by orders of Yaropolk, the elder son of Izyaslav. St. Michael's Gold-Domed Cathedral was founded in 1108 by Svyatopolk, who was then the Grand Prince of Kiev (Tolochko, 1976; Dehtiarov & Reutov, 1999; Ivakin, 2001).

In our palynological study, pollen preparation and processing followed the standard procedure proposed by V.P. Grichuk (Pokrovskaya, 1966). The samples were treated with heavy liquids ($KI + CdI_2$) with the specific gravity of 2.0, 2.1, and 2.2 g/cm^3. For pollen identification, we used the reference pollen collections of the Department of Vascular Plants at the M.G. Kholodny Institute of Botany and of the

Department of Biology at the National University "Kyiv-Mohyla Academy." We also referred to pollen-identification manuals and special palynomorphological articles on pollen analysis (Erdtman, 1943, 1957, 1965; Kupriyanova, 1965; Kupriyanova & Aleshina, 1972, 1978; Boros & Jarai-Komlodi, 1975; Bobrov, Kupriyanova & Tarasevich, 1983; Grichuk & Monoszon, 1971; Monoszon, 1950, 1973, 1976, 1985; Kazartseva, 1982; Askerova, 1987; Romanova & Bezusko, 1987; Savitsky, Bezusko, Savitska & Bezusko, 1998, and others). The scientific plant names follow the recent nomenclatural checklist of vascular plants of Ukraine (Mosyakin & Fedoronchuk, 1999). For interpreting the results of our paleopalynological analysis of the medieval spore-pollen (SP) samples, we used methodological principles and data based on previous actuopalynological studies (i.e., studies of modern pollen, as opposed to studies of fossil pollen, or paleopalynology). In particular, these studies demonstrated a dependence between SP spectra in recent and subrecent surface-soil samples and the present-day vegetation patterns in the forest and forest-steppe zones of Ukraine (Arap, 1972, 1974, 1976; Bezusko, Bezusko & Yesilevsky, 1998). The similarities revealed in these studies allow us, with a reasonable degree of probability, to extrapolate fossil SP data and thereby reconstruct basic vegetation patterns in this area of medieval Kiev.

Our analysis of the fossil palynoflora yielded a general list of 102 taxa of different levels (identified by species, genus, family, or order): See Table 1. The analysis also allowed us to establish ratios between the arboreal pollen (AP, pollen of trees and shrubs) and nonarboreal pollen (NAP, pollen of mostly herbaceous plants) content of the fossil spore-pollen spectra. As shown in Figure 1, all SP spectra are characterized by some domination of pollen from herbaceous plants (62.9% to 82.1%). Of course, the ratio of pollen from nonarboreal plants to pollen from arboreal plants in the fossil SP spectra provides only generalized information indicating the presence and very approximate shares of corresponding plants. In modern (recent) SP spectra, ratios vary greatly seasonally and annually depending on climatic and atmospheric conditions, phenological rhythms of flowering periods of various plants, and other factors. However, in steppe and forest-steppe zones, the corresponding ratios in recent and subrecent samples are usually lower.

Trees and Shrubs of Ancient Kiev

The list of arboreal pollen includes 30 taxa (12 identified genera and 18 identified species). The pollen of *Betula pendula*, *Pinus sylvestris*, and *Tilia cordata* was present in all four SP spectra. The forests surrounding the early medieval city of Kiev from the north were represented mainly by *Pinus sylvestris*, *Alnus glutinosa*, *Betula pendula*, *Betula pubescens*, *Corylus avellana*, *Salix* species, as well as other species of trees and shrubs. These species are still typical of modern-day forests of the forest zone, which lies north of Kiev. However, the data also show that the dendroflora of the ancient town was also composed of *Acer platanoides*, *Quercus robur*, *Tilia cordata*, *Carpinus betulus*, *Fraxinus excelsior*, *Ulmus* species, *Viburnum* species, *Rosa canina*, *Sambucus nigra*, and some other plants. These species are mostly typical of the more open plant communities of the forest-steppe zone to the south and are also abundant today, mostly in the southern parts of Kiev. Since Kiev is situated at the border of the forest and forest-steppe zones, it is not surprising to find these trees and shrubs represented.

The linden, or lime, tree, *Tilia cordata*, played an important economic role in ancient Kiev. It was harvested for its timber, bast, and tar, and its blossoms made into tea. It was also considered a medicinal and even sacred plant, and the practice of preserving linden trees endures to this day: The oldest linden tree in Kiev dates back 500 years and grows near the ruins of the Tithe (Desyatynna) Church (Voinstvensky, 1986).

Pollen of the walnut tree, *Juglans regia*, a source of nuts and high-quality wood, was identified in the SP spectra. Historical records indicate that walnut trees were first planted in the Kiev area in the gardens of the Mezhygorsky and Vydubetsky monasteries near ancient Kiev (now within modern-day Kiev). But the date of these introductions was defined rather widely, as probably sometime between the 10th and 12th centuries A.D. (Strela, 1990). Our palynological data is the first paleobotanical confirmation of the presence of this valuable cultivated species in the Kiev dendroflora of the second half of the 10th century to the 12th century A.D.

In the SP spectrum from deposits of the end of the 11th century through the 12th century A.D., pollen grains of apple trees, *Malus* species, were also identified. Historical sources tell of an abundance of apple gardens in the territory of early medieval Kiev. For example, chronicles of the 11th century mention the famous apple garden of the Kyivo-Pechersky Monastery (Kiev Cave Monastery) and also the gardens near the St. Sofia Cathedral (also known as the Cathedral of the Holy Wisdom) and the St. Cyril (Kirilovsky) Monastery (Uspenskaya, Klimenko, Kuznetsov & Davydenko, 1991; Kokhno & Kurdyuk, 1994). As a rule, gardens of ancient Kievan Rus were cultivated near monasteries, convents, estates of princes and boyars (members of Rus nobility, ranking immediately below the princes), as well as near houses of other town inhabitants (Uspenskaya, Klimenko, Kuznetsov & Davydenko, 1991).

Herbaceous Plants

The general list of plants identified in the SP spectra includes 72 herbaceous taxa (26 families, 7 genera, and 39 species). Analysis of the herbaceous components on the species level turned up a significant number of weedy plants, almost half of the total number.

We have compared our palynological data with paleoethnobotanical data for Kiev from the same era obtained by G.A. Pashkevich (1991, 1998): See Table 2. Notably, we have added *Beta vulgaris* and *Malus* (probably *M. domestica*) to Pashkevich's list of 11th- to 12th-century cultivated plants. According to A.I. Barbarych (1962), who based his work on the available historical chronicles and records, *Beta vulgaris* had been known in Kievan Rus since the 10th and 11th centuries A.D. It later spread to neighboring Lithuania and Poland.

It is noteworthy that A.I. Barbarych also mentions *Ribes* and *Rubus* among the plants cultivated in Kievan Rus times. We found microfossils for these genera in the 11th- to 12th-century deposits (see Table 1). These deposits (but not those from the 10th-century sites) also contained pollen grains of *Sorbus* species, *Rosa canina* s.l., *Sambucus nigra*, *Viburnum* species, *Valeriana* species, *Convallaria majalis*, *Thalictrum aquilegiifolium*, and other species, some of which were probably cultivated, or at least favored and preserved, in urban areas. Of the variety of weeds that appeared during the 11th and 12th centuries, *Chenopodium foliosum* is a species that was widely cultivated as a leaf vegetable in early medieval times.

Of course, in addition to the "standard" set of crops, many weedy species were occasionally used, in Kievan Rus and elsewhere in medieval Europe, as "famine food" or as complementary additions to the standard diet of medieval population.

We have made additions to Pashkevich's list (1991, 1998) of weedy flora of ancient Kiev (Table 2 [link here]). Among these species, newly listed archaeophytes (nonnative taxa introduced before the end of the 15th century) are represented by *Centaurea cyanus, Scleranthus annuus, Spergula arvensis*, *Atriplex sagitata*, *Chenopodium foliosum*, *Cichorium intybus*, *Sonchus arvensis*, *Fallopia convolvulus*, *Echinochloa crusgalli*, *Setaria glauca*, *Setaria viridis*. Newly listed apophytes (native taxa) are represented by *Artemisia absintium*, *Tussilago farfara, Cerastium arvense, Atriplex tatarica*, *Chenopodium botrys*, *Chenopodium glaucum*, *Chenopodium rubrum*, *Polycnemum arvense*, and *Plantago lanceolata*. New additions to the list of euapophytes (typical apophytes) are *Arctium tomentosum*, *Artemisia scoparia*, *Artemisia vulgaris*, *Cirsium arvense*, *Echium vulgare*, *Stellaria media*, *Chenopodium album* s.l., *Taraxacum officinale* s.l., *Chelidonium majus*, *Plantago major*, *Plantago media*, *Polygonum aviculare* s.l., *Rumex crispus*, *Rumex confertus*, *Galium aparine*, and *Equisetum arvense*.

From these data, we can confirm the immigration and naturalization status of many of the weedy species of present-day Kiev, as reported by V.V. Protopopova (1991). The most essential changes we've made are to the group known as the kenophytes (species that immigrated during the period from the 16th century to the present). Several weedy species should now be recognized as archaeophytes rather than kenophytes. Along with those mentioned above and others, *Cannabis sativa* (and its weedy races, usually known collectively as *Cannabis ruderalis* Janisch.) should now be considered an archaeophyte in Kiev.

The data provided here not only summarize the content of the crop and weed floras of ancient Kiev but also clearly demonstrate the prospects of further success in using paleoethnobotanical methods alongside palynological ones. The paleoethnobotanical method, for instance, considerably deepens our knowledge about grain crop species. This is because the palynological method can usually only identify the pollen of these grains to the level of "cereals" within the group collectively known in paleoethnobotanical studies as Cerealia. However, palynological materials are more informative when determining the species content of weedy flora. Undoubtedly, the most "trustworthy" taxa are those whose presence is confirmed by the two paleobotanical methods. In our study, these are the weedy species *Chenopodium album* s.l. and *Fallopia convolvulus*.

Modern-Day Descendants

We compared the species composition of the fossil weed flora (Table 2) with the diagnostic table of syntaxa of Ukraine's synanthropic vegetation compiled using the Braun-Blanquet method (Solomakha, Kostylev & Shelyag-Sosonko, 1992). The results of our analysis show that among the 36 species of weeds we reported as macrofossils and pollen remnants, 16 taxa are diagnostic species on the levels of syntaxonomic classes and orders of the modern syntaxa of ruderal and segetal vegetation of Ukraine. These syntaxa and their diagnostic species are listed below.

Class *Artemisietea vulgaris* Lohm., Prsg. et R. Tx. in R. Tx. 1950:
Diagnostic species: *Chelidonium majus, Atriplex sagitata*.
Order *Artemisietalia vulgaris* Lohm. in R. Tx. 1947:
Diagnostic species: *Tussilago farfara*.
Order *Galio–Alliarietalia* Oberd. ex Gors et Th. Mull. 1969:
Diagnostic species: *Galium aparine*.
Class *Chenopodietea* Br.-Bl. 1951; emend. Lohm., J. et R. Tx. 1961:
Diagnostic species: *Chenopodium album, Sonchus arvensis, Fallopia convolvulus.*
Order *Polygono–Chenopodietalia* J. Tx. et Matuszk. 1962:
Diagnostic species: *Echinochloa crusgalli, Setaria viridis*.
Class *Galio–Urticatea* Pass. 1962:
Diagnostic species: *Galium aparine, Chelidonium majus*.
Order *Calystegietalia sepium* Tx. 1950:
Diagnostic species: *Galium aparine*.
Class *Meliloto–Artemisietea absinthii* Elias 1980:
Diagnostic species: *Artemisia absinthium*.
Order *Meliloto–Artemisietalia absinthii* Elias 1979:
Diagnostic species: *Echium vulgare*.
Class *Plantaginetalia majoris* R. Tx. et Prsg. in R. Tx. 1950:
Diagnostic species: *Plantago major, Polygonum aviculare*.
Class *Polygono–Chenopodietea* (Lohm., J. et R. Tx. 1961) Elias 1984:
Diagnostic species: *Chenopodium album, Polygonum aviculare, Setaria glauca, Spergula arvensis*.
Class *Sisymbrio–Onopordetea* (Br.-Bl. 1964) Gors 1966:
Diagnostic species: *Atriplex tatarica, Chenopodium glaucum.*

Our data show that 7 of the 12 syntaxa listed are represented by several different species. The simultaneous presence (in our SP spectra) of several diagnostic species for each syntaxon is indirect evidence of the existence of these or similar syntaxa in the past. Thus, we can assume that in ancient Kiev, several paleosyntaxa of ruderal vegetation were already well developed by the 10th, 11th, and 12th centuries, and these paleosyntaxa were similar in their ecological and phytosociological characteristics to the listed syntaxa of the present-day ruderal vegetation of Ukraine.

Syntaxa of the class *Artemisietea vulgaris* are widespread on moderately humid sandy, chernozem and clayey substrata. They very seldom occur on rubbly substrata. Communities of mesophytic perennials, which are mostly represented in the order *Artemisietalia vulgaris*, occur at present mostly within the forest and forest-steppe zones of Ukraine. The class *Chenopodietea* includes communities dominated by annual ruderal species growing mostly on mechanically disturbed substrata (Solomakha, Kostylev & Shelyag-Sosonko, 1992). Communities of nitrophilous mesophytes growing mostly on dry or slightly humid soils are united within the class *Galio–Urticatea*. The class *Plantaginetalia majoris* contains ruderal plant communities of open habitats, especially pastures and livestock grazing fields with condensed (trampled) and nitrified soils. The class *Polygono-Chenopodietea* unites segetal and ruderal communities on light sandy soils, and the class *Sisymbrio-Onopordetea* contains ruderal communities of annuals and biennials growing on loose substrata in well-illuminated localities, often quite close to human dwellings (Solomakha, Kostylev & Shelyag-Sosonko, 1992).

Undoubtedly, these seven paleosyntaxa differed somewhat from their modern analogues in Ukraine's synanthropic vegetation (for example, they did not include some recent immigrants). However, it is important to note that the modern analogues of most of these paleosyntaxa occur within the studied area at present.

Our data also provide evidence that some synanthropic plant species (in particular, many archaeophytes and all kenophytes) achieved their community-forming role in ruderal and segetal vegetation only during the last millennium, as suggested earlier (Kostylev, Bezusko, Gotun & Pashkevich, 1997). Before that, they were mostly plants of marginal and naturally disturbed habitats, and their role in well-defined plant communities was nearly negligible.

Conclusion

In conclusion, we should point out that the data collected and analyzed here provide only a fragmentary view of the natural (nonsynanthropic) vegetation that surrounded the ancient city of Kiev from the 10th to the 12th century A.D. However, this set of data includes new and valuable paleobotanical information about the anthropic factors influencing the formation of the urban flora and vegetation of early medieval Kiev. For some synanthropic plant species traditionally regarded as kenophytes (recent migrants) in the Kiev area, there is now direct paleobotanical evidence of their archaeophytic status. Botanists have often underestimated the archaeophytic content of the flora and the degree to which humans have transformed the flora. There are numerous actualistic methods (i.e., those based on the concept of actualism or uniformitarianism, and thus on modern characteristics of plants, their communities, and present ranges) for assessing the status of archaeophytes in floras (see review in Zajac, 1983–1988), but paleobotanical evidence has the last word in establishing the native-versus-introduced status and the time of immigration of synanthropic plant species.

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Glossary

Actualistic: Based on the concept of actualism or uniformitarianism, and thus on modern characteristics of plants, their communities, and present ranges.

Dendroflora: Trees and other woody species.

Mesophytic: A land plant that grows in an environment that has a moderate amount of moisture.

Paleobotany: A branch of botany concerned with fossil plants.

Paleoethnobotany: A branch of botany concerned with how people used plants in the past.

Paleosyntaxa: A fossil plant community or association.

Palynological: Related to the study of spores and pollen.

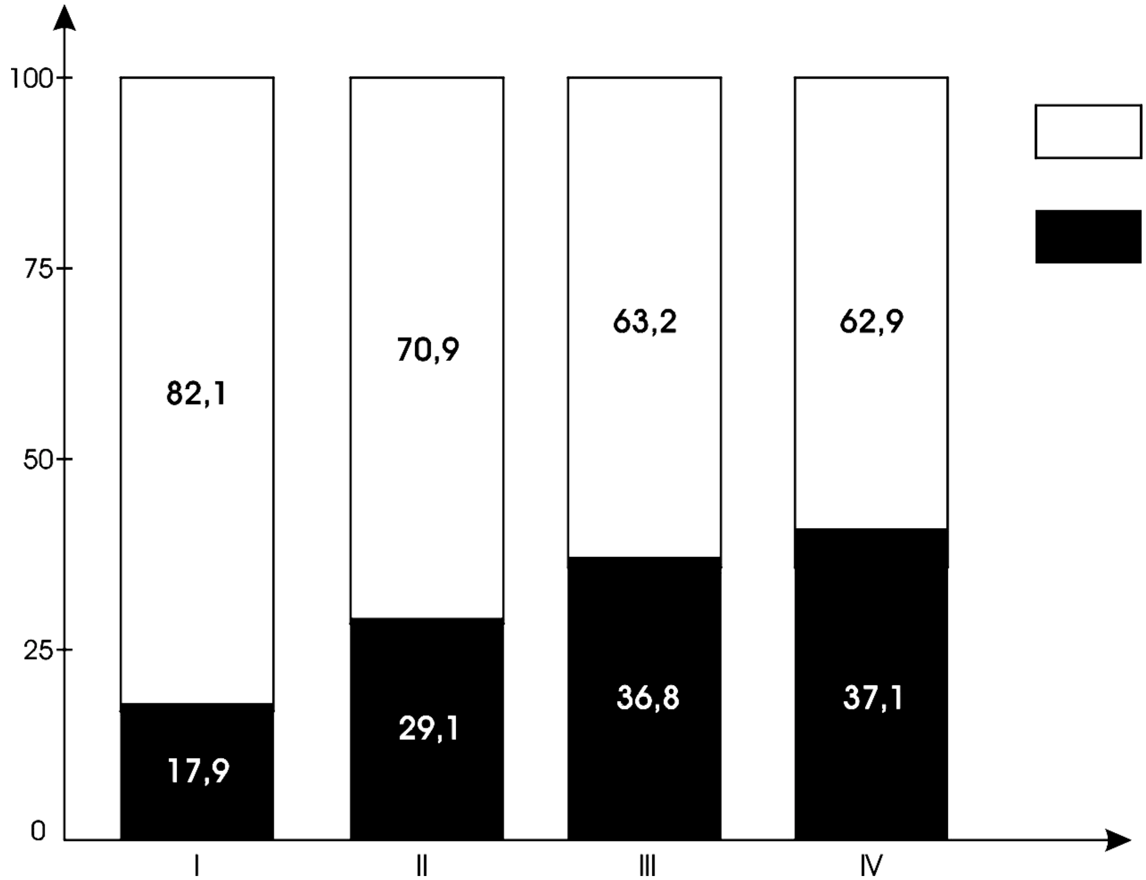
Ruderal: Characteristic of lands that are highly disturbed but rich in water, nutrients, and other resources.

Segetal: Growing in fields of grain.

Synanthropic: Living in close association with humans.

Syntaxa: A plant community or association.

Figure 1: Ratios of pollen grains of arboreal and herbaceous plants in spore-pollen spectra from early medieval deposits of Kiev (10th–12th centuries A.D.)



white – percentage of nonarboreal pollen (NAP, or pollen of herbaceous plants)

black – percentage of arboreal pollen (AP, or pollen of trees and shrubs)

I. Slavonic burial site, 10th century A.D. (modern St. Sophia Square)

II. Slavonic burial site, 10th century A.D. (modern St. Michael's Gold-Domed Cathedral, trench No. 6)

III. Scandinavian burial site, 10th century A.D. (modern St. Michael's Gold-Domed Cathedral, chamber No. 2 at the northern corner of the western side of cathedral gate)

IV. Construction fill from a building dating from the end of 11th to the 12th century A.D. (St. Michael's Gold-Domed Cathedral; trench No. 15, building No. 2)

Table 1. A list of microfossil taxa identified in four early medieval deposits from the territory of the St. Michael's Gold-Domed Cathedral and adjacent territories (arranged into two groups: arboreal and herbaceous plants)

		X century AD		XI–XII century AD	
	Taxon	I	II	III	IV
	Pollen grains of trees and shrubs				
	Aceraceae				
1.	*Acer* sp.			X	X
2.	*Acer platanoides* L.				X
	Betulaceae				
3.	*Alnus* sp.	X		X	X
4.	*Alnus glutinosa* (L.) Gaertn.	X		X	
5.	*Alnus* cf. *incana* (L.) Moench	X			
6.	*Betula* sp.	X	X	X	
7.	*Betula pendula* Roth	X	X	X	X
8.	*Betula pubescens* Ehrh.	X		X	X
	Caprifoliaceae				
9.	*Sambucus nigra* L.				X
10.	*Viburnum* sp.				X
	Corylaceae				
11.	*Carpinus betulus* L.	X			X
12.	*Corylus avellana* L.		X		X
	Ericaceae				
13.	*Calluna vulgaris* (L.) Hull	X			X
	Fagaceae				
14.	*Fagus sylvatica* L.				X
15.	*Quercus* sp.				X
16.	*Quercus robur* L.	X		X	X
	Juglandaceae				
17.	*Juglans regia* L.		X	X	X
	Grossulariaceae				
18.	*Ribes* sp.				X
	Oleaceae				
19.	*Fraxinus excelsior* L.		X	X	X
	Pinaceae				
20.	*Picea* sp.	X			
21.	*Picea abies* (L.) H. Karst.				X
22.	*Pinus sylvestris* L.	X	X	X	X
	Rosaceae				
23.	*Malus* sp.				X
24.	*Malus domestica* Borkh.				X
25.	*Rosa canina* L.				X
26.	*Rubus* sp.				X
27.	*Sorbus* sp.				X
	Salicaceae				

28.	*Salix* sp.	X		X	X
	Tiliaceae				
29.	*Tilia cordata* Mill.	X	X	X	X
	Ulmaceae				
30.	*Ulmus* sp.	X			X
	Pollen grains of herbaceous plants				
	Alismataceae				
31.	*Alismataceae* [gen. non ident.]	X			X
	Alliaceae				
32.	*Alliaceae* [gen. non ident,]				X
	Apiaceae				
33.	*Apiacaeae* [gen. non ident.]	X		X	X
	Asteraceae				
34.	*Asteracaeae* [gen. non ident.]	X	X	X	X
35.	*Arctium tomentosum* Mill.	X			X
36.	*Artemisia* sp.	X	X	X	X
37.	*Artemisia absinthium* L.	X		X	
38.	*Artemisia scoparia* Waldst. et Kit.	X			
39.	*Artemisia vulgaris* L.	X	X	X	
40.	*Centaurea cyanus* L.				X
41.	*Cichorium inthybus* L.	X	X	X	
42.	*Cirsium arvense* (L.) Scop.				X
43.	*Cirsium oleraceum* (L.) Scop.				X
44.	*Sonchus arvensis* L.				X
45.	*Taraxacum officinale* Wigg. aggr.	X			X
46.	*Tussilago farfara* L.	X		X	
	Balsamimaceae				
47.	*Impatiens noli-tangere* L.			X	
	Boraginaceae				
48.	*Boraginaceae* [gen. non ident.]			X	
49.	*Echium vulgare* L.	X			
	Brassicaceae				
50.	*Brassicaceae* [gen. non ident.]	X		X	X
	Cannabaceae				
51.	*Cannabaceae* [gen. non ident.]		X		
52.	*Cannabis* sp.	X	X		X
53.	*Cannabis sativa* L.		X		
	Caryophullaceae				
54.	*Caryophullaceae* [gen. non ident.]	X			X
55.	*Cerastium arvense* L.	X			
56.	*Scleranthus annuus* L.				X
57.	*Spergula arvensis* L.				X
58.	*Stellaria media* (L.) Vill.	X			
	Chenopodiaceae				
59.	*Chenopodiaceae* [gen. non ident.]	X	X	X	X
60.	*Atriplex sagittata* Borkh.	X			
61.	*Atriplex tatarica* L.	X	X		
62.	*Beta vulgaris* L.				X

63.	*Chenopodium album* L.s.l.	X	X		X
64.	*Chenopodium botrys* L.	X	X	X	X
65.	*Chenopodium foliosum* Asch.				X
66.	*Chenopodium glaucum* L.				X
67.	*Chenopodium rubrum* L.				X
68.	*Polycnemum arvense* L.				X
	Convollariaceae				
69.	*Convallaria majalis* L.				X
	Cyperaceae				
70.	*Cyperaceae* [gen. non ident.]	X			X
	Euphorbiaceae				
71.	*Euphorbiaceae* [gen. non ident.]	X			
	Fabacaeae				
72.	*Fabacaeae* [gen. non ident.]	X	X	X	X
	Lamiaceae				
73.	*Lamiaceae* [gen.non ident.]	X	X	X	X
74.	*Mentha* sp.	X			
75.	*Origanum vulgare* L.	X		X	X
76.	*Salvia* sp.	X		X	
	Lemnaceae				
77.	*Lemnaceae* [gen. non ident.]				X
	Liliaceae				
78.	*Liliaceae* [gen. non ident.]	X	X		X
	Papaveraceae				
79.	*Papaveraceae* [gen.non ident.]	X			X
80.	*Chelidonium majus* L.	X			
	Plantaginaceae				
81.	*Plantaginaceae* [gen. non ident.]	X	X	X	
82.	*Plantago lanceolata* L.	X		X	
83.	*Plantago major* L.	X			X
84.	*Plantago media* L.				X
	Poaceae				
85.	*Poaceae* [gen. non ident.]	X	X	X	X
	Polygonaceae				
86.	*Polygonaceae* [gen. non ident.]	X		X	X
87.	*Bistorta officinalis* Delarbre (*B. major* Gray)				X
88.	*Fallopia convolvulus* (L.) A. L?ve	X		X	X
89.	*Polygonum aviculare* L. s.l.	X		X	
90.	*Rumex confertus* Wild.			X	
91.	*Rumex crispus* L.	X		X	
	Potamogetonaceae				
92.	*Potamogetonaceae* [gen. non ident.]	X			X
	Primulaceae				
93.	*Primulaceae* [gen.non ident.]	X		X	X
	Ranunculaceae				
94.	*Ranunculaceae* [gen. non ident.]	X		X	X
95.	*Thalictrum aquilegifolium* L.				X
	Rosaceae				

96.	*Rosaceae* [gen.non ident.]	X		X	X
	Rubiaceae				
97.	*Rubiaceae* [gen. non ident.]	X			X
	Solanaceae				
98.	*Solanaceae* [gen.non ident.]	X			
	Typhaceae				
99.	*Typha* sp.	X			X
	Urticaceae				
100.	*Urtica* sp.	X		X	X
	Valerianaceae				
101.	*Valeriana* sp.				X
	Violaceae				
102.	*Violaceae* [gen.non ident.]				X
	Spores				
	Bryales				
103.	*Bryales* [gen.non ident.]	X	X	X	X
	Equisetales				
104.	*Equisetum arvense* L.			X	
	Lycopodiales				
105.	*Huperzia ?*	X			
106.	*Lycopodium* sp.		X	X	X
107.	*Lycopodium clavatum* L.	X	X		
108.	*Lycopodiella inundata* (L.) Holub		X		
	Polypodiales				
109.	*Polypodiales* [gen. non ident.]	X	X	X	X
110.	*Athyrium filix-femina* (L.) Roth			X	
111.	*Dryopteris filix-mas* (L.) Schott			X	
112.	*Sphagnum* sp.	X	X		

Table 2. A list of macrofossil and microfossil taxa identified in the early medieval deposits from Kiev (arranged into two groups: cultivated plants and weeds)

		Xth century AD		XI-XII century AD	
	Taxon	Macrofossils (Pashkevich 1991, 1998)	Microfossils	Macrofossils (Pashkevich 1991, 1998)	Microfossils
Cultivated plants (1 to 7 are pollen grains of Cerelia)					
1.	*Avena sativa* L.	X		X	
2.	*Hordeum vulgare* L.	X		X	
3.	*Panicum miliaceum* L.	X		X	
4.	*Secale cereale* L.	X		X	
5.	*Triticum aestivum* L.	X		X	
6.	*Triticum durum* Desf.	X		X	
7.	*Triticum monococcum* L.	X		X	
8.	*Beta vulgaris* L.				X
9.	*Cannabis sativa* L. s.l.		X		

10.	*Juglans regia* L.		X		X
11.	*Malus domestica* Borkh.				X
Weeds					
12.	*Arctium tomentosum* L.		X		X
13.	*Artemisia absintium* L.		X		X
14.	*Artemisia scoparia* Waldst. et Kit.		X		
15.	*Artemisia vulgaris* L.		X		X
16.	*Atriplex sagittata* Borkh.		X		
17.	*Atripex tatarica* L.		X		
18.	*Centaurea cyanus* L.				X
19.	*Cerastium arvense* L.		X		
20.	*Chelidonium majus* L.		X		
21.	*Chenopodium album* L. aggr.	X	X	X	X
22.	*Chenopodium botrys* L.		X		X
23.	*Chenopodium foliosum* Asch.				X
24.	*Chenopodium glaucum* L.				X
25.	*Chenopodium rubrum* L.		X		X
26.	*Cichorium intybus* L.		X		X
27.	*Cirsium arvense* (L.) Scop.				X
28.	*Echinochloa crusgalli* (L.) P. Beauv.	X			
29.	*Echium vulgare* L.		X		
30.	*Equisetum arvense* L.		X		
31.	*Fallopia convolvulus* (L.) A.L?ve	X	X		X
32.	*Galium aparine* L.	X			
33.	*Plantago lanceolata* L.		X		
34.	*Plantago major* L.		X		
35.	*Plantago media* L.				X
36.	*Polycnemum arvense* L.		X		
37.	*Polygonum aviculare* L.		X		
38.	*Rumex confertus* Willd.		X		
39.	*Rumex crispus* L.		X		
40.	*Scleranthus annuus* L.				X
41.	*Setaria glauca* (L.) P. Beauv.	X			
42.	*Setaria viridis* (L.) P. Beauv.	X			
43.	*Spergula arvensis* L.				X
44.	*Stellaria media* (L.) Vill.		X		
45.	*Sonchus arvensis* L.				X
46.	*Tarxacum officinale* Wigg. aggr.		X		X
47.	*Tussilago farfara* L.		X		