Some results of a floristic inventory within the city of Zürich (1984–1998)

Vybrané výsledky floristického průzkumu Curychu (1984–1998)

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Dedicated to the memory of Josef Holub

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Floristic survey of the city of Zürich carried out from 1984 to 1998 covered an area of 122 km^2. To assess possible floristic changes in the last 150 years, the results were compared with literature data from 1839 and herbaria. On the whole, the flora of Zürich includes nearly 2000 species. Of those, 1211 are either indigenous or introduced and subsequently naturalized. About 1/4 of the established species occur in more than a half of squares of 1 km^2 grid, whereas 1/3 was found in less than 6% of the squares. Average species number per square was 451, ranging from 294 to 607. Of the 1211 presently established species, 58% are indigenous (native), 19% archaeophytes, and 23% neophytes. Within the developed parts of the city, neophytes form about a half of all species. The group of extinct species includes 60% of indigenous species, 38% of archaeophytes and 2% of neophytes. At present, archaeophytes seem to be particularly threatened. Comparison with literature and herbaria revealed that 26% of all species are at present as frequent as in 1839, 32% increased their frequency or became newly naturalized, but 42% decreased in frequency or became extinct. Extinct species amount to 188, newly introduced ones to 294. Compared to the newly established species, the extinct ones have higher indicator values for nutrient content and temperature, and lower values for continentality. These differences indicate that the environment has changed within the last 160 years towards higher soil nutrient content, higher temperatures, and milder winters.

Keywords: Urban flora, species richness, long term dynamics, alien species, naturalization, ecological demands, indicator values, Zürich, Switzerland

Introduction

From 1984 to 1998, a survey of the flora of the city of Zürich was carried out. The aim of the project was to (1) document the current distribution of plant species within the city limits as a basis in planning of conservation measures, and (2) compare the present situation with that of other periods in order to understand the dynamics of the flora and factors influencing it over the last two centuries.

The complete results will be published in the book "Flora of the City of Zürich" (Landolt 2000). The present paper comprises some evaluation of the results. A general discussion of the results and a comparison with enormous number of results from other cities would be beyond the scope of this publication. Reviews of the literature on Central European floras and vegetation can be found e.g. in Sukopp et al. (1990), Wittig (1991), Pyšek (1993, 1995, 1998), or Sudnik-Wójcikowska & Moraczewski (1998).

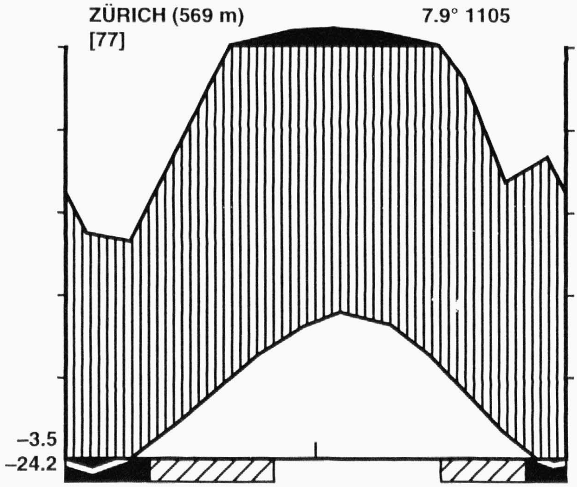


Fig. 1. – Climate diagram of Zürich. After Walter & Lieth (1967).

Special problems associated with distribution, ecology and taxonomy of various taxa of the Zürich flora have been discussed in a series of nine previous papers (Landolt 1994–1999). The nomenclature of the species as well as species concept and circumscription follows Hess et al. (1967–1972).

The city of Zürich (47°20' N, 8°30'E) is situated in western Central Europe at the altitude of 398–871 m a. s. l. and covers about 92 km^2. It is characterized by moderately oceanic temperate climate (Fig. 1), high amount of precipitation (1000 mm), relatively cool summers and mild winters. The mean annual temperature within the city limits varies between 7.0 and 10.5 °C. The main part of the town lies between two hilly ranges at the lower end of a lake. The ground is covered mostly by moraines. The slopes of the hills consist of rocks of tertiary origin; sandstone, marl, and (rarely) conglomerate. Some of the valley floor is covered by river gravel (see von Moos 1946 for geological maps and transects). Most of the relief shows mild forms. However, some steep slopes, sometimes with active erosion, are also present, especially along the Uetliberg Range and in a few glens of the Zürichberg Range. The soil is generally heavy, clayey and deep. Within the developed city, it is mostly disturbed and contains much rubble.

The population within the city limits reaches 350 000, and within the investigated 122 km^2 it is around 400 000. The whole agglomeration of Zürich amounts to about 1 million inhabitants. The area consists of 24% of forests (Fig. 2), 6% of lakes and rivers, 52% of meadows, fields, and gardens, and 18% of developed city, i. e. paved or built-over (sealed) ground (Fig. 3).

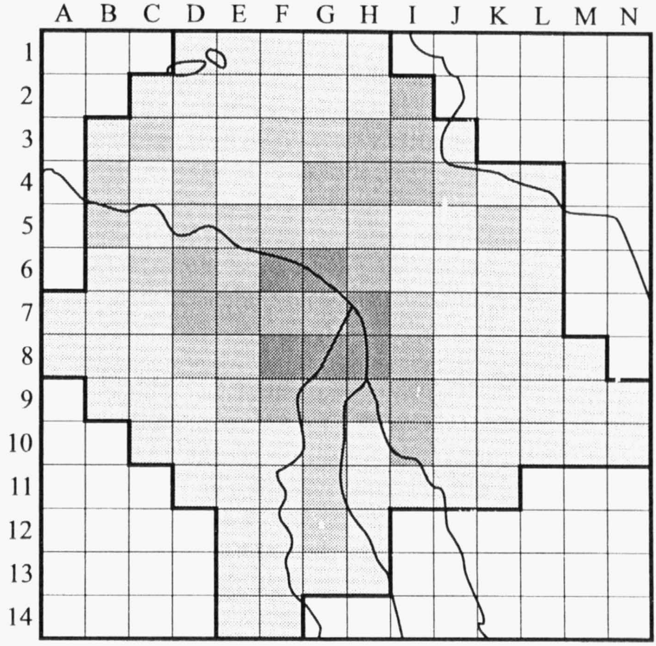


Fig. 2. – Estimated forest cover within 1 km² square grid at the territory of the city of Zürich. After Landolt (1991b). > 35%, 15–35%, 5–14%, < 5%.

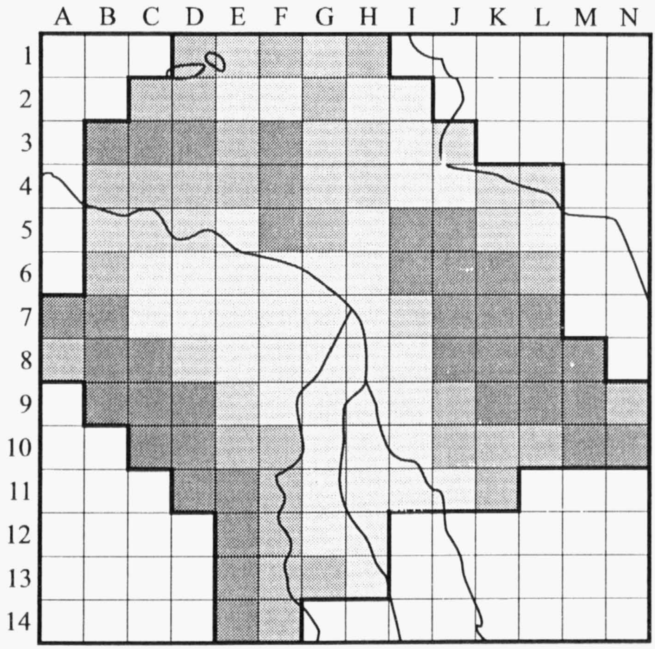


Fig. 3. – Percentage of built-over and sealed soils (± impermeable to water) within the city of Zürich (from "Umweltfachstelle der Stadt Zürich 1989"). After Landolt (1991b). > 65%, 50–65%, 35–49%, < 35%.

Methods

Between 1984 and 1998, the city area was checked for indigenous or naturalized species of flowering plants and pteridophytes. The city was divided into a grid of 122 square kilometer plots, and each square was completely surveyed at least five times during different seasons. Frequency within each square was evaluated in three levels: (1) very rare (populations of only 1–20 individuals each and not covering more than 100 m^2 in the whole area, (2) rare (at least one population with more than 20 individuals, and covering 100–10 000 m^2 in total), (3) not rare (at least one population with more than 200 individuals and covering more than 10 000 m^2 in the whole). Disappearence or new establishment of species was also registered.

Floristic literature dealing with the region of Zürich was extracted, and the two main herbaria in Zürich (Z, ZT) checked for plant occurrences within city limits. Notes on the flora of Zürich date back to Conrad Gessner (1516–1565). The first complete survey of the flora of Kanton Zürich was carried out by Kölliker (1839). This publication served as the main basis for comparisons with the recent distribution of species. A second valuable source was the list of adventive plants of Zürich (Naegeli & Thellung 1905). Baumann (1933) left an incomplete manuscript of the flora of Kanton Zürich which has never been published. It enabled me to pursue the changes of the flora in the first three decades of this century. Herbarium specimens served as supplements and for verification. Our own 7000 vouchers of collected plants which are deposited in ZT enable an identity check of difficult species at any time.

Number and distribution of the species

Of the 2000 species included in the Zürich "Flora" (Landolt 2000), 1211 are either indigenous or introduced and naturalized. In addition, 188 species which were either reported by Kölliker in 1839 or since then could not longer be found and must be considered as extinct. For these 1399 species, distribution maps are provided in Landolt (2000). Of the 600 further species given in the "Flora", 50 occur in the outskirts of Zürich, but not within the political boundaries, 150 are casual introductions, but do not spread (i. e. ephemerophytes sensu Holub & Jirásek 1967), and 400 were registered occasionally as escapes from gardens and crop fields (i. e. ergasiophytes).

The total of 1211 established species seems rather high for a city area not much bigger than 100 km^2 and with a population lower than half a million inhabitants. Cities in Central Europe with similar area and number of inhabitants (e. g. Braunschweig, Halle or Wuppertal) harbour approximately 900 species (Klotz 1990). The same is true for Köln with the area of more than 400 km^2 and around a million of inhabitants. Only such big cities as Warsaw or Berlin with the area of about 500 km^2 and ca. two millions of inhabitants reach species numbers of 1109 and 1432, respectively. More recent and more complete reviews of Pyšek (1993, 1998) show that of ca. 60 investigated Central European cities only Stuttgart (1447 species), Berlin (1432), Warszava (1416), Hamburg (1387), Wien (1476), and Leipzig (1319) contain more species than Zürich. Wroclav in Poland is the only city which corresponds in species number (1177) and inhabitants (517 000) to Zürich. However, the area in Wroclav is nearly twice as big (225 km^2) as that of Zürich. Stuttgart is also

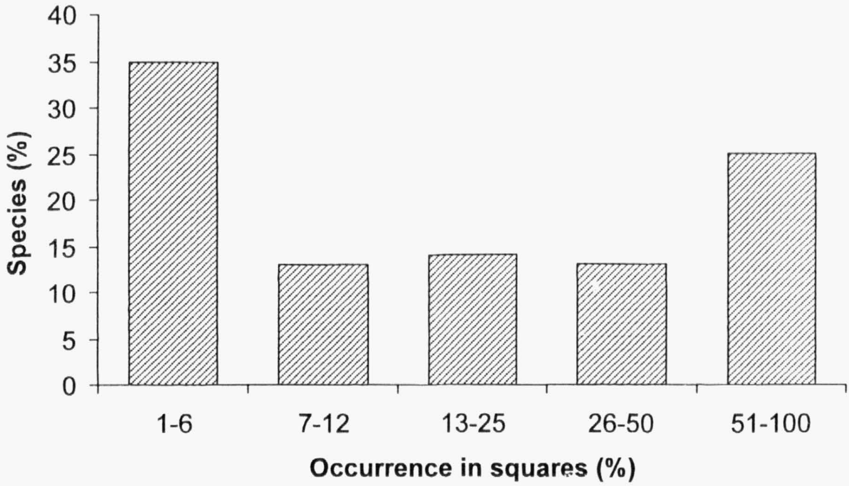


Fig. 4. – Frequency of species within the city of Zürich. Percentage of 1 km^2 squares in which the species occur is shown.

comparable to Zürich, having similar climate, but slightly more inhabitants (568 000) and larger area (250 km^2).

The high species number in Zürich can be explained by several factors. (1) The altitudinal range reaches 500 m within the city limits, and mean annual temperatures varies correspondingly (between 7.0 and 10.5° C). (2) Uetliberg, the mountain range in the western part of the city, has steep slopes with partly open forest and some erosion still going on. About 50 species are located only on this range within the city. (3) The region of Katzensee in the northern part of the city consists mainly of small lakes, swamps and fens, and is one of the richest wetland areas of the Swiss Midlands. Another 50 species are restricted to this area within the city. (4) Some apomictic or otherwise neglected species which were not considered in the species lists of most other cities are included in the "Flora", e.g. *Rubus*, *Ranunculus auricomus* agg., *Alchemilla*, *Oenothera*, *Cotoneaster.* In total, these species amount to 50–80. (5) Research intensity was probably higher than in most other cities; the inventarization of each square was performed at least 5 times over a period of 15 years and in different seasons.

Of the 122 squares, three are covered with more than 75% by the Lake of Zürich. These contain only 50, 320 and 375 species, respectively, and were excluded from the present evaluation. The average number of species per square in remaining 119 squares is 451, ranging from 294 to 607. In general, densely forested areas are relatively species-poor. The only two squares completely covered by forest contain 294 and 315 species, respectively. On the other hand, the Katzensee Region (540–607 species in a square), as well as extended railway areas (490–530 species) and the steep slopes of the Uetliberg Range (490–535 species) are species-rich. The two squares with old and new Botanical Garden contain 515 and 542 species, respectively. This demonstrates the importance of botanical gardens as sources of neophyte introduction.

Of the established species, 25% occur in more than a half of the mapped squares, 14% in more than 95% of the squares. On the other hand, 1/3 of established species were found in only 6% or less of the squares (Fig. 4).

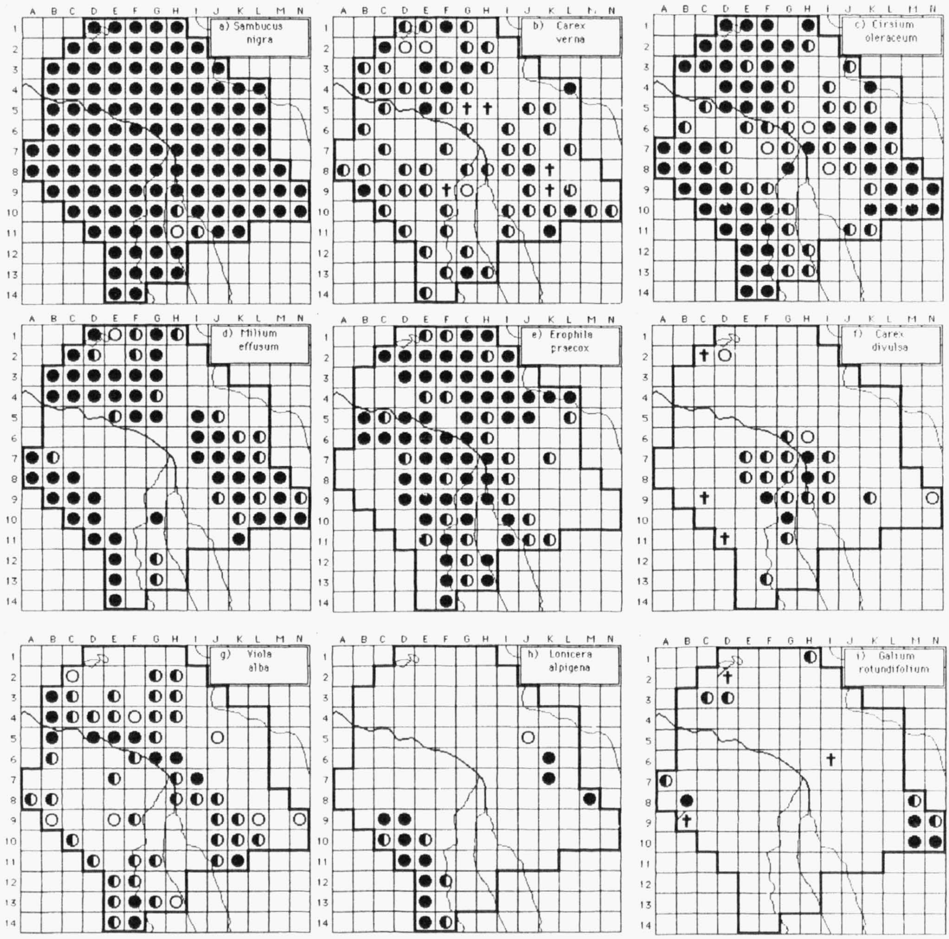
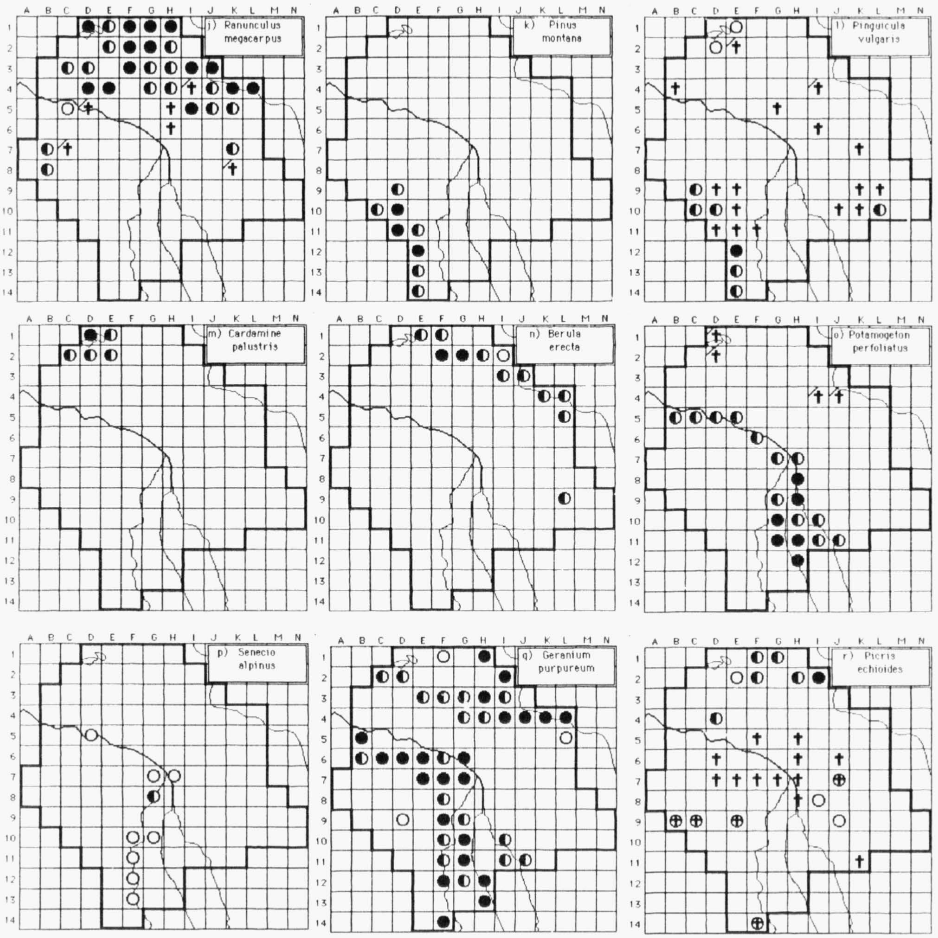


Fig. 5. – Various distribution patterns within the city of Zürich. Proportion of the total city flora attributed to the given category is shown in brackets (a) generally distributed and frequent throughout the whole area (20%), (b) generally distributed throughout the whole area, but dispersed (5%), (c) generally distributed and frequent outside the developed city area (10%), (d) restricted to forest and glade areas (3%), (e) generally distributed and frequent within the developed city area (15%), (f) restricted to the warmest areas in the city (4%), (g) restricted to southern slopes (1%), (h) restricted to cool and shady areas on neutral to basic soil (1%), (i) restricted to cool and shady areas on acid soil (less than 1%), (j) restricted to the northern part of the city(1%), (k) restricted to the Uetliberg Range (4%), (l) restricted to swamp areas (2%), (m) restricted to Katzensee area(4%), (n) restricted to Katzenbach area (less than 1%), (o) restricted to surroundings of the Lake of Zürich and River Limmat (less than 1%), (p) restricted to areas of the Rivers Sihl and Limmat (less than 1%), (q) restricted to railway areas (5%), (r) restricted to the superhighways in the northern part (less than 1%). Examples are shown for each category. Remaining 31% of species show no clear pattern. Abundance in squares: ○ very rare, ◐ rare, ● not rare, † extinct, ↲† extinct (no exact locality has been known and the presence in the square is only presumable), ⊕ extinct within the last 15 years.

Some typical distribution patterns can be recognized (see Fig. 5 for characterization and examples). However, the distribution of many species shows a transitional mode, or is very local. The occurrence of some species is more or less accidental or restricted to the



neighbourhood of places where it escaped from cultivation. The species of group (a) are well adapted to the general climate and not very specialized. They behave as urbanoneutral (sensu Wittig et al. 1985). The pattern of group (b) indicates a decline in frequency due to unfavourable conditions over the last few decades (e. g. different changes in management or change of nutrient conditions). Most species are meadow plants and behave as urbanoneutral or moderately urbanophobic. The species of group (c) are either ecologically not very specialized or live in wide-spread biotopes like wet meadows, forests etc. They are mostly indigenous, moderately urbanophobic, common and well adapted to the climate. Some species can also be found in the developed city in the shade of trees and shrubs of older gardens and parks. The group (d) consists of strongly urbanophobic species found only outside the developed city, mainly in forest and glade areas (Fig. 3). The species of group (e) are generally distributed and frequent within the developed city area. They are strongly urbanophilic, i. e. well adapted to city conditions, and grow along street borders, in pavements, gardens, lawns, fallow land etc. Outside the city, they are restricted to disturbed areas. The distribution of species belonging to the group (f)

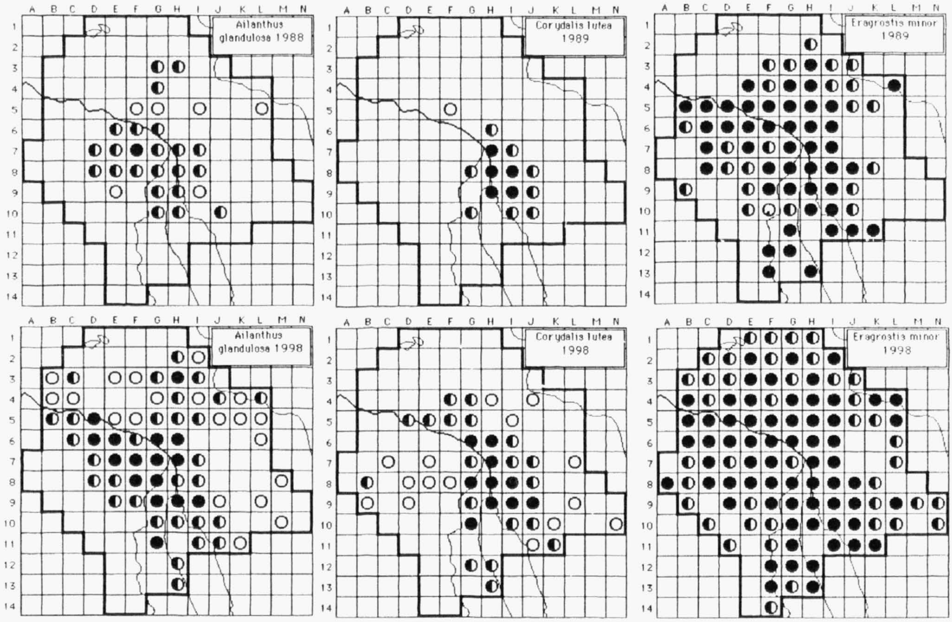


Fig. 6. – Examples of rapid expansion of *Ailanthus glandulosa, Corydalis lutea* and *Eragrostis minor* within the developed city area in the last decade. Abundance in squares: ○ very rare, ◐ rare, ● not rare.

is restricted to the warmest area of the inner city where mean temperatures are higher and winter is milder than in the outskirts. Many species of this group grow within the railway areas as well. Species demanding relatively high amount of insolation, but not dependent on high air temperatures, form the group (g). The groups (h) and (i) contain species which are restricted to cool and shady areas on neutral and basic soil, and on acid soils, respectively, and behave as strongly urbanophobic. Groups (j) to (r) are restricted to geographical areas characterized by special habitat conditions such as lower precipitation (j), mountains (k), swamps and ponds (l, m), creeks, lake an river shores (n, o, p), railways (q), and superhighways (r).

Origin and ecological behaviour of the species

Of the species established within the city limits of Zürich, 58% are indigenous (idiochorophytes), 18% archaeophytes (species introduced by humans before the year 1500), and 24% neophytes (introduced after 1500). The classification goes back to Thellung (1918/19) and is today well accepted throughout Central Europe (cf. Holub & Jirásek 1967). Within the developed parts of the city, neophytes correspond to about half of all species. The group of extinct species includes 60% indigenous species, 38% archaeophytes and 2% neophytes. Today, archaeophytes seem to be particularly threatened.

Table 1. – Proportion (%) of indigenous species, archaeophytes, and neophytes related to different degrees of urbanity. U1: not found under typical city conditions, U2 – U4: intermediate situations. U5: recorded only within the developed areas of the city. See text for explanation.

Degree of urbanity	U1	U2	U3	U4	U5	U1-5
Indigenous species	95	82	59	8	0	58
Archaeophytes	4	7	14	53	37	19
Neophytes	1	11	27	39	63	23

The species were classified according to their response to specific city conditions, i. e. higher temperature, lower air humidity, disturbed soils, air pollution, etc. The term "urbanity" was introduced by Wittig et al. (1985) who distinguished three groups of species: urbanophobic, urbanoneutral, and urbanophilic. In the present survey, five groups of urbanity were distinguished: U1 (strongly urbanophobic) – species avoiding the area of developed, highly urbanized city, and growing strictly only in forest or agricultural areas; U2 (moderately urbanophobic) – species rare in the developed area, occurring in the inner city only in older gardens and parks; U3 (urbanoneutral) – species growing both outside and within the developed city; U4 (moderately urbanophilic) – species growing rarely outside the developed city or restricted there to the surroundings of houses, gardens and fields; U5 (strongly urbanophilic) – species growing only in the developed city and in railway areas.

Fifteen percent of the 1211 currently present species behave as strongly urbanophilic (U5), another 15% as urbanoneutral (U3), and 20–25% can be assigned to each of the remaining categories. In contrast, 40% of the extinct species belong to the strongly urbanophobic, 25% to the moderately urbanophobic, and 25% to the moderately urbanophilic species.Urbanoneutral species amount to only 7%, and strongly urbanophilic to 3%.

Particular categories of urbanity considerably differ with respect to the origin of species (Table 1). Nearly two thirds of the species nowadays restricted mainly to developed areas (U4 and U5) are neophytes, one third belong to archaeophytes. In contrast, indigenous species are by far the most frequent among those avoiding the city center (U1 and U2).

Of the neophytes, 14% are native to other regions of Central Europe. They did not establish in the Swiss Midlands earlier, mostly because of low summer temperatures. Two percent are native to western Europe, 11% to eastern Europe and western Asia (including Caucasus), 42% to southern Europe and the Mediterranean area, 11% to eastern Asia, 16% to North America, 2% to Central- and South America, and 1% to eastern and southern Africa.

Floristic changes within the last 160 years

Since 1839, 159 species have become extinct and 29 later introduced species have disappeared again. On the other hand, 294 species have become newly established. Of the 1399 species considered (1211 indigenous or established and 188 extinct), 26% are nowadays as frequent as in 1839, 42% are extinct or decreased in frequency, and 32% increased or became newly established. Within the last 160 years, total number of species in Zürich increased by about 100.

Table 2. – Changes in the flora of Zürich as reconstructed for particular periods covering the last 160 years. Percentage of species whose occurrence increased, decreased or remained about the same is shown. Extinct species are included among those that decreased, newly-introduced among increased. The works of Kölliker (1839) and Naegeli & Thellung (1905) as well as herbaria were used to gain the information about the first period.

Period	Decreased	Increased	Remained	Extinct	Newly introduced
1839–1905	14	15	71	5	15
1905–1984	42	19	39	10	5
1984–1998	19	21	60	1	5
1839–1998	42	32	26	14	21

The investigated period was divided into three subperiods: 1839–1905, 1905–1984, and 1984–1998. These limits were predetermined by publications of Kölliker (1839) and Naegeli & Thellung (1905), and by the beginning of the present survey (1984) (Table 2). If the decline in species numbers is compared between these subperiods, it is found that the loss was greatest between 1905 and 1984, even if it is taken into account that this was the longest subperiod. This is mainly due to the changes in agricultural management during this time, such as intense fertilization of arable land, application of pesticides, drainage of wetlands etc. Many ecological niches disappeared. During the last subperiod, the efforts of natural conservancy showed some success. The relatively low number of newly introduced neophytes during the second subperiod is probably due to the fact that the floristic survey was less intense than during the other two subperiods.

The amount of species loss in the various squares reflects the degree of biotope changes and the intensity of floristic survey during different times. Big losses can be observed in squares with high biodiversity which were often visited by botanists. The Katzensee Region, for instance, contains 70 to 124 extinct species per square. The same is true for the railway areas often visited by A. Thellung and other botanists at the beginning of the century. The number of lost species amounts here to 80–200 species per square. Squares which contained large areas of wetland more than hundred years ago and have since been built over exhibit loss of more than 50 species. In contrast, squares whith a large proportion of dense forest or intensely cultivated agricultural fields which were only rarely visited by botanists, show less than 10 lost species.

A comparison of the ecological indicator values (according to Landolt 1977) of extinct and newly introduced species gives an indication of direction of changes in ecological conditions during the last 160 years (Table 3). The differences between indicator values of both groups were tested by using nonparametric Wilcoxon test and significant differences ($P < 0.001$) were found for all factors considered except of soil reaction.

The difference in the humidity factor (F) is due to the fact that about one third of the extinct species were confined to wetlands. In the last century, swamps, fens and shores were very wide-spread in the big valleys as well as on the hill slopes. The destruction of most of these wetlands is one of the most important impacts on landscape within the last 160 years. The lower value for dispersion and aeration deficiency of the soil (D) is also caused by the decline of wetland area. Wetland soils have very fine dispersion and insufficient aeration. The decline of mean humus value (H) is mostly also the result of the destruction of wetlands with peat soils. Newly established species are typical mainly of intermediate conditions.

Table 3. – Ecological indicator values after Landolt (1977) for 159 extinct (Ex) and 284 newly introduced (Ne) species. Scale ranges from 1 to 5 (low to high value for a factor). Proportion in % of the two species groups in the different classes is given. Significance of the difference between both groups was tested by nonparametric Wilcoxon text. Values for soil humidity (F), soil reaction (base content, R), nutrient content of soil (N), humus content of soil (H), dispersion and aeration deficiency of soil (D), light demands (L), temperature (T), and continentality (K) are given. Results obtained by Klotz (1987) for Halle (Germany) by using Ellenberg indicator values are shown for comparison (n. a. – not available). To make the comparison possible and take different scales used by both systems into account, the values from Halle were multiplied by 5/9 (see text for details).

	Humidity		Reaction		Nutrients		Humus		Dispersion		Light		Temperature		Continentality	
	Ex	Ne	Ex	Ne	Ex	Ne	Ex	Ne	Ex	Ne	Ex	Ne	Ex	Ne	Ex	Ne
1	9	11	4	0	6	0	1	0	0	4	0	0	1	0	1	1
2	37	37	18	7	40	18	11	15	3	9	3	11	13	1	21	44
3	17	39	37	60	31	36	51	62	32	31	21	32	25	8	44	35
4	11	9	39	32	19	45	25	20	31	45	71	54	41	40	34	20
5	26	4	2	1	4	1	13	3	34	10	5	3	20	51	0	0
Mean	3.1	2.6	3.3	3.3	2.7	3.2	3.4	3.1	4.0	3.5	3.8	3.5	3.6	4.4	3.1	2.8
P	0.0019		0.5819		<0.0001		0.0007		<0.0001		<0.0001		<0.0001		<0.0001	
Halle	3.6	2.7	3.2	3.6	2.2	3.1	n. a.	n. a.	n. a.	n. a.	3.9	3.8	3.2	3.6	2.1	2.4

The mean values for nutrient content (N) are clearly higher in newly established species than in extinct ones. This demonstrates that most meadows and fields poor in nutrients have been either built over or fertilized. Also, steady input of nutrients from the air is showing up. About 20% of the extinct species were confined to agricultural land poor in nutrients. Interestingly, some species which grow in soils very rich in nutrients have also disappeared. Places such as manure heaps, open sewers, sewage inlets, and other localities with very high nitrogen content hardly exist in modern cities any more.

The lower light value (L) of the newly established species is caused by the high proportion of extinct meadow and wetland plants and weeds that show high demands for light. Many newly established species escaped from planting as understory garden plants or spring geophytes which grow under shady conditions.

The highest differences were found in temperature demands (T); this has two causes. Some extinct species were confined to the mountains, in the lowland being able to grow only in wet or dry meadows with a low nutrient content (e. g. *Gentiana verna, Primula farinosa*). Under the current agricultural management, they have had no chance to survive. The second cause is more important and reflects the general temperature increase and the warming effect of the expanding city.

The continentality value (K) is lower in newly established species than in extinct ones. The shift can be explained by milder winters of recent years and by the increase of haze and smog in the modern cities which results in lower insolation.

The only value which did not change is the reaction value (R) which can be taken as an indication of the base content of the soil. However, a slightly different proportional distribution within the different classes can be observed. Extinct species are more frequently represented in the categories of more extreme values, whereas the newly established species concentrate mostly around mean values.

Klotz (1987) published a similar comparison between extinct and newly established species in the flora of Halle (eastern Germany) since 1848. He used the indicator values of Ellenberg (1979) with a scale of 1 to 9. Since the values of Landolt (1977) used in the present paper vary between 1 and 5, those of Ellenberg were multiplied by the factor 5/9 to make the results comparable. However, the values do not correspond to each other in every respect. The values of Ellenberg are focused on Central Europe whereas those of Landolt on Switzerland and adjacent areas. Especially the values for continentality are different. Switzerland has much more oceanic climate than Central Europe on average. Therefore, the continentality values of Ellenberg for the same species are on average lower than those given by Landolt. Apart from continentality, most changes found in other indicator values throughout the studied period point to the same direction: drier soils, more nitrogen, less light, and higher temperatures. Most differences in the results obtained in Halle and Zürich can be explained by regional factors or different delimitation of the investigated area (more forest area in Zürich compared with Halle).

The colonization of the city by newcomers can be extremely fast (Fig. 6). Within 10 years, many introduced species have more than doubled their distribution area. The following species can be given as examples: *Ailanthus glandulosa* had not begun to spread before 1980 in the city; it was present in 29 squares in 1988, while 66 squares occupied were recorded by 1998. *Eragrostis minor* was first collected in the inner city in 1873, but did not spread until about 1980. It colonized 68 squares very rapidly by 1989, and within the next 10 years, it reached 106 squares. *Corydalis lutea* escaped from gardens as early as at the beginning of the 19th century. The first herbarium specimens from walls in the old city date back to 1834. The invasion of walls outside the inner city began 20 years ago. In 1988, it could be observed in 14 squares, and in 1998 in 44 squares, respectively. The most astonishing establishment could be observed in *Geranium purpureum*. This species was first seen in 1990 at the goods station (freight station) of the railway. It is strongly restricted to the gravel. In 1991, it was found already in 5 different places. Since then, it has spread through all gravelled railway areas below 500 m a. s. l., and nowadays it is found in 43 squares (Fig. 5q). The expansion of the mentioned species is mainly caused by the warmer temperatures of the last 20 years. It is interesting to note that the mode of dispersal was not relevant for these fast expanding species. *Ailanthus* and *Eragrostis* are spread by wind, *Corydalis* by ants, and *Geranium* by slinging and rarely by animals. In addition, all these species are hemerochorous, i. e. they are unintentionally dispersed by humans.

Current status of threat to the flora

Table 4 shows the degree of threat to the species of Zürich within the city area, and compares how threatened are these species in the eastern Swiss Midlands and in the whole Switzerland. The number of extinct species is highest in the city which can be explained by much smaller area (122 km^2 in Zürich compared to 4000 km^2 in eastern Swiss Midlands and 40 000 km^2 of the whole Switzerland). Although in general, more species are extinct or threatened in the city than in the Swiss Midlands, the opposite is true for about 50 species. The latter group is formed by species which (1) have found favourable ecological niches within the city that compensate for the lost habitats (e. g. *Allium vineale*, annual *Cerastium* species, *Dianthus armeria*, *Potentilla micrantha*, *Sagina apetala*), and (2) are mainly distributed in higher mountains and relatively frequent on Uetliberg Range (*Cirsium tuberosum* and *Stachys alpina*). Some of these species might also have become more frequent in other regions during the recent warmer years, and are thus less vulnerable. However, it is noteworthy that the city reveals surprisingly many survival possibilities for threatened species.

Table 4. – Indigenous or naturalized species recorded at the territory of Zürich between 1839 and 1998 (including species extinct during this period) and their status according to the degree of threat. The situation in Zürich is compared with threat status of the same species set in Eastern Swiss Midlands and the whole Switzerland, based on values given by Landolt (1991a) for the latter two regions. Ex – extinct, having occurred in the region longer than 30 years before. E – endangered. V – vulnerable. R – rare. A – attractive. (Ex) – extinct, but having occurred in the region only 10–30 years before. (R) – rare, having occurred only 10–30 years in the region. U – not threatened. – not mentioned in the Red List for eastern Swiss Midlands or for the whole Switzerland.

	Zürich		E Swiss Midlands		Switzerland	
	Species no.	%	Species no.	%	Species no.	%
Ex	159	11	26	2	8	1
E	219	16	210	15	88	6
V	166	12	233	17	137	10
R	53	4	75	5	16	1
A	14	1	24	2	29	2
(Ex)	29	2	2	0	0	0
(R)	218	16	63	5	30	2
U	541	39	568	41	931	67
–	0	0	198	14	160	11
Total	1399	100	1399	100	1399	100

Conclusions

1. The flora of Zürich, and of a city in general, shows unusually high biodiversity. This is in contrast to many agricultural areas in the surroundings. The species richness in Zürich is due to (a) many different ecological niches within the city, (b) rich pool of potential neophytes in the gardens, and (c) preservation of several semi-natural areas, especially the Uetliberg Range, with steep and partly open slopes, and the Katzensee Region, with several lakes and extended wetland areas. The highest species number per square kilometer occurs not in the developed parts of the city, but rather in these two seminatural areas.
2. Within the last 160 years, the species number has increased. Whereas 188 species became extinct, 294 have become newly established. The ecological characteristics of the species has changed. Extinct species often behave stenoic; they either need very special combination of ecological factors or long lasting stable conditions. If conditions change, these species are not able to adapt and hence disappear. In contrast, new species are mostly "all-rounders". They are well adapted to city conditions and form large populations within a short time. However, they only rarely penetrate into closed natural or seminatural communities.

3. The new species clearly indicate a change of environmental conditions which has taken place during the last 160 years, and especially during the last two decades. They are often thermophilic and prefer soils rich in nutrients.
4. New species recruit either as escapes from gardens or from seeds introduced along road sides, in meadows or lawns, or from diaspores incidentally introduced by transport.
5. To keep or enhance the species richness, it is necessary (a) to preserve all existing natural or seminatural habitats and create similar sites wł ere original habitats have become so small that populations will not be able to survive; (b) to create pioneer habitats within the city, around school houses, in parks and gardens, along streets and on parking places etc., in order to provide many currently endangered archaeophytes with suitable habitats; (c) to create meadows which are poor in nutrients and not mown before summer time. The seeds for sowing should contain only native species or archaeophytes and originate from the same region; (d) to reduce the use of herbicides and fertilizers within the city to the minimum; (e) to foster public tolerance for the "disorder" of wild nature and enhance appreciation of its beauty, hence fascinate the public with the diversity of nature so that they are willing to invest funds in the care for such biotopes.

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Souhrn

Floristický průzkum Curychu probíhal v letech 1984–1998 a pokrýval plochu 122 km^2. Výsledky byly srovnány s literárními údaji z roku 1839 a herbářovými doklady z příslušné doby, což umožnilo zhodnotit změny, ke kterým ve složení flóry došlo za posledních přibližně 160 let. Flóra Curychu zahrnuje téměř 2000 druhů, z nichž 1211 je původních nebo zdomácnělých po zavlečení. Asi 1/4 těchto druhů se vyskytuje ve více než polovině čtverců kilometrové sítě, zatímco 1/3 byla zjištěna v méně než 6 % čtverců. Ve čtverci bylo zjištěno průměrně 451 druhů (minimum 294, maximum 607). Z 1211 výše zmíněných druhů, jejichž výskyt je v současné době stabilizován, tvoří 58 % druhy původní, 19 % archeofyty a 23 % neofyty. V nejvíce urbanizovaných částech města však tvoří neofyty zhruba polovinu počtu druhů. Mezi druhy, jež z flóry Curychu za posledních 160 let vymizely, bylo 60 % původních, 38 % archeofytů a 2 % neofytů. Archeofyty je nutné v současnosti považovat za obzvlášť ohroženou skupinu. Srovnání se starými literárními a herbářovými údaji ukazuje, že 26 % druhů flóry města vykazuje dnes stejnou frekvenci jako v roce 1839, 32 % je dnes hojnější (nebo byly nově zavlečeny) a 42 % tvoří skupiny druhů, jež se vyskytují s frekvencí nižší nebo vymizely. Celkem v tomto období vymizelo 188 druhů a nově bylo zavlečeno 294. Ve srovnání s nově zavlečenými mají vyhynulé druhy vyšší indikační hodnoty pro obsah živin a teplotu a nižší hodnoty pro kontinentalitu. Toto zjištění svědčí o tom, že v průběhu posledních 160 let došlo na území Curychu ke zvýšení obsahu živin v půdě, zvýšila se teplota a zimy jsou mírnější.

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