Biodiv. Res. Conserv. 9-10: 35-42, 2008

BRC
www.brc.amu.edu.pl

DOI 10.14746/biorc.2008.9-10.5

Selected aspects of diversity of synanthropic flora in the chosen cities of central Poland

Anna Bomanowska[1] & Piotr Witosławski[2]

Department of Geobotany and Plant Ecology, University of Łódź, Banacha 12/16, 90-237 Łódź, Poland, e-mail: [1]knopikaa@biol.uni.lodz.pl, [2]witoslaw@biol.uni.lodz.pl

Abstract: Changes in the geographical-historical, biological and ecological structure of synanthropic flora are among visible effects of urban development pressure. Taxonomic and geographical-historical diversity of synanthropic floras was analysed for the selected cities in central Poland: Łódź, Piotrków Trybunalski, Tomaszów Mazowiecki, Zgierz, Pabianice, Bełchatów and Radomsko. Floras of the analysed cities encompass 954 vascular plant species and are characterised by conspicuous uniformity (30.5% of species occur in all investigated cities). The most uniform flora is that of archaeophytes, followed by apophytes, kenophytes and diaphytes. The city of major importance for the spatial floristic system of cities in central Poland is Łódź. The flora of Łódź is characterised by highest species richness (820 species) and specificity (11.7% of the total pool of species and as many as 38.8% of diaphytes occur exclusively in Łódź), highest share of kenophytes (19.6%) as well as anthropophytes (56.3%), and the lowest share of archaeophytes (13.9%). Similarity analysis and classification conducted for total floras and separately for geographical-historical groups of plants in individual cities led on both occasions to the separation of two distinct groups of objects, the first consisting of the territorially adjacent Łódź, Zgierz and Pabianice (excluding the classification based on archaeophytes) and the second consisting of remaining cities.

Key words: urban flora, synanthropization, central Poland

1. Introduction

Urban agglomerations consist of social and natural areas and at the same time they are complex natural systems composed of technical, urban and biotic elements (Sukopp 1987; Wittig 1991, 2002).

The impact of human activity on the structure and function of the biotic components of a city may be observed on all levels of their organisation. Transformations in the taxonomic, geographical-historical, biological and ecological structure of flora are a manifestation of urban development pressure. Within urban territory, they lead to: formation of flora with a divergent structure from the one originally present (disturbance of natural floristic continuity in time), formation of flora with a divergent structure from the one present in extra-urban areas (disturbance of floristic continuity in space), taxonomic and ecological homogenisation of floras in different urban areas (Jackowiak 1998; Sudnik-Wójcikowska 1998).

According to the thesis presented by Jackowiak (1998), cities constitute a supra-regional spatial floristic system, the essence of which is the similarity of species composition of the spontaneous flora. The aim of the present study is to compare the taxonomic and geographical-historical diversity of synanthropic floras of the selected large cities in central Poland.

2. Material and methods

Diversity of synanthropic floras in cities of central Poland was analysed with regard to the 7 largest (with populations over 50 thousand inhabitants) cities in the region: Łódź, Piotrków Trybunalski, Tomaszów Mazowiecki, Zgierz, Pabianice, Bełchatów and Radomsko (Fig. 1).

The selected cities (apart from Tomaszów Mazowiecki) were founded between the 14th and 18th centuries (Table 1), but they emerged as urban centres as late as in the 19th or even 20th century, thanks to the process of industrialisation which transformed them both in a social and economic manner as well as with regard to urban geography (Koter *et al*. 2000; Liszewski 2001). The single exception is Piotrków Trybunalski which

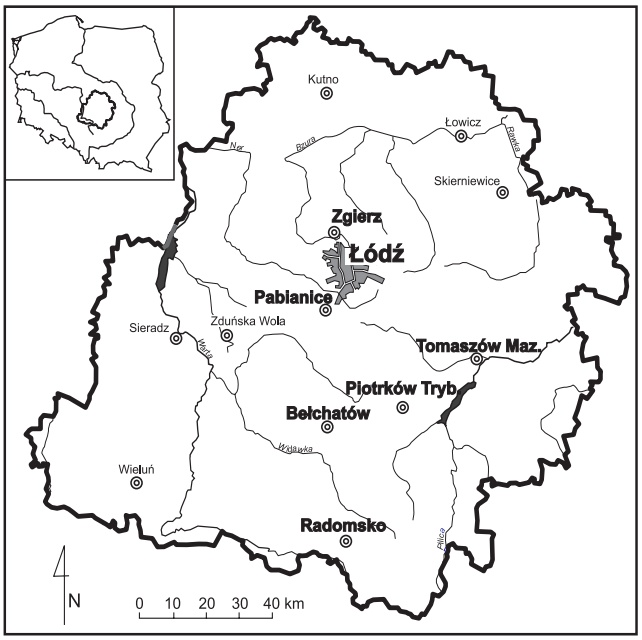

Fig. 1. Localization of cities taken under study of synanthropic floras in central Poland

belongs to the oldest and most significant urban centres of the region.

Nowadays, the described cities differ from each other with regard to their size and dominant functions (Table 1). Zgierz and Pabianice are the basic (apart from Łódź) industry and services hubs of the Łódź agglomeration, while Piotrków Trybunalski and Radomsko are major subregional centres of Łódź Voivodeship. Tomaszów Mazowiecki and Bełchatów occupy exclusive positions – the former grew as an industrial centre, while the latter is a housing and service centre of the Bełchatów Industrial Region. Łódź, the capital of Łódź Voivodeship, dominates the region not only due to its size and number of inhabitants, but also due to the development of metropolitan functions (Koter *et al*. 2000).

The analysis concerned synanthropic floras of selected cities. The complete list of vascular plant species was prepared based on floristic data derived from many years of the second author's own field studies (Witosławski 2006) as well as literature data (Mowszowicz 1960, 1978; Sowa 1971, 1991; Sowa & Nasiłowski 1978; Sowa & Warcholińska 1980, 1981, 1984). Due to the somewhat discountinous extent of the floristic studies carried out at various locations, the analysis includes exclusively species that occur only in synanthropic (ruderal and segetal) habitats, while the data on species occurrence were encoded in a binary fashion (0-1, absent-present) without taking into account their quantitative occurrence. Species nomenclature was adopted from Mirek *et al*. (2002).

The study implements the geographical-historical classification of flora following the clasification proposed by Kornaś (1981) and supplemented by Mirek (1981) and Jackowiak (1990). The degree of naturalisation of alien species was related to local conditions. Status of naturalised anthropophytes was determined according to the studies by Zając (1979) and Tokarska-Guzik (2005).

Three groups of species were distinguished depending on their response to the intensity of urban development pressure: urbanophiles (urbanophilous plants), urbanoneutrals (urbanoneutral plants) and urbanophobes (urbanophobic plants). Urbanity was determined according to the data base "Biolflor" (Klotz *et al*. 2002).

Floristic analysis included calculation of selected indexes of anthropogenic transformation of the flora. The indexes was calculated according to Jackowiak (1990) formula:

1. Indexes of anthropophytisation (WAn_c – index of total anthropophytisation, WAn_t – index of permanent anthropophytisation)

$$WAn_c = \frac{An}{Sp + An} \times 100\% \qquad WAn_t = \frac{M}{Sp + M} \times 100\%$$

Table 1. Characteristic of cities taken under study of synanthropic floras

City	Total area [km^2]	Number of inhabitants		Time of location	Year of bestowed of city rights	Dominant function	
		in thousands	per 1 km^2			administrative	economic
Łódź	294.0	767600	2608	XV	1423	capital of voivodeship	regional center, metropolis function
Bełchatów	35.0	64600	1845	XVIII	1743 and, for the second time, 1925	capital of county	attentive, services
Pabianice	33.0	69682	2185	XIV	1354	capital of county	industrial
Piotrków Trybunalski	67.3	79599	1183	XIII	1313	capital of county	industrial, attentive, services
Radomsko	51.4	50399	no data	XIII	1266	capital of county	industrial
Tomaszów Mazowiecki	41.3	67159	1626	XIX	1830	capital of county	industrial
Zgierz	42.0	58400	1376	XIII	before 1288	capital of county	industrial, attentive, services

Source: Statistical Yearbook of the Republic of Poland 2007; Statistical Yearbook of the Łódź Voivodeship 2007; Koter *et al*. 2000; Liszewski 2001

2. Indexes of archaeophytisation (WAr_c – index of total archaeophytisation, WAr_t – index of permanent archaeophytisation)

$$WAr_c = \frac{Ar}{Sp + An} \times 100\% \qquad WAr_t = \frac{Ar}{Sp + M} \times 100\%$$

3. Indexes of kenophytisation (WKn_c – index of total kenophytisation, WAr_t – index of permanent kenophytisation)

$$WKn_c = \frac{Kn}{Sp + An} \times 100\% \qquad WKn_t = \frac{Kn}{Sp + M} \times 100\%$$

4. Index of modernisation

$$WM = \frac{Kn}{M} \times 100\%$$

5. Index of fluctuation of the flora

$$WF = \frac{D}{Sp + An} \times 100\%$$

where: An - number of anthropophytes, Sp – number of spontaneophytes, M – number of metaphytes, Ar – number of archaeophytes, Kn – number of kenophytes, D – number of diaphytes

Similarity of synanthropic floras in individual cities was determined using the Jaccard similarity coefficient with the objects grouped by the unweighted pair group methods with arithmetic mean (Dzwonko 2007).

3. Results and discussion

3.1. Species richness of the floras

Floras of analysed cities include a total of 954 vascular plant species (Fig. 2). The highest number of species was recorded from Łódź (820 species), the lowest one – from Radomsko (384 species). The varying number of species in individual cities may stem from several complementary factors, with their largeness and functional divergence as the seemingly most important factors in the case of cities under study, because it implies heterogeneity of habitats. The positive impact of habitat diversity and moderately strong anthropogenic disturbances on the increase of floristic richness of urban areas has been addressed, e.g. by Peet *et al.* (1983); Kowarik (1988, 1990, 1995); Sudnik-Wójcikowska (1991, 1998); Pyšek (1993, 1998a, 1998b); Jackowiak

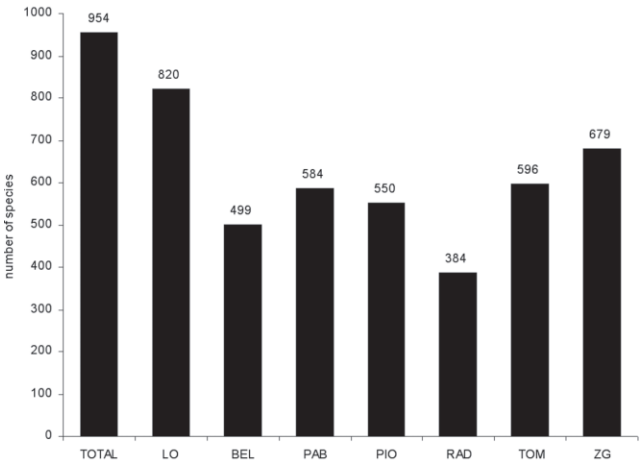

Fig. 2. Species richness of synanthropic floras in large cities of central Poland
Explanations: LO – Łódź, BEL – Bełchatów, PAB – Pabianice, PIO – Piotrków Trybunalski, RAD – Radomsko, TOM – Tomaszów Mazowiecki, ZG – Zgierz

(1998); Roy *et al.* (1999); Wołkowycki (2000); Kim *et al.* (2002); Kühn *et al.* (2004). It seems that these particular factors influence the following observations:

- the high and relatively similar richness of floras in Łódź and Zgierz – cities which otherwise have a several-fold difference in area and more than ten-fold difference in the number of inhabitants;
- small differences in floristic richness between Tomaszów Mazowiecki, Piotrków Trybunalski and Pabianice which are the cities of different size and number of inhabitants, but have similar functional diversity;
- relative floristic poverty of Bełchatów which constitutes mainly a social backdrop and living quarters for employees of the nearby mine and power plant.

However, based on these rules it is difficult to explain the relative poverty of the flora of Radomsko, albeit the smallest town among those analysed, but still one with diversified functions.

3.2. Homogenization and species diversity of the floras

Floras of analysed cities are characterised by high homogenity. The floristic component common to all cities includes 291 species, i.e. 30.5% species occur in all cities (Table 2). The most uniform floras are that of archaeophytes and subsequently apophytes, kenophytes

Table 2. Frequency of synanthropic species in the selected cities of central Poland

Geographical-historical group	1		2		3		4		5		6		7		Total	
	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
Apophytes	41	8.6	52	10.9	71	14.9	40	8.4	36	7.6	52	10.9	184	38.7	476	100
Kenophytes	14	8.6	28	17.2	40	24.5	14	8.6	16	9.8	24	14.7	27	16.6	163	100
Archaeophytes	10	8.4	12	10.1	8	6.7	5	4.2	11	9.2	10	8.4	63	52.9	119	100
Diaphytes	82	41.8	40	20.4	24	12.2	10	5.1	10	5.1	13	6.6	17	8.7	196	100
Total	147	15.4	132	13.8	143	15.0	69	7.2	73	7.7	99	10.4	291	30.5	954	100

Explanations: 1-7 – number of cites in which species occurs, No – number of species

Table 3. Percentage of species pools belonging to different geographical-historical groups in the synanthropic floras in the selected cities of central Poland

Geographical-historical group	% of species pool						
	LO	BEL	PAB	PIO	RAD	TOM	ZG
Apophytes	75.2	65.5	68.7	71.6	48.1	79.2	74.4
Kenophytes	98.8	33.1	67.5	44.2	30.1	49.1	81.6
Archaeophytes	95.8	72.3	70.6	75.6	63.9	73.9	80.7
Diaphytes	95.4	24.0	32.1	24.0	15.3	26.0	49.0
Total	86.0	52.3	61.2	57.7	40.3	62.5	71.2

Explanations: see Fig. 2

and diaphytes. The varying degree of homogenization of local floras in separate geographical-historical groups is an expression of: natural conditions, time which had passed since their naturalisation, their biology and mode of dispersal (Bazzaz 1986; Noble 1989; Roy 1990; Pyšek 1993; Kowarik 1995; Roy *et al*. 1999; Wołkowycki 2000; Kühn *et al*. 2004). The varying level of homogenization of floras with regard to individual geographical-historical groups is shown by the following indicators:

- share of species common to all the cities,
- degree of implementation of the species pool in individual cities;
- values of floristic similarity between each pair of cities.

The highest share of species common to all the cities is shown by archaeophytes (52.9%) and apophytes (38.7%), with smaller shares of kenophytes (16.6%) and diaphytes (8.7%). On the other hand, the highest share of species occurring exclusively in one of the cities is characteristic for diaphytes (41.8%), while in other geographical-historical groups it is much smaller and has similar values (8.4% – among archaeophytes, 8.6% – among kenophytes and apophytes).

The degree of implementation of the species pool of individual geographical-historical groups in the analysed floras is never smaller than: 63.9% – for archaeophytes, 48.1% – for apophytes, 30.1% – for kenophytes 15.3% – for diaphytes (Table 3).

Values of Jaccard similarity coefficient between local floras from geographical-historical groups in any two selected cities are never smaller than 0.65 – for archaeophytes; 0.54 – for apophytes; 0.33 – for kenophytes and 0.15 – for diaphytes (Fig. 3).

High uniformity of local archaeophyte floras results from the characteristics of their spreading, their long period of naturalisation and the source of dispersal. Archaeophytes spread in segetal habitats by diffusion, therefore there are currently no significant environmental barriers which would isolate individual cities in this regard. It is of no significance for the eventual uniformity of archaeophyte floras that nearly all studied cities (except Piotrków Trybunalski) adopted urban characteristics not earlier than during the first half of 19th century, while earlier, despite having city rights, they were in fact rural centres isolated by forests, with segetal species from surrounding fields contributing to their ruderal floras – also predominantly archaeophytes. They lost their isolated character to a large extent only in the first half of the 19th century with the transformation of urban function, development of transport pathways, increase in goods trade and, above all, the increase in the area of agriculturally utilised land. It may thus be presumed that local fields and fallows were initially the

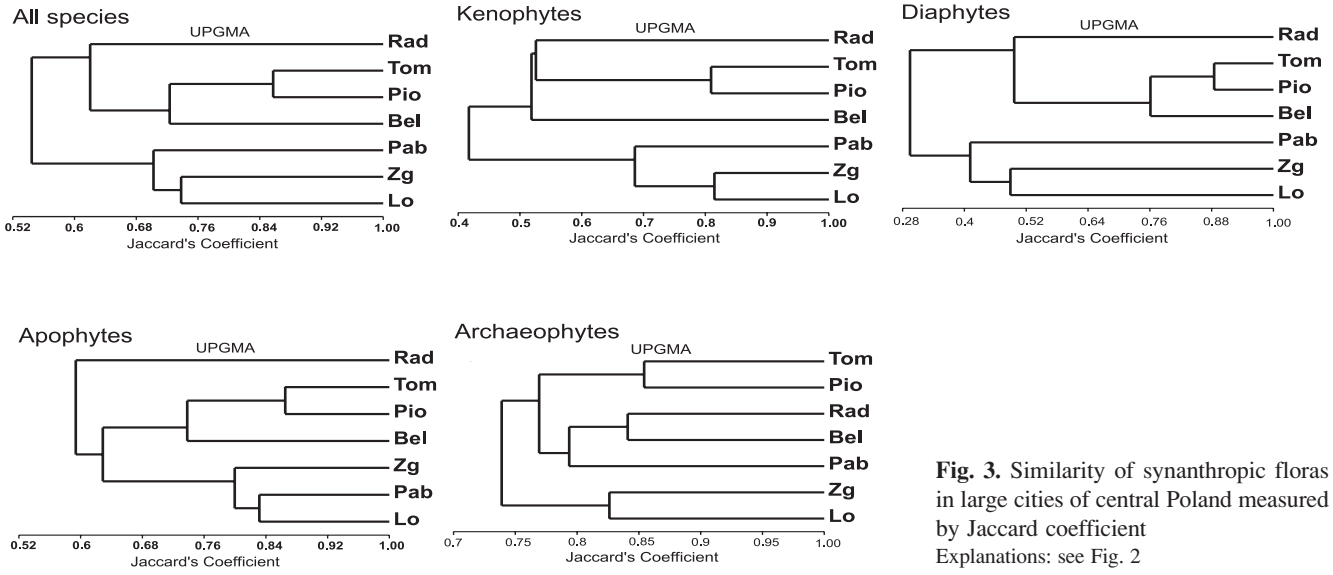

Fig. 3. Similarity of synanthropic floras in large cities of central Poland measured by Jaccard coefficient
Explanations: see Fig. 2

main source of diaspores for settlement of ruderal habitats in the cities, and with time they became corridors which facilitated the migration of species. The late loss of isolation of individual cities was of no significance for preservation of separate character of archaeophyte floras in view of high saturation of archaeophytes from the respective neighbouring agricultural areas.

Differences with regard to apophytes seem to result mostly from local habitat conditions which are of increasing importance with decreasing distance between respective urban centres.

It may be presumed that in the beginning of the 19th century, the environmentally isolated local urban floras consisted predominantly of apophytes and archaeophytes. Kenophytes appeared in larger numbers only with the development of industry in the first half of the 19th century and with the concurrent functional transformations in individual cities. The relatively small homogenisation of local kenophyte floras results from the different, than in the case of archaeophytes, secondary sources of dispersal (located within individual cities) and from the stronger isolation of separate centres with regard to this group of plants. As opposed to archaeophytes, for the major part of kenophytes the arable fields connecting the cities are environmental barriers which may be surmounted only by leaps.

The largest differences may be observed between local diaphyte floras. Their occurrence is usually limited to the area where they originally appeared – as species that escape from cultivation or that are inadvertently imported with industrial and building materials.

The observed relations between floristic homogenisation and geographical-historical affiliation of species, as well as the resulting conclusions, find corroboration in studies on ruderal floras in northern Podlasie (Wołkowycki 2000) and studies on urban floras in Central Europe (Pyšek 1998a, 1998b).

Similarity (cluster) analysis and classification conducted for total floras and separately for geographical-historical groups in individual cities has always led to the separation of two groups of objects: the first one is always composed of the territorially adjacent Łódź and Zgierz; the other one – of Bełchatów, Piotrków Trybunalski, Tomaszów Mazowiecki and Radomsko (Fig. 3). Pabianice, with the exception of classification which takes into account only archaeophytes, are linked in one cluster with Łódź and Zgierz (Fig. 3). In each group of cities, similarity relations are structured alike, independent on whether the subject of analysis was the total flora or individual geographical-historical groups. In the first group of cities, the predominant place is reserved for Łódź, which both for the total flora and for all antropophyte groups displays closer similarity to Zgierz than to Pabianice, while for apophytes the similarity is closer to Pabianice than to Zgierz; the similarity between Pabianice and Zgierz in both these cases is smaller than between each of these cities and Łódź. In the second cluster of cities, the dominant position is reserved for the grouping of Piotrków Trybunalski and Tomaszów Mazowiecki, with the similarity between these two cities stronger than to any other city, independent of the selection of a floristic group as the basis of the analysis. Bełchatów and Radomsko are clustered together exclusively in the analysis which concerns the species similarity of archaeophytes. The archaeophyte flora of both these cities is strongly similar to the archaeophyte flora of Pabianice, more so than the latter to the same group of species in Łódź. It has to, however, be stressed that classification of cities with regard to archaeophytes is based on significantly smaller differences in similarities than in the case of the remaining geographical-historical groups.

3.3. Geographical-historical diversity and indicators of anthropogenic transformations of the floras

Ratios of anthropophytes to apophytes in individual local floras conform to the model presented by Faliński (1971). The obtained results are similar to those from other urbanized areas in Central Europe (Krawiecowa

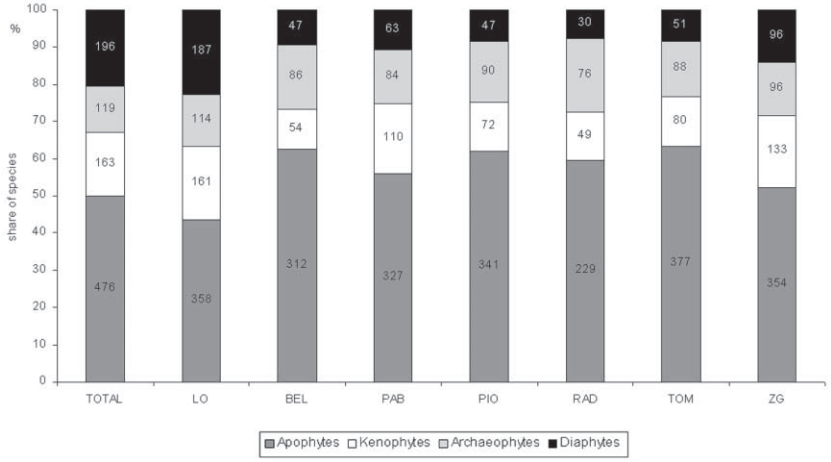

Fig. 4. Proportion of geographical-historical groups of species in synanthropic floras in large cities of central Poland
Explanations: see Fig. 2; numbers on graph: 476, 163, … – number of species

Table 4. Indexes of anthropogenic changes in synanthropic floras in large cities of central Poland

Index	LO		BEL		PAB		PIO		RAD		TOM		ZG	
	val.	dev.	val.	dev.	val.	dev.	val.	dev.	val.	dev.	val.	dev.	val.	dev.
WAn_c	56.3	12.4	37.5	-5.2	44.0	-2.2	38.0	-4.2	40.4	-9.4	36.7	-6.7	47.9	-4.5
WAn_t	43.4	16.8	31.0	-6.7	37.2	0.1	32.2	-3.4	35.3	-5.1	38.8	-7.1	39.3	5.6
WAr_c	13.9	11.5	17.2	38.2	14.4	15.3	16.4	31.2	19.8	58.7	14.8	18.4	14.1	13.3
WAr_t	18.0	14.7	19.0	21.2	16.1	2.7	17.9	14.0	21.5	36.8	16.1	2.9	16.5	4.9
WKn_c	19.6	14.9	10.8	-6.7	18.8	10.2	13.1	-3.4	12.8	-5.3	13.4	-1.4	19.6	14.6
WKn_t	25.4	18.3	11.9	-4.4	21.1	-1.8	14.3	-3.4	13.8	-5.6	14.7	-1.7	22.8	6.1
WM	58.5	1.3	38.6	-3.3	56.7	-1.9	44.4	-3.1	39.2	-2.2	47.6	-7.6	58.1	0.5
WF	22.8	11.0	9.4	54.2	10.8	-7.5	8.5	-8.4	7.8	-2.0	8.6	-8.3	14.1	-3.2

Explanations: WAn_c – index of total anthropization, WAn_t – index of permanent anthropization, WAr_c – index of total archaeophytization, WAr_t – index of permanent archaeophytization, WKn_c – index of total kenophytization, WKn_t – index of permanent kenophytization, WM – index of modernization, WF – index of fluctuation, val. – real value of index, dev. – difference between real and expected value of index, LO, BEL, PAB, PIO, RAD, TOM, ZG – see Fig. 2

& Rostański 1976; Kornaś 1977; Pyšek 1998b). The share of anthropophytes (426 taxa; 56.3% of total – Fig. 4) in the total synanthropic flora of Łódź is much higher than in the remaining cities in the region and is also higher than the share of apophytes. In other cities, apophytes are more numerous than anthropophytes.

Kenophytes predominate over archaeophytes in Łodź and in neighbouring cities – Zgierz and Pabianice (Fig. 4). The highest share of kenophytes is characteristic for Łódź (161 species; 19.6% of total), Pabianice (110; 18.8%) and Zgierz (133; 19.6%), while the lowest is present in Bełchatów (54; 10.8%) and Radomsko (49; 12.8%). The highest share of archaeophytes is shown by floras of Radomsko (76; 19.8%) and Bełchatów (86; 17.2%), with the number only slightly lower in the remaining cities (Fig. 4).

The highest share of diaphytes is distinctive for Łódź, where there is 1/3 more of them than in Zgierz and at least twice more than in any of the other cities.

Deviations of the observed values of anthropogenic transformation indexes from expected values are similar to the classification of cities with regard to their floristic similarity (Table 4):

- Łódź is distinguished from the remaining cities by the higher than expected value of WAn_c and WF;
- Łódź and Zgierz are distinguished from the remaining cities by the higher than expected value of WAn_t, WKn_t and WM (Pabianice show WKn_t and WM only slightly lower than expected);
- Łódź, Zgierz and Pabianice are distinguished from remaining cities by the higher than expected value of WKn_c.

There are conspicuous differences in parameter values between groups of species. These differences ensue not only from the causes described in more detail above, but also from the time and mode of data collection. Investigations in individual towns were performed for relatively varied periods of time (20-40 years), while the duration of each study was also inconsistent, which most probably had a significant impact on the divergent number of diaphytes encountered in the compared sites. Differences in the mode of information gathering were also not without significance – data were collected in a systematic manner only in Łódź, using the cartogram method, while the remaining towns had only standard floristic lists compiled for them.

3.4. Urbanity of species

Abundance of vascular plant species in the city depends on the mode and intensity of urban space usage, especially on the structure of the built-up area (Wittig *et al.* 1985; Jackowiak 1998, 2000; Sudnik-Wójcikowska 1998; Witosławski 2005).

Floras of individual cities differ with regard to the share of species which show specific preferences concerning occurrence in urban areas.

The highest share of urbanophilous species (eu- and mesourbanophiles) is characteristic for the floras of Łódź (20.4%), Zgierz (17.4%) and Pabianice (15.1%). These cities are territorially adjacent, which may affect the similarity of their synanthropic floras with regard to the share of urbanophilous species (Table 5).

The highest share of urbanophobic species (eu- and mesourbanophobes) is characteristic for the floras of

Table 5. Urbanophobic and urbanophilous species in synanthropic floras in the selected cities of central Poland

Group of species	LO		BEL		PAB		PIO		RAD		TOM		ZG	
	val.	dev.	val.	dev.	val.	dev.	val.	dev.	val.	dev.	val.	dev.	val.	dev.
urbanophobes	47.8	-11.1	53.6	8.9	48.5	-1.7	54.1	12.0	47.3	-0.5	56.2	15.2	49.1	-4.4
urbanoneutrals	31.7	14.0	34.4	23.7	36.4	30.7	34.7	24.6	41.5	49.2	32.7	17.6	33.6	20.6
urbanophiles	20.4	16.3	12.0	-25.4	15.1	-6.2	11.2	-28.6	11.2	-27.8	11.0	-30.8	17.4	3.6

Explanations: val. – real number of species, dev. – difference between the real and expected number of species, LO, BEL, PAB, PIO, RAD, TOM, ZG – see Fig. 2

Tomaszów Mazowiecki (56.2%), Piotrków Trybunalski (54.1%) and Bełchatów (53.6%).

Values of deviation of observed number of urbanophilous and urbanophobic species from the expected values point to the higher than expected importance of urbanophiles in Łódź and Zgierz, while urbanophobes are conspicuously predominant in Tomaszów Maz., Piotrków Tryb. and Bełchatów (Table 5).

4. Conclusions

The analysis has shown that floras of urban areas show distinct taxonomic, geographical-historical and ecological characteristics, and confirmed the notion that cities constitute a supra-regional spatial floristic system.

Analyses and classifications performed for total floras and separately for geographical-historical groups in individual cities have yielded the conclusion that analysed objects form two distinct groups: the first one being composed of Łódź, Zgierz and Pabianice, the other one including Bełchatów, Piotrków Trybunalski, Tomaszów Mazowiecki and Radomsko.

Łódź occupies a particular position among the compared cities. Its synanthropic flora is distinguished by:

- highest species richness;
- high number of specific species;
- indicators of anthropogenic transformations in the flora higher than in the remaining cities (apart from indicators of archaeophytization);
- share of diaphytes higher than in the remaining cities.

References

Bazzaz F. A. 1986. Life history of colonizing plants: some demographic genetic and physiological features. In: H. A. Mooney & J. A. Drake (eds.). Ecology of biological invasions of North America and Hawaii. Ecological Studies, pp. 96-110. Springer Verlag, New York.

Dzwonko Z. 2007. Przewodnik do badań fitosocjologicznych. In: J. B. Faliński (ed.). Vademecum Geobotanicum, 304 pp. Sorus, Instytut Botaniki Uniwersytetu Jagiellońskiego, Poznań-Kraków.

Faliński J. B. 1971. Flora i roślinność synantropijna wsi i miast – próba analizy porównawczej. Mater. Zakł. Fitosoc. Stos. UW Warszawa-Białowieża 25: 15-23.

Jackowiak B. 1990. Antropogeniczne przemiany flory roślin naczyniowych Poznania. Wyd. Nauk. UAM, seria Biologia, 42, 232 pp. Poznań.

Jackowiak B. 1998. Struktura przestrzenna flory dużego miasta. Studium metodyczno-problemowe. Prace Zakładu Taksonomii Roślin UAM w Poznaniu 8: 1-227. Bogucki Wyd. Nauk., Poznań.

Jackowiak B. 2000. Chorological and ecological model of urbanophilous plant in Central Europe. In: B. Jackowiak & W. Żukowski (eds.). Mechanisms of Anthropogenic Changes of the Plant Cover. Publications of the Department of Plant Taxonomy of the Adam Mickiewicz University in Poznań 10: 125-141. Bogucki Wyd. Nauk., Poznań.

Kim Y.-M., Zerbe S. & Kowarik I. 2002. Human impact on flora and habitats in Korean rural settlements. Preslia 74: 409-419.

Klotz S., Kühn I. & Durka W. 2002. Biolflor – Eine Datenbank mit biologisch-ökologischen Merkmalen zur Flora von Deutschland. Schriftenr. Vegetationsk. 38: 1-334.

Kornaś J. 1977. Analiza flor synantropijnych. Wiad. Bot. 21: 85-91.

Kornaś J. 1981. Oddziaływanie człowieka na florę: mechanizmy i konsekwencje. Wiad. Bot. 25: 165-182.

Koter M., Liszewski S. & Suliborski A. 2000. Łódź i region Polski Środkowej. 397 pp. Łódzkie Tow. Nauk., Łódź.

Kowarik I. 1988. Zum menschlichen Einfluss auf Flora und Vegetation. Theoretische Konzepte und ein Quantifizierungssansatz am Beispiel von Berlin (West). Landschaftsentw. u. Umweltforsch. TU Berlin 56: 1-280.

Kowarik I. 1990. Some responses of flora and vegetation to urbanization in central Europe. In: H. Sukopp, S. Hejny & I. Kowarik (eds.). Urban ecology: plants and plant communities in urban environments, pp. 45-74. SPB Academic Publishing, Amsterdam.

Kowarik I. 1995. On the role of alien species in urban flora and vegetation In: P. Pyšek, K. Prach, M. Rejmánek & M. Wade (eds.). Plant invasions: general aspects and special problems, pp. 85-103. SPB Academic Publishing, Amsterdam.

Krawiecowa A. & Rostański K. 1976. Zależność flory synantropijnej wybranych miast polskich od ich warunków przyrodniczych i rozwoju. Acta Univ. Wratisl. 303, Prace Bot. 21: 5-61.

Kühn I., Brandl R. & Klotz S. 2004. The flora of German cities is naturally species rich. Evol. Ecol. Res. 6: 749-764.

Liszewski S. (ed.). 2001. Zarys monografii województwa łódzkiego. 456 pp. Łódzkie Tow. Nauk., Łódź.

Mirek Z. 1981. Problemy klasyfikacji roślin synantropijnych. Wiad. Bot. 25: 45-54.

Mirek Z., Piękoś-Mirkowa H., Zając A. & Zając M. 2002. Flowering plants and pteridophytes of Poland. A checklist. In: Z. Mirek (ed.). Biodiversity of Poland 1,442 pp. W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków.

Mowszowicz J. 1960. Conspectus Florae Lodziensis. Przegląd flory łódzkiej. Cz. 1. Rośliny naczyniowe. Prace Wydz. Mat.-Przyr. Łódzkie Tow. Nauk. 69: 1-375.

Mowszowicz J. 1978. Conspectus florae Poloniae Medianae. Przegląd flory Polski Środkowej. 395 pp. Wyd. Uniw. Łódzkiego, Łódź.

Noble I. R. 1989. Attributes of invaders and the invading process: terrestrial and vascular plants. In: J. A. Drake, H. A. Mooney, F. Di Castri, R. H. Groves, F. J. Kruger, M. Rejmánek & M. Williamson (eds.). Biological invasions: a global perspective, pp. 301-313. SCOPE 37. John Wiley and Sons Ltd., Chichester.

Peet R. K., Gleen-Lewin D. C. & Walker-Wolf J. 1983. Prediction of man's impact on plant species diversity. In: W. Holzner, M. J. A. Werger & I. Ikusima (eds.). Man's impact on vegetation, pp. 41-54. Dr W. Junk Publishing, the Hague, Boston, London.

Pyšek P. 1993. Factors affecting the diversity of flora and vegetation in Central European settlements. Vegetatio 106: 89-100.

Pyšek P. 1998a. Alien plants in Czech village flora: an analysis of species numbers. Feddes Repert. 109: 139-146.

Pyšek P. 1998b. Alien and native species in Central European urban floras: a quantitative comparision. J. Biogeogr. 25: 155-163.

Roy J. 1990. In search of the characteristics of plant invaders. In: F. Di Castri, A. Hansen J. & M. Debussche (eds.). Biological invasions in Europe and Mediterranean Basin, pp. 335-352. Kluwer Academic Publishing, Dordrecht.

Roy D. B, Hill M. O. & Rothery P. 1999. Effects of urban land cover on the local species pool in Britain. Ecography 22: 507-515.

Sowa R. 1971. Flora i zbiorowiska ruderalne na obszarze województwa łódzkiego ze szczególnym uwzględnieniem miast i miasteczek. 282 pp. Wyd. Uniw. Łódzkiego, Łódź.

Sowa R. 1991. Flora synantropijna Pabianic. Spraw. Łódzkiego Tow. Nauk. 45(3): 1-8.

Sowa R. & Nasiłowski S. 1978. Flora synantropijna Zgierza. Spraw. Łódzkiego Tow. Nauk. 32(3): 1-7.

Sowa R. & Warcholińska A. U. 1980. Flora synantropijna Bełchatowa. Spraw. Łódzkiego Tow. Nauk. 34(12): 1-7.

Sowa R. & Warcholińska A. U. 1981. Flora synantropijna Radomska. Spraw. Łódzkiego Tow. Nauk. 35(7): 1-8.

Sowa R. & Warcholińska A. U. 1984. Flora synantropijna Piotrkowa Trybunalskiego i Tomaszowa Mazowieckiego. Acta Univ. Lodz., Folia bot. 2: 41-101.

Sudnik-Wójcikowska B. 1991. Synanthropization indices of urbanfloras – an attempt at definition and assessment. Acta Soc. Bot. Pol. 60(1-2): 163-185.

Sudnik-Wójcikowska B. 1998. Czasowe i przestrzenne aspekty procesu synantropizacji flory na przykładzie wybranych miast Europy Środkowej. 167 pp. Wyd. Uniw. Warszawskiego, Warszawa.

Sukopp H. 1987. Stadtökologische Forschung und deren Anwendung in Europa. Düsseldorfer. Geobot. Koloq. 4: 3-28.

Tokarska-Guzik B. 2005. The Establishment and Spread of Alien Plant Species (Kenophytes) in the Flora of Poland. Prace naukowe Uniw. Śląskiego w Katowicach 2372: 1-192.

Wittig R. 1991. Ökologie der Großstadtflora. 261 pp. Gustav Fischer Verlag, Stuttgart.

Wittig R. 2002. Siedlungsvegetation. 252 pp. Verlag Eugen Ulmer, Stuttgart.

Wittig R., Diesing D. & Gödde M. 1985. Urbanophob – Urbanoneutral – Urbanophil. Das Verhalten der Arten gegenüber dem Lebensraum Stadt. Flora 177: 265-282.

Witosławski P. 2005. Distribution of grasses in condition of urban pressure in the teritory of Łódź. In: L. Frey (ed.). Biology of grasses, pp. 159-170. W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków.

Witosławski P. 2006. Atlas of distribution of vascular plants in Łódź. 386 pp. Wyd. Uniw. Łódzkiego, Łódź.

Wołkowycki D. 2000. Różnicowanie i ujednolicanie się flor ruderalnych w warunkach izolacji środowiskowej. Monogr. Bot. 87: 1-157.

Zając A. 1979. Pochodzenie archeofitów występujących w Polsce. Rozpr. Habil. Uniw. Jagiell. 29: 1-213.