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Factors affecting the diversity of flora and vegetation in central European settlements

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Abstract

Published data on the number of plant species and/or communities were gathered for 77 European cities and 85 villages. The relationships between the floristic and vegetation diversity and some environmental variables were analysed. Species number in cities showed log linear increase with city size (expressed as the population size or city area). A linear increase in the species number with size was found in the village flora. The richness of both city and village flora was not significantly related to any climatic variable. On the contrary, the number of communities in both villages and cities was correlated not only with settlement size but also with altitude and mean annual temperature. The diversity of village vegetation was closely related to the climax type of the respective region. The features of human settlements that make it possible to consider them as landscape islands are discussed.

Introduction

It has repeatedly been recognized that species numbers in cities are higher than those in the surrounding landscape (Walters 1970; Haeupler 1974; Wittig & Durwen 1981; Kowarik 1985; Pyšek 1992a; but see Rapoport *et al.* 1983). Having compared some European cities, Klotz (1988, 1990), Pyšek (1989a), and Brandes & Zacharias (1990) have shown that the species richness is closely related to the city size. This is usually explained by the considerable habitat heterogeneity and better possibilities of species immigration in big cities (Sukopp *et al.* 1979; Sukopp & Werner 1983; Pyšek 1989a; Kowarik 1990).

The recent studies have mostly been restricted to the urban floras and, moreover, the numbers of cities used for analyses were rather small. Moreover, the interpretation of results may be also biased by the quality of data and depends on the extent to which the authors are aware of data limitations (Pyšek 1989a; Brandes & Zacharias 1990). This paper considers a more extensive data set that includes both village and urban settlements. Furthermore, it focuses on the diversity of vegetation. It addresses the following questions:
1. What is the relative importance of settlement size compared to other factors in affecting the floristic and vegetation diversity?
2. Is the diversity of both flora and vegetation ruled by the same principles?
3. Are there any particular differences between villages and cities in the relationships analysed?

Data sources

Previously published data on the numbers of species and communities were gathered for 77 Eu-

Fig. 1. Location of European cities used for analysis. Different symbols were used to show whether the number of species (O), number of communities (×) or both data (⊗) were reported from the particular city. For references see Fig. 2.

ropean cities located within 48.08–54.22° N and 4.21–22.53° E (Fig.1, for references see Fig.2). In all, 56 reports on species numbers and 37 on the number of communities were brought together. The settlements with more than 10 thousand inhabitants were considered as cities. As original data sources do not always contain information on settlement features, these characteristics were not considered and the 'village' flora and vegetation was distinguished from the 'city' flora and vegetation only on the basis of settlement size. Each city was characterized by both the number of inhabitants and the city area, these data being taken from respective papers or from statistical yearbooks and maps. Mean annual temperature, annual amount of precipitation and altitude were taken from climate diagrams (Walter & Lieth 1967); if these were not available directly for a given city, the nearest one located in an area of similar geographical characteristics was considered. In addition, longitude and latitude were recorded for each city.

Eighty-five villages situated in the western part of Czechoslovakia (between 12–16° E) were characterized by the number of inhabitants, number of houses and the altitude. Information on the climax community of the area in which the respective village was located was taken from Mikyška *et al.* (1972). Altogether, the species numbers for 41 villages (A.Pyšek, unpublished data; Šandová 1976; Pyšek & Rydlo 1984; Pyšek 1989b) and the numbers of communities for 85 villages (Pyšek 1973a, b; 1981a, 1988; Šandová 1976; Pyšek 1981b, 1992b; Pyšek & Pyšek 1985; Pyšek & Rydlo 1984) were collected. The area covered by an individual plant community was given in the original data sources which made it possible to characterize each village by its vegetation diversity (Pyšek & Pyšek 1987). This was expressed using the Shannon index (e.g. Peet

1974). The relative contributions of particular communities to the total area covered by vegetation in the respective village were used as importance values in the formula.

In this paper, 'community' is understood as being the basic unit of the phytosociological system (e.g. Mueller-Dombois & Ellenberg 1974), i.e. the association or an unit of the corresponding level. 'Number of communities' is therefore the number of such units distinguished by the author.

Data were analysed using linear regression, partial correlation, and non-parametric Kruskall-Wallis test (Sokal & Rohlf 1981). Differences between slopes of regression lines were estimated by the F-test (Snedecor & Cochran 1967).

Results

Number of plant species

The species number in cities shows a highly significant log linear increase with the city size, whenever this size is expressed as the number of inhabitants or the city area (Table 1, Fig. 2A and 3A). The relationship between the species number and population density was, however, less significant (Table 1). An increase in the species number with the population size was also obtained when particular countries for which enough data are available were treated separately (Germany: $r = 0.89$, $P < 0.0001$, $n = 22$; Poland: $r = 0.74$, $P < 0.0001$, $n = 29$). The number of spe-

Table 1. Regressions of species numbers (S) and numbers of communities (C) on various settlement characters. Only significant relationships are presented. Models providing the best fit to the data are indicated: L – linear $Y = a + bX$, M – multiplicative $Y = aX^b$, E – exponential $Y = \exp(a + bX)$. If two models provided similar fit, the equation is presented for the first one. * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$. Effects of interactive outlier regression on the slope b, correlation coefficient r and, if changed, the significance level P are noted. [1] mean annual temperature, H' – vegetation diversity expressed by Shannon index.

	Model	Intercept a	Slope b	d.f.	F	P	r	R^2 (%)	outliers
Cities:									
S/population size	M	209.45	0.225	1,54	86.27	***	0.78	61.5	1 (b = 0.220, r = 0.83)
S/city area	M	233.40	0.229	1,54	58.97	***	0.72	52.2	1 (b = 0.242, r = 0.76)
S/population density	M	163.86	0.178	1,54	4.82	*	0.29	8.2	2 (b = 0.289, r = 0.44,**)
C/population size	L	23.12	0.053	1,37	16.05	***	0.58	33.1	1 (b = 0.060, r = 0.63)
C/city area	L	18.94	0.171	1,37	17.99	***	0.57	32.7	
C/population density	M	0.23	0.641	1,37	11.04	**	0.48	23.0	
C/altitude	E	3.71	− 0.00195	1,37	4.41	*	− 0.32	10.7	1 (b = 0.0029, r = − 0.46,**)
C/temperature[1]	E	− 0.279	0.442	1,37	16.51	***	0.56	30.9	
Villages:									
S/population size	L	168.36	41.25	1,39	7.45	**	0.40	16.0	
S/number of houses	L	168.74	0.158	1,39	6.63	*	0.38	14.5	
C/population size	M, L	13.43	0.136	1,83	14.81	***	0.39	15.1	
C/no. of houses	M, L	5.44	0.174	1,83	28.88	***	0.52	25.8	
C/altitude	E	3.27	− 0.00196	1,83	83.39	***	− 0.71	50.1	
H'/population size	L	2.66	0.4134	1,83	10.93	**	0.34	11.6	
H'/no. of houses	M	1.87	0.096	1,83	26.31	***	0.49	24.1	
H'/altitude	L	4.21	− 0.00309	1,83	92.07	***	− 0.72	52.6	
Settlements total:									
S/population size	M	237.70	0.197	1,95	581.67	***	0.93	86.0	
S/altitude	E	6.51	− 0.0024	1,95	54.18	***	− 0.60	36.3	
C/population size	M	13.46	0.161	1,122	130.44	***	0.72	51.7	
C/altitude	E	3.66	− 0.0026	1,122	114.96	***	− 0.70	48.5	
C/S	L	5.43	0.044	1,56	80.95	***	0.76	59.1	

cies in cities was not significantly correlated with any other measured city character. It did tend to increase with the mean annual temperature; this relationship, however, was not significant ($r = 0.24$, $P < 0.101$, $n = 56$).

In villages, a linear increase of species number with both the number of inhabitants and the number of houses was found. The correlation was, however, weaker than was the case with cities (Table 1). Mean species numbers in villages did not differ among particular climax types. The following values were recorded (means ± S.E. are

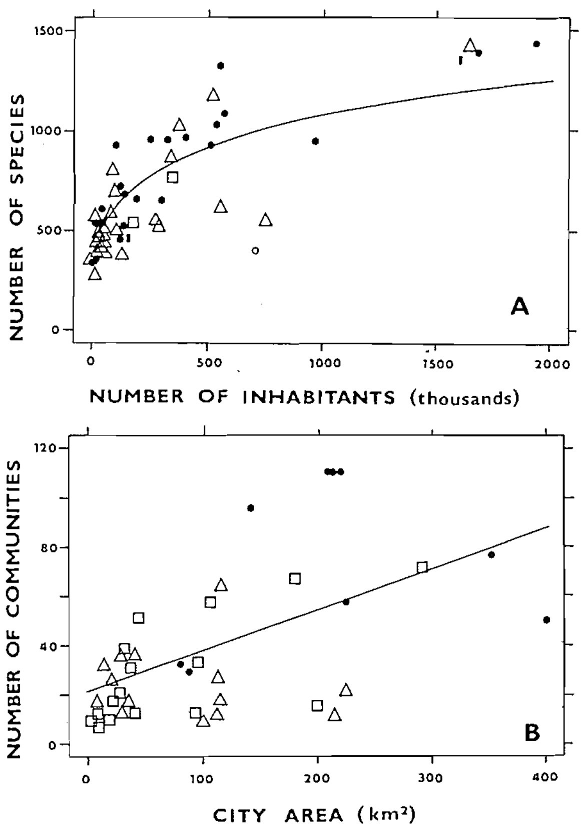

Fig. 2. Relation of floristic and vegetation diversity to the city size. German (●), Polish (△), Czechoslovak (□) and other (■) cities are distinguished using different symbols. (A) Species number plotted against the number of inhabitants. Interactive outlier regression was applied to fit the curve; the outlier (Amsterdam) is marked with empty circle. $Y = 199.475X^{0.220}$, $r = 0.83$, $P < 0.0001$. The following cities were included: Berlin, 1432 species (Sukopp *et al.* 1981; Kowarik 1990), Warszawa 1416 (Sudnik-Wójcikowska 1988), Hamburg 1387 (Mang 1981 cited by Kowarik 1985), Wien 1348 (Forstner & Hübl 1971), Leipzig 1319 (Gutte 1990), Wrocław 1177 (Krawiecowa & Rostański 1976), Stuttgart 1080 (Kreh 1951 cited by Kowarik 1985), Duisburg 1036 (Düll & Kutzelnigg 1980), Gdańsk 1030 (Schwarz 1967), Wuppertal 965 (Stieglitz 1987), Braunschweig 947 (Brandes 1987), Halle 946 (Klotz 1984), Köln 938 (Kunick 1983), Dessau 925 (Voigt 1980, 1982), Hannover 914 (Haeupler 1976), Szczecin 871 (Ćwikliński 1970), Opole 802 (Michalak 1970), Brno 764 (Grüll 1979), Göttingen 732 (Garve 1985), Tarnów 694 (Kucharczyk & Święs 1988), Paderborn 684 (Sukopp *et al.* 1979), Osnabrück 657 (Overdieck & Scheitenberger 1988), Mannheim 648 (Nährig *et al.* 1988), Poznań 605 (Zukowski 1971), Saarlouis 603 (Maas 1983 cited by Klotz 1990), Sanok 579 (Kucharczyk & Święs 1988), Legnica 575 (Anioł-Kwiatkowska 1974), Koszalin 550 (Ćwikliński 1971), Łodz 547 (Sowa 1964), Euskirchen 537 (Zimmermann-Pawlowsky 1985), Herzogenaurach 531 (Meister 1980 cited by Kowarik 1985), Plzeň 530 (Pyšek & Pyšek 1988), Bremerhaven 518 (Kunick 1979 cited by Kowarik 1985), Lublin 510 (Fijałkowski 1967), Zielona Góra 507 (Ćwikliński 1971), Bełchatow 506 (Sowa & Warcholińska 1980), Sieradz 498 (Sowa & Warcholińska 1984), Jarosław 496 (Kucharczyk & Święs 1988), Krosno 486 (Kucharczyk & Święs 1988), Lubin 468 (Anioł-Kwiatkowska 1974), Pyrzyce 466 (Szmajda 1974), Bruxelles 458 (Holland 1976), Würzburg 454 (Hetzel & Ullman 1981 cited by Kowarik 1985), Tarnobrzeg 432 (Kucharczyk & Święs 1988), Jasło 430 (Kucharczyk & Święs 1988), Zduńska Wola 418 (Sowa & Warcholińska 1984), Gorlice 413 (Kucharczyk & Święs 1988), Chełm 404 (Fijałkowski 1963), Amsterdam 390 (Bolman 1976), Rzeszów 388 (Kucharczyk & Święs 1988), Rabka 383 (Skowrońska 1965), Stalowa Wola 383 (Kucharczyk & Swięs 1988), Schmalkalden 356 (Klotz 1990), Ballenstedt 344 (Klotz 1990), Polkowice 287 (Anioł-Kwiatkowska 1974); (B) Number of communities plotted against the city area. $Y = 18.937 + 0.171X$, $r = 0.57$, $P < 0.001$. Düsseldorf 110 communities, Essen 110, Münster 110 (Gödde 1986), Leipzig 95 (Goldberg & Gutte 1988), München 76 (Springer 1985), Praha 71 (Kopecký 1980–84, 1986, 1990), Bratislava 67 (Jarolímek 1985), Poznań 64 (Ratyńska & Szwed 1988), Hannover 57 (Tüllmann & Böttcher 1983), Olomouc 57 (Tlusták 1990), Przemyśl 51 (Święs & Witkowska-Wawer 1988), Köln 50 (Bornkamm 1974), Dęblin 38 (Święs 1986), Legnica 36 (Anioł-Kwiatkowska 1974), Lublin 35 (Fijałkowski 1967), Plzeň 32 (Pyšek 1978), Regensburg 32 (Frost 1985), Lubin 31 (Anioł-Kwiatkowska 1974), Jaroslaw 31 (Święs & Piórecki 1988), Würzburg 29 (Hetzel & Ullman 1981 cited by Kowarik 1985), Bydgoszcz 27 (Kępczyński 1975), Tarnobrzeg 25 (Święs & Kucharczyk 1982), Wrocław 21 (Rostański & Gutte 1971), Chomutov 20 (Pyšek 1975), Chełm 18 (Fijałkowski 1963), Toruń 17 (Fabierkiewicz 1971, Kępczyński & Zienkiewicz 1974), Polkowice 17 (Anioł-Kwiatkowska 1974), Sanok 17 (Święs 1985), Brno 15 (Grüll 1981), Bielsko-Biała 13 (Zając 1974), Most 13 (A.Pyšek & S. Hejný, unpubl. data), Gorzów 12 (Misiewicz 1971), Košice 12 (Krippelová 1981), Łódź 11 (Sowa 1964, 1971), Sušice 11 (Pyšek 1972), Slupsk 10 (Kępczyńska 1974), Malacky 9 (Krippelová 1972), Liptovský Mikulás 9 (Hilbert 1981), Bechyně 8 (Hadač 1982).

given): 197.2 ± 25.3 (beech forests – *Fagion, Luzulo-Fagion*), 180.6 ± 10.3 (hornbeam forests – *Carpinion betuli*), 194.0 ± 11.2 (oak forests – *Quercion robori-petraeae, Pino-Quercetum*), and 187.3 ± 11.2 (elder stands – *Alno-Padion, Ulmion*).

Plotting of the whole data set on a logarithmic scale (Fig. 3A) makes it possible to compare the rate of increase in species number with settlement size between villages and cities. The higher value of the slope b for cities indicates the more rapid increase. However, the difference between the slopes is not significant ($F_{1,91} = 0.95$) because of the great variance within the data sets.

When all settlements are analysed together, there is an exponential decrease in the species number with altitude (Fig. 4A), a relationship which is not apparent when each settlement type is treated separately.

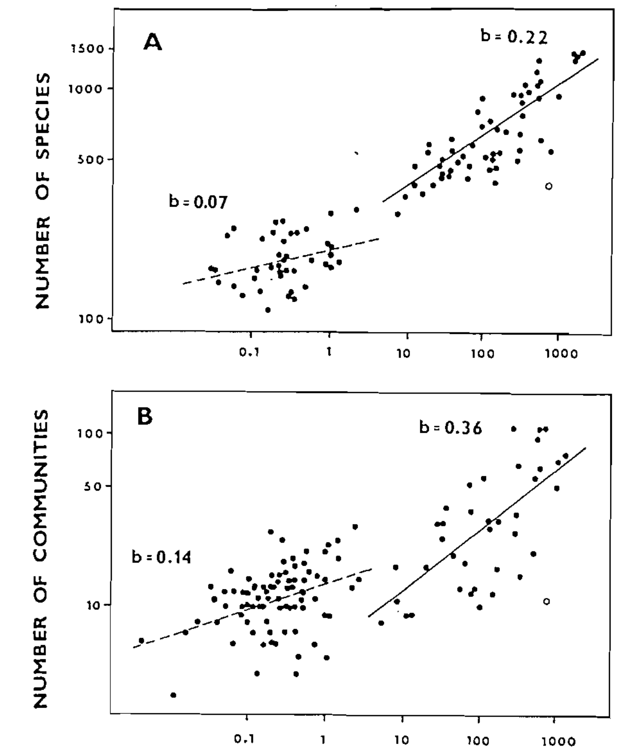

Fig. 3. Logarithmic plotting of floristic (A) and vegetation (B) diversity against the number of inhabitants in both villages and cities ($\log_e$ was used). The regression lines are plotted separately for villages (dotted) and cities (full lines). Slopes are indicated for comparison. (A) Number of species in villages is fitted by the equation LOG Y = 5.2917 + 0.0718 LOG X, r = 0.40, P < 0.01, in cities LOG Y = 5.2956 + 0.220 LOG X, r = 0.83, P < 0.0001 (interactive outlier regression, deleted point is marked with empty circle). The regression fi tted to the whole data set is LOG Y = 5.471 + 0.197 LOG X, r = 0.93, P < 0.0001. (B) For the number of communities in the villages the regression is LOG Y = 2.598 + 0.1357 LOG X, r = 0.39, P < 0.001, in the cities LOG Y = 1.6301 + 0.367 LOG X, r = 0.70, P < 0.0001 (interactive outlier regression, one point deleted); The whole data set is fitted by the equation LOG Y = 2.613 + 0.161 LOG X, r = 0.72, P < 0.0001. P < 0.001.

Vegetation diversity

The number of communities in cities increased markedly both with the population size and city area (Fig. 2B, Table 1). Both the multiplicative and linear models provided similar, highly significant fit to the data. A weaker correlation was recorded between the number of communities and population density (Table 1). Furthermore, significant increase with the mean annual temperature (P < 0.001, Fig.4D) and decrease with altitude (P < 0.05, Table 1) in the number of communities were found.

The number of communities and the vegetation diversity H′ increased with the village size (Table 1). Moreover, there was an exponential decrease in the number of communities and a linear decrease in the value of H′ with altitude (Fig.4C). The vegetation diversity of a village, however expressed, was closely related to the respective climax type (Table 2), being most in the region of hornbeam forests *(Carpinion betuli)* and least in the villages located within the beech area *(Fagion, Luzulo-Fagion)*.

The increase in the number of communities with the settlement size in cities was steeper than that found in villages (Fig.3B). The slopes of regression lines were, however, not significantly different ($F_{1,118} = 2.25$, P < 0.25). The whole data set showed a strong negative correlation between the number of communities and altitude (Fig.4B, Table 1). Regressions between the diversity of flora and vegetation and other variables analysed —

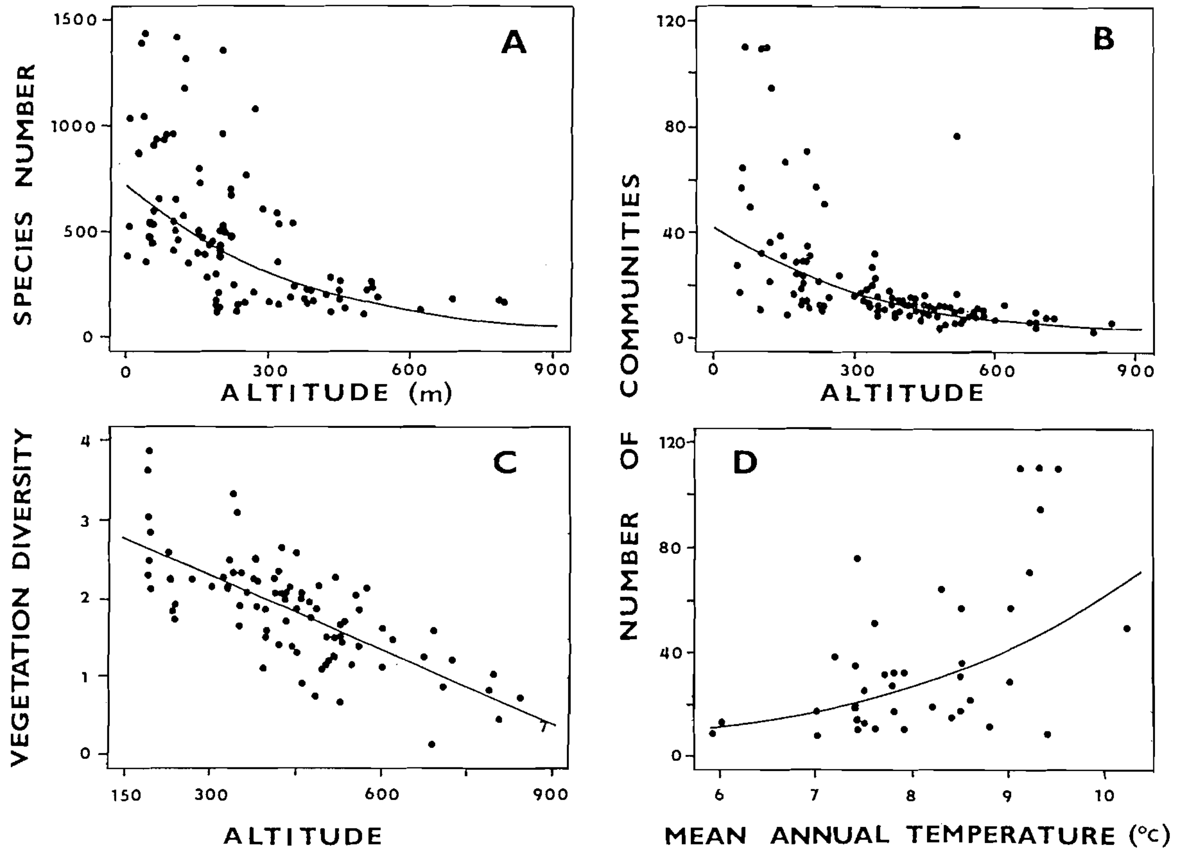

Fig. 4. Relation of floristic and vegetation diversity in settlements to environmental characteristics. (A) Number of species plotted against settlement altitude. Y = exp(6.505 − 0.002387X), r = −0.60, P < 0.0001. (B) Number of communities related to the settlement altitude. Y = exp(3.657 − 0.00263X), r = −0.70, P < 0.0001. The regression calculated separately for cities is Y = exp(3.710 − 0.00195X), r = −0.32, P < 0.05 and for villages Y = exp(3.269 − 0.00196X), r = −0.71, P < 0.0001. (C) Vegetation diversity in villages expressed by Shannon index H′ plotted against altitude. Y = 4.212 − 0.00309X, r = −0.72, P < 0.0001. (D) Number of communities in the city related to its mean annual temperature. Y = exp(−0.2799 + 0.4426X), r = 0.56, P < 0.001.

precipitation, Lang's rain factor (Lang 1920), longitude and latitude -- did not reveal any significant relationships.

Relative importance of the settlement size and climatic factors

The factors used to characterize the settlements included in analyses were in some cases mutually correlated. There were highly significant correlations within the both main groups of factors, the first group being related to the settlement size and the other one to the climatic conditions. Significant correlations between the number of inhabitants and city area (r = 0.91, P < 0.0001) and between the mean annual temperature and altitude (r = −0.41, P < 0.0001) were confirmed. Moreover, there is a highly significant relationship (P < 0.0001) between the city size and its altitude (r = −0.53 for the number of inhabitants, and r = −0.41 when the city area is taken into account) indicating that the bigger cities are located mainly in lowlands. This is also reflected by the correlation between city size and the mean annual temperature (r = 0.42, P < 0.01 for the population size, r = 0.29, P < 0.05 for the city area), a relationship which is, moreover, emphasized by the 'urban heat island'-effect (Sukopp & Werner 1983).

Table 2. Differences in the number of communities S (bottom left) and vegetation diversity H' (top right) between villages located in the areas belonging to different climax types (beech forests -- *Luzulo-Fagion, Fagion*, oak forests -- *Quercion robori-petraeae, Pino-Quercetum*, hornbeam forests -- *Carpinion betuli*, elder stands -- *Alno-Padion, Ulmion*). The values of Kruskall-Wallis statistics are given. ** P<0.01, *** P<0.001, NS - non-significant. For species numbers and Shannon indices H' the mean values and S.E. are given. Numbers of villages located in the respective regions are presented in the diagonal.

	Mean H'	2.17 ± 0.12	2.86 ± 0.08	3.29 ± 0.10	2.83 ± 0.11	
Mean S		Beech	Oak	Hornbeam	Elder	
7.85 ± 0.61	beech	14	14.40***	19.78***	10.98***	
11.69 ± 0.62	oak	11.93***	49	7.55**	NS	vegetation
15.93 ± 1.23	hornbeam	18.96***	10.96***	16	7.79**	diversity H'
11.48 ± 0.80	elder	7.37**	NS	9.94**	37	
			number of communities			

To separate the factors related to size and climate from each other and assess their relative effect on the diversity of flora and vegetation in both settlement types, the partial correlation method was used. This revealed that the settlement size may be considered as the decisive factor on which the species number depended. Its importance is greater in cities than in village settlements. Climatic factors played a more important part in affecting the number of communities. This was particularly conspicuous in villages where the climate could be considered to be the main determinant of vegetation diversity (Table 3).

Discussion

The relation between the number of plant species and the settlement size is described by the power function equation (Table 1) that is generally considered to provide the best fit to the relation between species number and area (Williamson 1981). In villages and small cities, there was a linear increase in the number of species with size reflecting a rapid increase in the heterogeneity of habitats. Furthermore, it is supported by transport and trade activities that enhance the probability of immigration of new species (Sukopp *et al.* 1979; Sukopp & Werner 1983; Pyšek 1989a;

Table 3. Relative dependence of the floristic (bottom left) and vegetation (top right) diversity on the settlement size and climate. Partial correlation coefficients were used to measure the relationships between variables. Diversity was expressed in terms of numbers of species and communities. Number of inhabitants was used to express the settlement size. Mean annual temperature (in cities) and altitude (in villages) were used as climatic variables. n = sample size.

	Number	Size	Climate	
A. Cities				
number	x	0.45	0.42	
size	0.77	x	0.15	communities
climate	0.17	0.05	x	(n = 39)
		species (n = 56)		
B. Villages				
number	x	0.27	- 0.64	
size	0.42	x	- 0.01	communities
climate	0.14	- 0.20	x	(n = 85)
		species (n = 41)		

Kowarik 1990). The levelling of maximum species number at approximately 1500 in the biggest cities (West Berlin, Warszawa, Wien, Hamburg) corresponds to the total number of 2061 species recorded in 9 large European cities (Kunick 1982). The pool of species potentially contributing to the richness of urban flora is clearly limited by climatic conditions which determine not only the richness of the local native flora but also the number of neophytes capable of establishing in the area.

The pattern of increase in the species number is the same when either the number of inhabitants or the city area is taken into account (Klotz 1990). The former character may be considered as a measure of intensity of the anthropogeneous impact with resulting variety of habitats, whereas the latter is related rather to the space available to vegetation. The less obvious relationship between the species number and the population density is not surprising since the density of human inhabitants is positively correlated with the city size (partial correlation coefficient $r = 0.54$) but negatively with its area ($r = -0.50$).

Human settlements scattered in the agricultural landscape represent, with respect to their surroundings, areas of different habitat quality. They may be described as landscape islands (in the sense of Van der Maarel 1988). This type of 'islandness' in European cities is supported by the slope of the species-area graph ($b = 0.22$, Table 1) being steeper than usually found in arbitrarily defined areas of mainland ($b = 0.10$–0.16, see in Begon *et al.* 1986: Table 20.1) and corresponding rather to the values typical of habitat islands ($b > 0.17$). Several authors point out that species richness of habitat islands may not always be explained in terms of the theory of island biography (McArthur & Wilson 1967) alone. Species number is also a function of habitat diversity (Begon *et al.* 1986; Van der Maarel 1988; Dzwonko & Loster 1988). On the basis of the settlement data it is difficult to decide whether the observed pattern of increase in species number is the result of environmental heterogeneity or an area per se (Begon *et al.* 1986). Although some classifications of urban habitats were proposed (e.g. Hejný 1971), the vast majority of data sources do not contain any quantitative assessment of the habitat heterogeneity within the city studied. Nevertheless, it is assumed that the effect of habitat heterogeneity in cities is principally involved in increasing the species richness (Sukopp & Werner 1983; Pyšek 1992a). The species number in isolated woodlands, which represent similar islands within the agricultural landscape, is a function of not only area but also of habitat diversity and the degree of isolation (Dzwonko & Loster 1988). However, the spatial isolation in the agricultural landscape does not equally affect all the species. The dispersal of some species between urban areas is limited which may contribute to a degree of isolation. This is the case especially with rarely occurring ephemerals and aliens not capable of successful naturalization outside the city boundaries. These species, however, occur presumably in the larger cities and they contribute substantially to extensions of floristic lists. Similarly, the rare species among flora of isolated woodlands tend to occur in large patches (Dzwonko & Loster 1989; Zacharias & Brandes 1990).

The principles similar to those concerned in flora richness may be expected to hold when the number of communities is taken into account. Vegetation diversity within cities should not increase indefinitely with city size. However, the deceleration of its increase is less obvious than that seen in the species number data (Fig. 2B). This is partially due to the fact that the number of communities is a measure even more liable to be affected by the subjectivity of an author's approach than is the number of species (Pyšek 1992b). Klimeš (1989) compared numbers of ruderal communities reported from various regions of Europe and found the correlation on the border of significance between the number of communities and size of the investigated area. His analysis, however, included areas of different habitat quality (i.e. settlements vs. open landscape) which were therefore not directly comparable. In the present paper, consideration of urban areas alone yielded a highly significant correlation between the number of communities and the city area.

Low data reliability appears to be the main problem linked with analyses like those presented in this paper. Number of species reported to occur in a given city may be strongly affected by the investigator's approach (see Pyšek 1989a for a detailed discussion). It may depend on (1) the sampling method (which species groups are included, Sukopp & Weiler 1988; Klotz 1990), (2) delimitation of the study area (especially whether the marginal zones are concerned, see Haeupler 1974; Sukopp & Werner 1983; Brandes & Zacharias 1990), and (3) the research duration (Pyšek 1992b). However, it is difficult to apply any screening procedures to the data since there is often no information on the sampling method used by the original author. The low precision of data is a general problem in studying relationships at the landscape level. Variation in sampling may be reduced by including only cities investigated by similar methods, i.e. within the frame of a particular research school (Pyšek 1989a). However, it is convenient to consider the continental scale when trying to reveal the relationships between flora and vegetation and climatic variables. In the present paper, all data available were thus included in analyses and their great inherent variance was reduced by deleting the outliers (Table 1) although taken into account when drawing the conclusions. The number of cities analysed was thus much higher (n = 77) than those used in previous studies on the relationship between floristic richness and city size (n = 21 in Pyšek 1989a, n = 13 in Brandes & Zacharias 1990, n = 13 in Klotz 1990).

Vegetation diversity, i.e. the number of communities, is more affected by the climate of a given region than is the number of species. In the central European ruderal phytosociology, communities are mostly distinguished according to the dominant species (Pyšek 1991). The number of communities reported may thus be, roughly speaking, considered closely related to the number of ruderal species capable of successful establishment and forming the stands. The occurrence of a species may be rather accidental and an ephemeral event and chance may play a more important role in determining the final number of species on the list. On the other hand, it may be assumed that only those species for which the climate of the given area is favourable are able to form stands. It appears that despite the greater 'sampling error' involved in compiling the list of communities, their number is a better indicator of environmental conditions than simply the number of species.

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