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Distribution pattern of flora and vegetation in a small industrial town: an effect of urban zones

Vliv urbanizace na rozšíření flóry a vegetace na území malého průmyslového města

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Flora and vegetation of a small industrial town (Horažďovice, Czech Republic) was analysed with respect to its spatial distribution in particular urban zones (historical town centre, industrial zone, periphery). Ellenberg indicator values were used to express the relationship of flora and vegetation to soil nitrogen, moisture, reaction and light. Flora of particular zones did not differ with respect to nitrogen and moisture. The town centre harboured more species tolerant to shade and drought. No differences in the distribution of life forms, life strategies and origin (i.e. native/alien status) were found between particular zones. It is concluded that the response of the flora to the inner town-periphery gradient of human impact in the area under study is less obvious than in large urban agglomerations. The comparison of vegetation revealed that the occurrence of particular community types is differentiated with respect to the urban zones. The communities were arranged along gradients of ecological conditions, among which the soil nitrogen appears to be most responsible for vegetation differentiation. During the last 24 years, the proportion of thermophilous species decreased and that of acidophilous species increased, a trend which appears to be related to retreat of calcium rich sites harbouring seminatural vegetation (mostly due to building activities and changes in land use management). Proportion of archaeophytes decreased during that period, presumably as a consequence of changes in life style and land use management having occurred in the last decades.

Introduction

Flora and vegetation in urban environment is governed by a specific set of factors among which those imposed by man are the crucial ones (Kunick 1974, Sukopp et Werner 1983, Gilbert 1989, Kowarik 1990, 1991). The effects of these factors are remarkably heterogeneous and differ in particular parts of a settlement. Large urban agglomerations and medium-sized cities usually posses clear spatial structure stemmimg from historical and economical aspects and reflecting the life style of their inhabitants (Sukopp et Werner 1983, Wittig, Diesing et Gödde 1985, Sudnik-Wójcikowska 1988, Kowarik 1990, Pyšek 1993a). Several classifications dividing cities into particular urban zones have been proposed (Hejný 1971, Klotz 1986, Schulte et al. 1986, Sukopp et al. 1986, Blume et al. 1987) and relationships of flora and vegetation to these zones have been repeatedly investigated (e.g. Kunick 1974, Pyšek 1978, Klotz 1987, Goldberg et Gutte 1988, Tlusták 1990, Chojnacki 1991). So far, most of the effort devoted to urban ecological studies was focused upon large cities and detailed studies of smaller towns are not that frequent.

A possible explanation for such disproportion may be that the impact of man in large urban agglomerations is undoubtedly very strong so that the pattern reflected in spatial distribution of flora and vegetation is more conspicuous and easier to determine than in the case of smaller towns (Pyšek et Mandák 1993). Hence the question raised by the present study is whether the spatial distribution of flora and vegetation in a small industrial town obeys the same rules as those reported from large urban agglomerations.

Man impact acting in urban environment can be envisaged through (a) direct effects on vegetation (disturbance, stress, dispersal of diaspores etc.), and (b) indirect effects mediated through changes in ecological conditions of a site (soil conditions, availability of light). The former group includes factors that are difficult or even impossible to quantify (Kowarik 1990, 1991, Pyšek 1993a). In the present study, the effects of the ecological conditions of the site were assessed by means of indicator values to reveal the differences between particular urban zones. Furthermore, the current state of the flora is compared with that more than twenty years ago and this comparison is used for assessment of temporal changes in the quality of urban environment.

Study site

The study was carried out in the town of Horaždovice (West Bohemia, Czech Republic) which is located along the Otava river at an altitude of 420-486 m (427 m on average). The area belongs to a mild climatic district with mean temperature 7.8°C and mean annual amount of precipitation 518.6 mm (Horažďovice meteorological station, 50-years average;

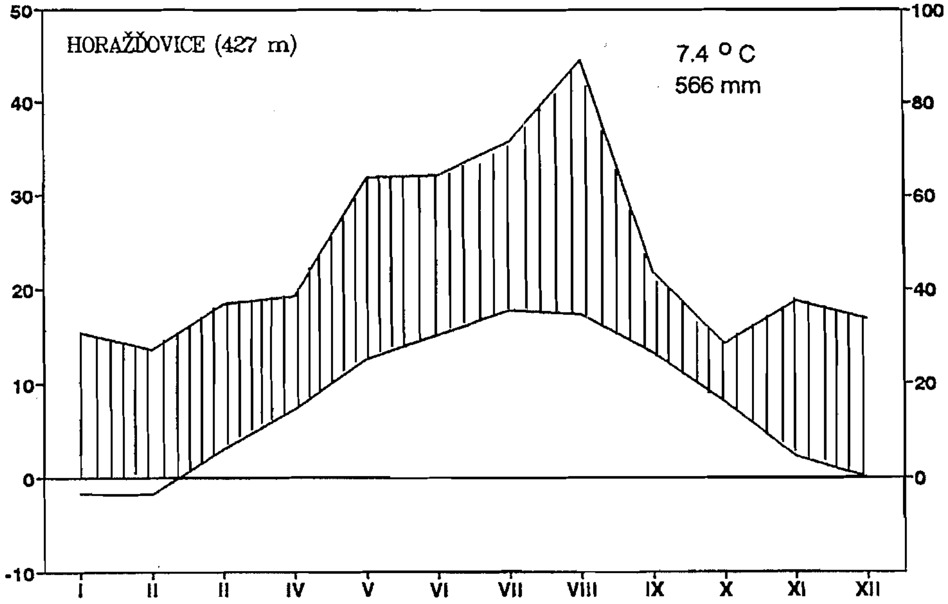

Fig. 1. - Climate diagram (after Walter 1984). Means from 1982-1992 are shown.

see Fig. 1 for the course of weather in the last decade). The town territory was originally covered by *Alno-Padion* and *Quercion robori-petraeae* forests (Mikyška et al. 1972). The geological substrate is formed mostly by gneiss, soils are brown or of alluvial origin. The town is surrounded by relatively undisturbed environment with both acidic and calcareous geological substrates. The Otava river is connecting the town with higher altitudes of the Šumava Mountains.

At present, the town has 5820 inhabitants of which 54.9 % are employed in industry and 12.4 % work in agriculture. Out of 1007 houses currently inhabited, 78.5 % are family houses, 13.4 % are being used seasonally for recreational purposes and 8.0 % represent blocks of flats and prefab buildings.

Three main zones (further termed as urban zones) were distinguished at the territory of the town: (a) historical centre with old houses densely located, providing only a limited space for spontaneously occurring vegetation, (b) the zone in which the industrial activity is concentrated, with factories, more or less loosely located buildings and temporarily not managed areas in which the spontaneous succession of vegetation is allowed to run, and (c) town periphery with less disturbed banks of the Otava river, railway and its facilities, and open spaces in contact with surrounding seminatural vegetation.

Methods

The field research was carried out by the first author in 1991-92. A complete list of vascular plant species spontaneously occurring at the territory of the town studied was made. Further, separate species lists were compiled for each urban zone. The floristic lists obtained were analysed with respect to species life forms, life strategies, origin and their response to principle ecological factors.

Data on species life form (according to the Raunkiaer's scheme, see e.g. Mueller-Dombois et Ellenberg 1974), life strategies (following the Grime's scheme, see Grime 1979) were extracted from Grime, Hodgson et Hunt 1988, Frank et Klotz 1990 and Ellenberg et al. 1991. Native/alien status of a species (with archaeophytes and neophytes distinguished in the latter category, see e.g. Holub et Jirásek 1967) was classified using various sources (Frank et Klotz 1990, Opravil 1980). Ellenberg indicator values (Ellenberg et al. 1991) were used to express the relationship of the flora to basic ecological factors (further termed like that). The following factors were included: light (tabulated value was available for 94.0 % of species present in the flora of Horažďovice), temperature (71.4 %), moisture (88.7 %), soil reaction (62.9 %) and nitrogen (83.7 %).

The floristic lists obtained for particular zones were compared with respect to the above plant traits. Furthermore, the present state was compared with that recorded in the past (Vaněček 1969) using the same criteria.

Vegetation was sampled by means of the relevé method using the 7-grade Braun-Blanquet scale (Mueller-Dombois et Ellenberg 1974). The sampling plots were selected in order to cover a whole range of repeatedly occurring stands. In total, 146 relevés were made. Some community types were impossible to classify as an association or a unit of the corresponding level due to their high heterogeneity and a number of irregularly repeated dominants. These were grouped according to habitats; their floristic composition is given in Table 1 but they were excluded from further analyses. The community types were distinguished on the basis of dominant species and overall species composition. As the focus in this study was not upon the vegetation classification, standard classification procedure was applied and most community types were attributed to the associations of the contemporary phytosociological system using that published by Hejný et al. (1979) and Kopecký et Hejný (1992). The communities which were impossible to be identified with any previously described association are named according to their dominant species. An alternative classification using the so-called deductive method (Kopecký et Hejný 1978) is also provided (Table 2).

Ecological demands of the community types distinguished were quantified using Ellenberg indicator values (Ellenberg et al.1991). Mean value was calculated for each relevé. Species quantities were expressed as their values in the Braun-Blanquet scale after transformation to 1-7 numerical scale and taken into account in calculation.

Area covered by each community type was estimated in the field according to Pyšek et Pyšek (1987). The area which was surveyed in detail within each urbanization zone was estimated from the map. That part of this area, which was available to vegetation, was then calculated by excluding the land covered with buildings and main roads.

Nomenclature of species follows Neuhäuslová et Kolbek (1982), that of phytosociological units was taken from Hejný et al. (1979) and Kopecký et Hejný (1992).

Results

Overview of flora and vegetation

In total, 399 spontaneously occurring species were found at the town territory. Native species contributed 73.9% to the total species number, the corresponding figure being 12.5% for archeophytes and 12.3% for neophytes. Hemicryptophytes (51.9%) and therophytes (32.1%) were most common among the life forms (Table 1).

Twenty community types classified as associations or units of the corresponding level were found in the area studied (Table 2). The floristic composition of particular communities is summarized in Table 3 (for the complete relevé material see Mandák 1993). The communities recorded may be roughly divided into 3 groups according to the factors conditioning their occurrence (Table 2): (a) Those encouraged by various types of

Table 1. - Composition of the flora of Horažďovice. Number of species is given. See Table 5 for total numbers of species in each urban zone.

	Total	Inner town	Industrial zone	Periphery
Archaeophytes	50	26	47	32
Neophytes	49	15	45	21
Native	295	107	270	228
Other origin	5	2	4	3
Therophytes	128	55	119	81
Geophytes	20	4	14	16
Hemicryptophytes	209	82	196	152
Chamaephytes	10	5	10	6
Phanerophytes	32	4	27	27

Table 2. - Main human-induced factors and their effects on the occurrence of particular community types. The area (m^2) covered by a given community type with respect to particular urban zones is also given: IT - inner town, IZ - industrial zone, PER - periphery, TOT - total. The factors considered as conditioning the occurrence and/or persistence of particular communities are marked with asterisks. TRAM - trampling, DIST - disturbances, SPONT - spontaneous development allowed for a longer period of time, ANIM - effect of animals, BUILD - building activity. Higher classification units follow in brackets after the community name: AEG - *Aegopodion podagrariae*, AG - *Agropyretalia repentis*, AGR - *Agropyretea repentis*, AR - *Arrhenatherion elatioris*, ARC - *Arction lappae*, ART - *Artemisietea vulgaris*, CA - *Convolvulo-Agropyrion*, CCHEN - *Convolvulo-Chenopodiea*, DM - *Dauco-Melilotion*, GA - *Galio-Alliarion*, GU - *Galio-Urticetea*, CHEN - *Chenopodietea*, CHG - *Chenopodion glauci*, LCH - *Lamio albi-Chenopodietalia boni-henrici*, MA - *Molinio-Arrhenatheretea*, MAL - *Malvion neglectae*, ON - *Onopordetalia acanthii*, PAV - *Polygonion avicularis* Br.-Bl. 1931, PLA - *Plantaginetalia majoris* Tx. et Preising in Tx. 1950, PLANT - *Plantaginetea majoris*, S - *Sisymbrion officinalis*, SIS - *Sisymbrietalia*. n.e. - area covered was not estimated.

	Area covered (m^2)				Main human-induced factors				
Community (higher units)	IT	IZ	PER	TOT	TRAM	DIST	SPONT	ANIM	BUILD
Chenopodietum albi-viridis[1] (S,SIS,CHEN)		65		65		*			*
Atriplicetum nitentis (S,SIS,CHEN)		130		130		*			*
Chenopodietum glauco-rubri (CHG,SIS,CHEN)		75		75		*			
Malvetum neglectae (MAL,SIS,CHEN)		8		8		*		*	
Melilotetum albae-officinalis[2] (DM,ON,ART)		43		43		*			
Erigeronto-Lactucetum (S,SIS,CHEN)		15		15		*			*
Tanaceto-Artemisietum vulgaris (ARC,LCH,GU)		40	12	52			*		
Balloto-Chenopodietum boni-henrici (ARC,LCH,GU)		40		40		*		*	
Lappo-Ballotetum nigrae[3] (ARC,LCH,GU)	5	63		68					
Alliario officinalis-Chaerophylletum temuli (GA,LCH,GU)	30			30			*		
Agropyro repentis-Aegopodietum podagrariae[5] (AEG,LCH,GU)	65	165	23	253			*		
Chaerophylletum aurei[5] (AEG,LCH,GU)		5	45	50			*		
Agropyretum repentis[6] (CA,AG,AGR)		25	65	95			*		
com. *Calamagrostis epigeios*[7] (CCHEN)		30	40	70			*		
com. *Arrhenatherum elatius*[8] (AR,MA)			n.e.				*		
Polygonetum avicularis[9] (PAV,PLA,PLANT)	45	190	15	250	*	*			
Plantagini-Poetum compressae[10] (PAV,PLA,PLANT)	13		13		*				
Lolio-Plantaginetum majoris[11] (PAV,PLA,PLANT)	85	220	20	325	*				
Sagino-Bryetum (PAV,PLA,PLANT)	5	2		7	*				
Stellario-Alnetum glutinosae			75	75			*		
Total	240	1129	295	1664					

Alternative classification using the deductive method (Kopecký et Hejný 1978):[1] bc. *Chenopodium album* - [*Chenopodietea/Secalinetea*],[2] bc. *Melilotus alba-officinalis* - [*Dauco-Melilotion*],[3] bc. *Arctium-Ballota nigra* - [*Arction lappae*],[4] bc. *Urtica dioica-Aegopodium podagraria* - [*Galio-Urticetea*],[5] dc. *Chaerophyllum aureum* - [*Lamio albi-Chenopodietalia boni-henrici*],[6] dc. *Agropyron repens* - [*Convolvulo-Chenopodiea*],[7] dc. *Calamagrostis epigejos* - [*Convolvulo-Chenopodiea*],[8] bc. *Arrhenatherum elatius* - [*Arrhenatheretalia*],[9] bc. *Polygonum arenastrum* - [*Polygonion avicularis*],[10] dc. *Poa compressa* - [*Plantaginetalia majoris*],[11] dc. *Lolium perenne* - [*Plantaginetalia majoris*]. bc. - basal community, dc. - derivate community (in the sense of Kopecký et Hejný 1978, 1992).

Table 3. - Species composition of particular communities. Chav - *Chenopodietum albi-viridis*, An - *Atriplicetum nitentis*, Chgr - *Chenopodietum glauco-rubri*, Mn - *Malvetum neglectae*, Mao - *Melilotetum albae-officinalis*, EL - *Erigeronto-Lactucetum*, TA - *Tanaceto-Artemisietum vulgaris*, BCh - *Balloto-Chenopodietum boni-henrici*, LB - *Lappo-Ballotetum nigrae*, ACh - *Alliario officinalis-Chaerophylletum temuli*, AA - *Agropyro repentis-Aegopodietum podagrariae*, Chau - *Charophylletum aurei*, Ar - *Agropyretum repentis*, Cep - com. *Calamagrostis epigeios*, Ae - com. *Arrhenatherum elatius*, LPm - *Lolio-Plantaginetum majoris*, PPc - *Plantagini-Poetum compressae*, Pav - *Polygonetum avicularis*, SB - *Sagino-Bryetum*, SA - *Stellario-Alnetum glutinosae*. Vegetation types which were difficult to classify are shown in the last columns: RAIL - vegetation of railway areas, DIST - vegetation of permanently disturbed sites in building areas, MARG - road margins. Number of communities in which the species was recorded, i.e. the criterion according to which the species are arranged, is displayed in the last column. The constancy class (V - species present in 81-100% of relevés, IV - 61-80%, III - 41-60%, II - 21-40%, I - 1-20%) and range of dominance in Braun-Blanquet 7-grade scale are given. In those communities, for which less than five relevés were made, the number of occurrences is given instead of constancy class. Species occurring in less than 3 community types are listed below the Table, unless representing a dominant species of some of the communities.

Species	Chav	An	Chgr	Mn	Mao	EL	TA	BCh	LB	ACh	AA	Chau	Ar	Cep	Ae	LPm	PPc	Pav	SB	SA	RAIL	DIST	MARG	N
Number of relevés	5	5	6	4	5	3	5	2	6	5	10	5	8	5	14	15	5	15	3	5	6	5	4	
Artemisia vulgaris	IVr+	IIr+	I+		Vr3		V+5	I1	V+1	IIr1		IVr+	IVr+	IIIr+	IVr+	Ir	IV+2	Ir			IVr2	IVr+	IIr2	18
Dactylis glomerata	Ir				Vr+		IIIr1		I+	I+	IIIr+	III+1	IIr1	I+	IIIr	Ir1	I1			I+	IIr		I1	17
Taraxacum s. *Ruderalia*	IIr	Ir	IIr		IVr+	IIr+	Ir			IIr+	IIr+		IIr		I1	IVr2	IVr1	IIr	IIIr1		IVr2	IIr+	Ir	17
Poa annua	IIr+		V+1	Ir		IIr+		I1	Ir	IVr	IIr2				I+	V+3	IIIr	IIIr+	III2	Ir	IIr	IVr+		16
Urtica dioica	IVr+	Ir		I+			V+1	I2	Vr2	Vr1	V+2	IVr	IIIr+	Ir	IIIr		II+			IVr3				14
Elytrigia repens	Ir	IIr	IIr				IVr2	I2		I+	V13	IV+2	V15	IIr	IVr2		Vr2	Ir						13
Matricaria maritima	V+1	V+1	Vr1	I+		III+2			Ir				Ir		IIr1	Ir	II+	IIr1			I+	V+3		13
Lolium perenne			IIIr1	Ir		I+	Ir		II+1	Ir	IIr1					V14	V+	IIr1	Ir		III1			12
Polygonum arenastrum		Ir	IIIr1	IIIr+		Ir		Ir	IIIr	I1	Ir					IIr+		V25	IIIr2			IIr		12
Heracleum sphondylium		Ir			IIr		IIIr				IIr+	IVr+		IIr	Vr2	Ir				Ir	IIr+		I+	11
Plantago major	I+		IVr+	Ir		Ir				IVr1	IIr+					V+2	Vr1	Vr1	III+1			Ir		11
Arrhenatherum elatius					Vr1		I1		Ir		IIr+	V1	IIIr1	Ir	V25						I+		II+2	10
Trifolium repens	I+		Ir			Ir	I+				IIr1					IIIr1	II+1	Ir+				IIIr+		10
Cirsium arvense		I+			II+1		IIIr2		I2		Ir	IVr+	IVr+	II+1	IVr2									9
Conyza canadensis						III13								Ir		Ir	Ir	IIr+	I+		IV+3	IIIr2	Ir	9
Lapsana communis	IIr	Ir							Ir	Vr1	IIr							Ir		IIr		I+	Ir	9
Chenopodium album	V34	III12	IVr1			II+1			IIr+								Ir	IIr				Vr2		8
Sonchus oleraceus	I+					IIr+					Ir	Ir					IIr+	Ir			IIr1	IIIr1		8
Anthriscus sylvestris					I1			II+	IIr		IVr2	IIIr			IIIr3	Ir+								7
Atriplex patula	V+2	V+2	IIr+					I1	IIr+		Ir													7
Chamomilla suaveolens			IIr+	I+												IIIr1	Ir	IVr1	IIIr+			Ir		7
Convolvulus arvensis	Ir							Ir				Ir	IV13	IIr	IIIr1						Ir			7
Crepis biennis		Ir			IVr+	Ir							Ir		Ir						I2		IIr+	7
Daucus carota		I+			IVr1				Ir						Ir					Ir	Ir		Ir	7
Medicago lupulina		Ir	Ir		I+											Ir					Ir	I+	Ir	7
Poa pratensis					I+		II+2		Ir					Ir	IIIr+			Ir					IIr2	7
Poa trivialis					IIr+		II+			I1	IIr+	Ir	Ir		Ir+									7
Potentilla reptans							Ir		Ir				Ir		Ir	Ir					I1		I2	7
Aegopodium podagraria		Ir							I1	I1	V25	II+								IV+1				6
Galeopsis tetrahit	I1	I+			Ir		Ir	I1							Ir									6
Galium aparine	IIIr+	III+1									IVr2	Ir			IIIr1					Ir1				6
Lamium album	IIr+							IIr+	IIIr1		IIIr+		IIr		I+									6
Plantago lanceolata				Ir											I+	Ir		Ir+			I+	Ir		6
Rubus fruticosus agg.											Ir		Ir		IIIr2					Ir	IIIr	III+2		6
Rumex obtusifolius		Ir	IIr						Ir	II+1	I1											IIIr1		6
Achillea millefolium					II+1		Ir								IIr	Ir							I+	5
Agrostis stolonifera						I+							Ir				Ir				I+	IIr+		5
Apera spica-venti		Ir												IIr	Ir			Ir						5
Capsella bursa-pastoris		I12	IIr															IIr1	IIr			IIIr+		5
Chaerophyllum aureum											Ir	V35			Ir+					I+		Ir		5
Descurainia sophia	II+1	Ir		Ir					IIr												Ir			5
Equisetum arvense					III12							I+		IIr	IIr+						V2			5
Impatiens parviflora								Ir	I+		IIIr1									IIIr1		IVr1		5
Lactuca serriola	IIr	III+1				III+3											I+					II1		5
Sisymbrium officinale		Ir		Ir				Ir	IIr	IIIr+														5
Torilis japonica							IIr1		Ir				Ir				Ir						II+	5
Amaranthus retroflexus		I1	Ir																		I+	II+1		4
Chenopodium polyspermum	IIIr+		Ir							Ir												IIIr2		4
Cirsium oleraceum		Ir									Ir	Ir			Ir									4
Galium album							III+					I+			IVr3							IIr		4

Species	Chav	An	Chgr	Mn	Mao	EL	TA	BCh	LB	ACh	AA	Chou	Ar	Cep	Ae	LPm	PPc	Pav	SB	SA	RAIL	DIST	MARG	N
Number of relevés	5	5	6	4	5	3	5	2	6	5	10	5	8	5	14	15	5	15	3	5	6	5	4	
Galium verum												I+	IIr+	IIIr+	IVr2									4
Glechoma hederacea							Ir	IIr1			IIr									I1				4
Hypericum perforatum					II+					I+				I+							Ir			4
Lepidium ruderale				I+	I+													IIr3	Ir					4
Malva neglecta		Ir		IV14					Ir									Ir						4
Papaver rhoeas	IIr+									IIr					Ir							IIr		4
Poa compressa					IIr1											I+	V23				IIr			4
Polygonum amphibium		I+	Ir						Ir													IIr		4
Potentilla anserina			I1	I+			Ir				I+													4
Senecio viscosus	I+																Ir				IIIr3	IIr+		4
Vicia cracca					I+									Ir	IIr+						I+			4
Arctium tomentosum			Ir	IIr+					IV+1															3
Atriplex nitens	IIIr+	V25																I+						3
Ballota nigra								II24	V13		I+													3
Calamagrostis epigejos												I1		V5			I1							3
Carduus acanthoides													Ir								Ir		I+	3
Cerastium holosteoides					Ir										Ir		Ir							3
Chelidonium majus	I+							I+		II+2														3
Epilobium ciliatum		Ir								I+											IIr2			3
Festuca gigantea									Ir		IIr1									I1				3
Galinsoga parviflora									Ir		Ir+											Ir		3
Geranium pusillum	Ir			IV13				Ir																3
Lamium purpureum		Ir																				IIr	Ir	3
Linaria vulgaris					IIr2									IIr							Ir			3
Lotus corniculatus					I+										Ir						I+			3
Melilotus alba					Vr3											Ir							Ir	3
Polygonum nodosum		I+	Ir																		Ir			3
Rubus caesius					I1					I1				II+1										3
Scrophularia nodosa							I+													Ir		IIr+		3
Silene vulgaris			Ir		Ir																I+			3
Stellaria nemorum							Ir				I+									V13				3
Stellaria media		IIr1									IIIr1									I+				3
Tanacetum vulgare							IV34															IIr	Ir	3
Sagina procumbens																		Ir	III34					2
Alliaria petiolata										V13														1
Chaerophyllum temulum										V24														1
Chenopodium glaucum			V+2																					1
Chenopodium rubrum			V+2																					1
Echium vulgare					V12																			1
Melilotus officinalis					IV+3																			1

Species occurring in less than three community types:
Agrostis capillaris Chau-Ir; *Allium sativum* MARG-Ir; *Alnus glutinosa* SA-Vr+; *A. incana* SA-IIr; *Alopecurus pratensis* TA-Ir, Ae-IIr+; *Anagallis arvensis* Chgr-Ir; *Anchusa officinalis* Ae-Ir; *Angelica sylvestris* TA-Ir; *Anthoxanthum odoratum* Ae-Ir; *Anthemis cotula* Mn-IIIr+; *Arctium minus* BCh-IIr1; *Atriplex prostrata* Chgr-I2; *Bromus hordeaceus* subsp. *hordeaceus* TA-Ir; *Campanula patula* Ae-Ir, RAIL-Ir; *C. rapunculoides* Ae-Ir1; *Centaurea jacea* Ae-Ir; *Cerastium arvense* An-Ir; *Chamerion angustifolium* Ar-I+; *Chaenorrhinum minus* Mao-I+, RAIL-Ir; *Chaerophyllum aromaticum* LB-II+1; *Chenopodium bonus-henricus* BCh-II+1; *Ch. ficifolium* Chgr-IIr; *Ch. hybridum* An-IIIr2; *Ch. strictum* Chgr-I+; *Ch. suecicum* An-IIr; *Cichorium intybus* Mao-I2; *Cirsium vulgare* AA-Ir; *Coronilla varia* Ae-I+2; *Cuscuta europaea* Ae-Ir; *Cymbalaria muralis* ACh-IIIr+; *Echinochloa crus-galli* RAIL-III+1, DIST-Ir; *Epilobium hirsutum* TA-Ir, ACh-Ir; *E. montanum* ACh-Ir; *Erysimum marschallianum* An-Ir, Mao-Ir; *Fallopia convolvulus* An-Ir; *Festuca pratensis* Ee-I+; *F. rubra* AA-Ir+; *Filipendula ulmaria* SA-Ir; *Galeopsis bifida* AA-Ir; *Galium* x *pomeranicum* Ae-Ir; *Galinsoga ciliata* AA-I+; *Geranium columbinum* MARG-Ir; *G. robertianum* SA-Ir; *Geum urbanum* AA-IVr+; *Impatiens noli-tangere* SA-IVr1; *Knautia arvensis* Ae-IIr; *Lamium maculatum* SA-IVr+; *Leontodon autumnalis* Ae-Ir; *Leonurus cardiaca* LB-IV14; *Leucanthemum ircutianum* RAIL-Ir; *Medicago sativa* Mao-I+, RAIL-Ir; *Melandrium album* An-Ir, Ae-Ir; *Mentha longifolia* TA-I+; *Myosoton aquaticum* AA-Ir; *Padus avium* SA-Ir; *Phalaris arundinacea* SA-II1; *Ph. canariensis* AA-Ir; *Pimpinela saxifraga* RAIL-Ir; *Plantago media* Ae-I+; *Poa nemoralis* LB-Ir; *P. palustris* Chgr-I+, TA-II+; *Polygonum brittingeri* Chgr-I1; *P. hydropiper* Chgr-Ir; *P. persicaria* Chgr-IIIr; *Ranunculus acris* Ae-Ir; *R. repens* EL-Ir, AA-IIr+; *Reseda lutea* Mao-II+, RAIL-II12; *Roegneria canina* SA-II+1; *Rorippa palustris* An-Ir; *R. palustris* Chgr-IIIr+; *Rumex acetosa* Ar-Ir; *R. acetosella* Mao-Ir; *R. crispus* Ae-Ir; *Senecio vulgaris* Chav-IIr+; *Setaria viridis* Pav-Ir; *Solidago canadensis* Mao-Ir; *Stachys sylvatica* SA-IIIr1; *Stellaria graminea* TA-I+; *Symphytum officinale* AA-Ir; *Symphoricarpos rivularis* AA-Ir; *Thlaspi arvense* Chgr-Ir; *Trifolium dubium* Chgr-I+, Pav-Ir; *T. hybridum* Mao-Ir; *T. pratense* Ae-I2; *Triticum aestivum* TA-Ir; *Turritis glabra* RAIL-Ir; *Urtica urens* Mn-IVr1; *Verbascum densiflorum* Mao-Ir; *V. nigrum* TA-Ir; *Veronica persica* An-Ir; *Vicia hirsuta* DIST-IIr+, MARG-Ir; *Viola arvensis* Mao-II+1, AA-Ir.

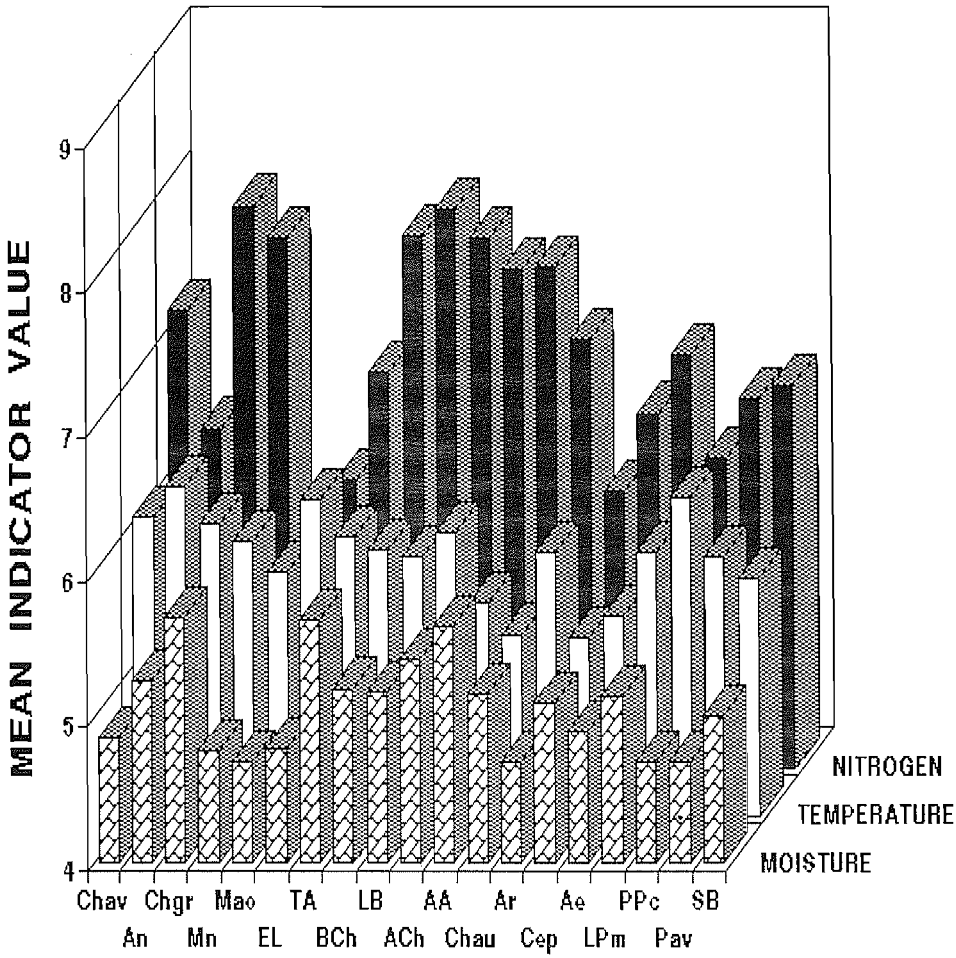

Fig. 2. - Mean indicator values for nitrogen, temperature and moisture as obtained for particular community types. See Table 2 for community codes.

disturbance, among which the building activity may be considered the most important; *Atriplicetum nitentis* (contributing 8.2% to the total area covered by vegetation in the area studied) and *Chenopodietum viridis* (4.1%) were the most frequent community types within this group. (b) Communities allowed for undisturbed, at least several-years lasting development; in this group, *Agropyro-Aegopodietum* (15.9%), *Agropyretum repentis* (6.0%) and the community dominated by *Calamagrostis epigeios* (4.4%) were most common. (c) Vegetation of trampled sites, with *Lolio-Plantaginetum majoris* (20.4%) and *Polygonetum avicularis* (15.7%) being the most important components.

Table 4. - Ecological requirements of particular community types. The relationship to particular factors was expressed using mean Ellenberg indicator value for a given community (see Methods for details). Number of relevés is shown for each community type (n).

Community	n	Light	Temperature	Moisture	Reaction	Nitrogen
Chenopodietum albi-viridis	5	7.24	6.08	4.87	7.03	7.18
Atriplicetum nitentis	5	7.69	6.28	5.27	6.89	6.36
Chenopodietum glauco-rubri	6	7.51	6.03	5.71	7.00	7.90
Malvetum neglectae	4	7.50	5.91	4.78	7.10	7.68
Melilotetum albae-officinalis	5	7.68	5.70	4.70	7.35	5.12
Erigeronto-Lactucetum	3	8.27	6.19	4.79	6.99	6.01
Tanaceto-Artemisietum	5	7.08	5.94	5.69	7.31	6.75
Balloto-Chenopodietum	2	7.73	5.84	5.21	7.00	7.69
Lappo-Ballotetum	6	7.41	5.79	5.19	7.31	7.88
Alliario-Chaerophylletum	5	5.85	5.97	5.42	7.09	7.68
Agropyro-Aegopodietum	10	6.25	5.47	5.65	6.72	7.46
Chaerophylletum aurei	5	6.81	5.26	5.17	7.79	7.48
Agropyretum repentis	8	7.16	5.83	4.70	6.97	6.98
com. *Calamagrostis epigeios*	5	6.98	5.24	5.11	6.99	5.93
com. *Arrhenatherum elatius*	14	7.25	5.41	4.92	6.87	6.48
Lolio-Plantaginetum majoris	15	7.61	5.83	5.16	6.87	6.87
Plantagini-Poetum compressae	5	7.95	6.21	4.70	8.00	6.15
Polygonetum avicularis	15	7.61	5.79	4.70	6.97	6.56
Sagino-Bryetum	3	7.29	5.65	5.03	7.00	6.65
Mean±S.D.[1]	126	7.29±0.59	5.76±0.11	5.08±0.43	7.05±0.37	6.86±0.76
Coefficient of variation (%)[2]	19	7.90	1.37	6.66	4.48	11.30

[1] The mean indicator value calculated on the basis of all relevés.
[2] Calculated as between-community coefficient of variation.

Table 5. - Relationships between diversity of flora and vegetation and spatial characteristics of particular urban zones..

	Area surveyed (ha)	Area available to vegetation (ha)	%	Species number	Species number/ available area	Number of communities	Community number/ available area
Inner city	26.2	10.3	39.3	150	14.5	7	0.67
Industrial zone	158.4	121.5	76.7	366	3.0	16	0.13
Periphery	110.7	94.4	85.3	284	3.0	8	0.08

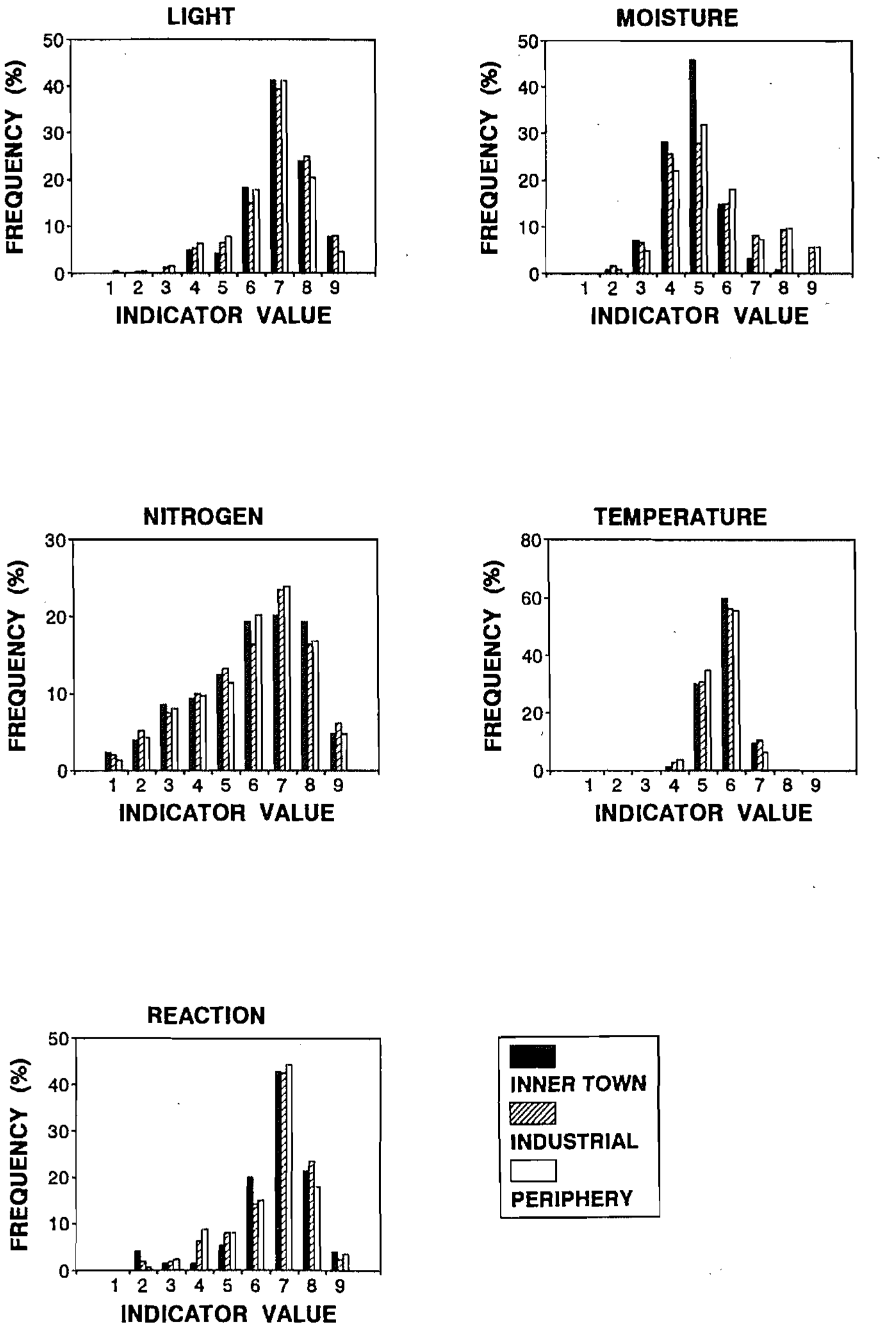

Fig. 3. - Frequency distribution of indicator values of the flora in particular urban zones. All species present in a given zone for which the values were available (see Table 6 for n) are included.

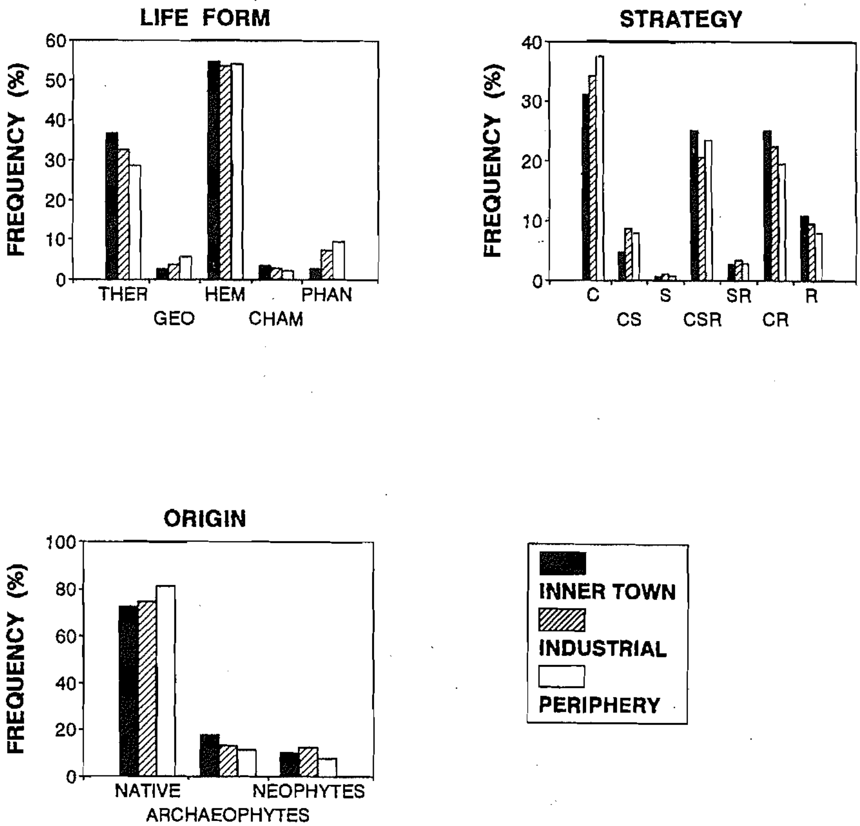

Fig. 4. - Frequency distribution of flora characteristics in particular urban zones. THER - therophytes, HEM - hemicryptophytes, GEO - geophytes, CHAM - chamaephytes, PHAN - phanerophytes. Life strategies according to Grime (1979). No significant differences between zones were found using chi^2 test.

Ecological requirements of particular community types

The relationship of particular community types to basic ecological factors (expressed as the mean relevé indicator value for a given community) is summarized in Table 4. A higher variation in the data set expressed as the between-community coefficient of variation was found for nitrogen, light and moisture; on the other hand, it was lower for soil reaction and especially the temperature, indicating the more important role of the former factors in differentiation of vegetation within the study area (Table 4).

There was a considerable overlap in mean indicator value between communities and only a low number of those occurring on both sites of the respective gradients differed remarkably from most of the others (Table 4). Nevertheless, some general conclusions emerge if the higher units of the phytosociological system rather than those of the association level are taken into account (Fig. 2):

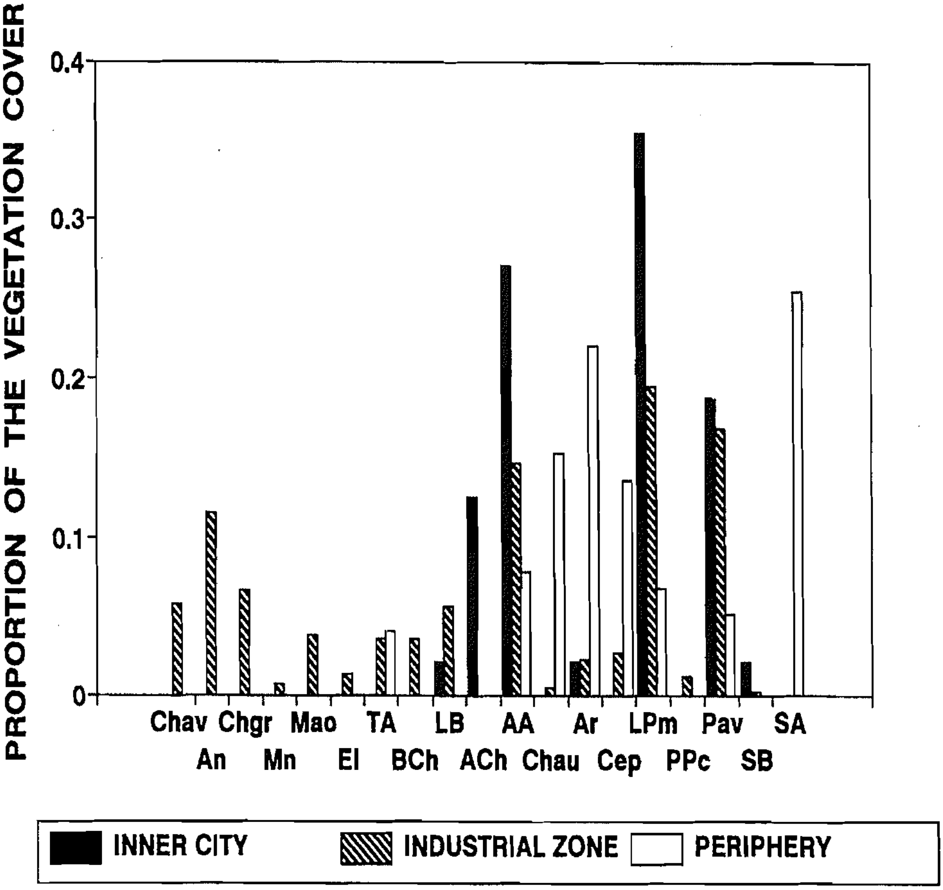

Fig. 5. - Contribution of particular community types to the vegetation cover of particular urban zones. See Table 2 for community codes.

1. Communities of the class *Galio-Urticetea* tend to occur in nitrogen rich, moist and shaded sites.
2. Communities of annuals (belonging mostly to *Chenopodietea* class) prefer nutrient rich, warmer sites and harbour a high number of heliophilous species.
3. *Artemisietea* communities appear to be confined to nutrient poor to moderately rich, drier habitats.
4. Trampled communities (*Plantanginetea majoris*) may be considered as typical of moderately nutrient-rich, rather drier soils; heliophilous species play an important part in this vegetation type.

Table 6. - Ecological requirements of flora compared between urbanization zones. Ellenberg indicator values were used to express the relationship to basic ecological factors. Mean indicator value, calculated for all species occurring in the given zone for which the data were tabulated (n), is given. Means ± S.D. are given. Means that were not significantly different in pairwise comparisons (Kruskal-Wallis test) are followed by the same letter rowwise.

Factor	Inner city	n	Industrial zone	n	Periphery	n
Light	6.97±1.15a	143	6.91±1.30a	346	6.67±1.34b	70
Temperature	5.77±0.62a	97	5.74±0.67a	261	5.64±0.65a	94
Moisture	4.79±0.97a	129	5.44±1.73b	324	5.53±1.62b	252
Reaction	6.69±1.43a	75	6.63±1.39a	226	6.55±1.37a	174
Nitrogen	5.89±1.96a	129	5.89±1.98a	311	5.93±1.88a	238

Table 7. - Changes in ecological requirements of flora during the last 25 years. Ellenberg indicator values were used to express the relationship to basic ecological factors. Mean indicator value was calculated for species that have disappeared from the flora of Horažďovice in that period (i.e. those occurring only in 1969 data set, n=53) and for those that have arrived (i.e. present only in 1993, n=54). Means ± S.D. are given. The significance of difference between means (Kruskal-Wallis test) is given in the last column. * P<0.05, NS - non-significant.

Factor	1969	1993	
Light	7.08±1.33	7.17±1.01	NS
Temperature	6.27±0.89	5.85±0.90	*
Moisture	4.71±1.88	5.06±1.46	NS
Reaction	7.25±1.21	6.68±1.31	*
Nitrogen	5.18±2.00	5.49±2.12	NS

Effect of urban zones on the distribution of flora and vegetation

Concerning the number of species recorded, the industrial zone (366 species) was richest among those considered, followed by the periphery (284) and the inner town (150) (Table 5).

When particular urbanization zones were compared, their indicator values (calculated as a mean for all species present in a given zone for which the value was available) for nitrogen, soil reaction and temperature did not differ. Significant differences in relationship of the flora to basic ecological factors were only found for light and moisture (Table 6). Higher shade tolerance of species growing in inner town and industrial zone compared to those occurring at the periphery was recorded. Similarly, there were more species with low moisture indicator value among those found in the inner town (Fig. 3).

The urbanization zones did not differ in the proportion of particular life forms, life strategies and categories of the flora origin status (Fig. 4).

Seven community types were recognized in the inner town, the corresponding figure for industrial zone and periphery being 16 and 8, respectively.

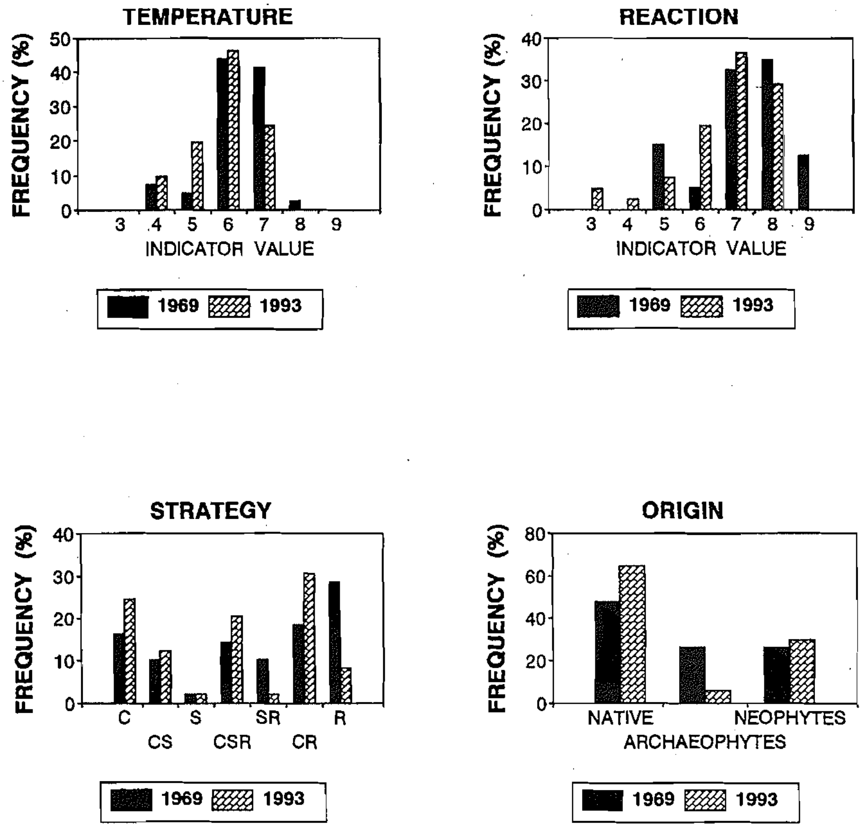

Fig. 6. - Changes in the frequency distribution of flora characteristics between 1969 and 1993. Those species that were occurring at the town territory only in the respective year were included (n=53 for 1969, and 54 for 1993, respectively). See Table 7 for testing the differences in temperature and reaction. Life strategies: chi^2=23.91, d.f. 1,6, P<0.001. Origin: chi^2=15.22, d.f. 1,2, P<0.001.

Different composition of vegetation cover in particular zones may be envisaged from Table 2 and Fig. 5. In the town centre, trampled communities prevail; however, the presence of locally occurring undisturbed sites is reflected by the occurrence of some *Galio-Urticetea* communities. Vegetation of later successional stages (i.e. that for which non-disturbed sites are necessary to allow spontaneous development) represents the most important components of the vegetation cover at the periphery. Communities of disturbed sites occur only in the industrial zone which, however, represents the zone harbouring the highest number of communities among which the late successional and those of trampled sites also contribute considerably to the vegetation cover of this zone. The seminatural community *Stellario-Alnetum glutinosae*, occurs exclusively in the peripheral zone (Fig. 5).

The percentage of area available to vegetation within each urbanization zone was increasing from the town centre to the periphery (Table 5). The ratios number of species (communities)/area available were highest in the inner town and decreased considerably in both the industrial and peripheral zones (Table 5).

Changes in composition of the flora over a quarter of the century

Total number of species in the flora of Horažďovice almost did not change since 1969 (397 compared to 399 in 1992). However, the floristic similarity between both lists is 88% (Sörensen index, see e.g. Mueller-Dombois et Ellenberg 1974) indicating that 12% of species has exchanged during this period. In 1969, there were 53 species[1] occurring at the town territory that were not recorded in the present study. On the contrary, 54 species[2] found in 1991-92 are absent from the 1969 species list.

Having compared these two species sets, we found significantly higher mean indicator values for temperature and reaction in 1969 (Table 7). Furthermore, both lists differed significantly in distribution of life strategies, the most conspicuous change being an increase in the contribution of C- and CR-strategists on the debt of the species possessing R- and RS-strategies (Fig. 6). A remarkable decrease in the proportion of archaeophytes which have been replaced by native species lead to the significant difference in the distribution of species in particular origin categories (Fig. 6). No principal changes in the distribution of life forms occurred between 1969 and 1993.

Discussion

Changes in the composition of flora on the inner city-outskirts gradient have been repeatedly reported and an increase in the occurrence of aliens and decrease in the proportion of therophytes is generally accepted (Kunick 1974, Sukopp, Blume et Kunick 1979, Sukopp et Werner 1983, Kowarik 1985, 1988, 1990, Pyšek et Pyšek 1991). In the present study, the flora of particular zones did not differ in this respect. Moreover, only small differences were found in ecological demands of the flora between particular zones, the most remarkable being the one indicating drier environment in the town centre than in the other zones (Sukopp et Werner 1983, Pyšek et Pyšek 1991). In a similar vein, neither the trampling nor the level of disturbance, i.e. the factors directly acting on vegetation, were found to be related to the zone of urbanization in another study from the territory of Horažďovice (Pyšek et Mandák 1993). Hence a conclusion

[1] *Alyssum alyssoides, Amaranthus albus, Anthemis austriaca, A. tinctoria, Barbarea stricta, Bromus arvensis, Bromus commutatus, Bromus secalinus, Carduus personata, Carex flacca* subsp. *flacca, Chenopodium urbicum, Chenopodium vulvaria, Chondrilla juncea, Conringia orientalis, Consolida regalis, Datura stramonium, Eragrostis minor, Escholtzia douglasii, Galeopsis speciosa, Hordeum murinum, Iberis umbellata, Inula britannica, Kohlrauschia prolifera, Leersia oryzoides, Linaria arvensis, Linum usitatissimum, Lychnis coronaria, Malope trifida, Misopates orontium, Neslia paniculata, Nigella arvensis, Ononis repens, Papaver argemone, Petasites albus, Phacelia tanacetifolia, Polemonium coeruleum, Polycnemum majus, Potentilla intermedia, Primula elatior, Ranunculus frieseanus, Rorippa austriaca, Rumex conglomeratus, Salix triandra, Saponaria ocymoides, Sedum spurium, Silene dichotoma, S. noctiflora, Sisymbrium volgense, Thalictrum aquilegiifolium, Tragopogon dubius, Turgenia latifolia, Veronica longifolium, Xanthoxalis fontana.*

[2] *Aconitum variegatum* subsp. *variegatum, Alchemilla micans, Alchemilla monticola, Alchemilla xanthochlora, Aquilegia vulgaris, Atriplex prostrata* subsp. *latifolia, Bidens frondosa, Bromus inermis, Campanula persicifolia, Campanula trachelium, Cardaminopsis halleri, Carduus crispus, Carduus nutans, Centaurea rhenana, Cerastium arvense, Chaerophyllum bulbosum, Chamerion angustifolium, Chenopodium ficifolium, Chenopodium opulifolium, Chenopodium pedunculare, Chenopodium pumilio, Chenopodium strictum, Chenopodium suecicum, Clinopodium vulgare, Cruciata laevipes, Digitaria sanguinalis, Epilobium ciliatum, Epilobium montanum, Erigeron acris* subsp. *acris, Festuca gigantea, Festuca rupicola, Fragaria viridis, Galanthus nivalis, Galeopsis pubescens, Geranium columbinum, Heracleum mantegazzianum, Hieracium sabaudum, Hypericum maculatum, Impatiens glandulifera, Juncus inflexus, Lathyrus nissolia, Lepidium virginicum, Leucanthemum ircutianum, Lycopsis arvensis, Malva sylvestris, Mentha x piperita, Myosotis nemorosa, Myosotis stricta, Nepeta cataria, Oenothera fallax, Phalaris canariensis, Phleum phleoides, Polygonum brittingeri, Turritis glabra.*

may be drawn that the generally accepted pattern of the spatial distribution of flora is not as pronounced in a small town as in large cities. Nevertheless, the distribution of particular community types with respect to urban zones distinguished in the study area essentially confirms the results reported from various kinds of urban environment (Kunick 1974, Pyšek 1978, Goldberg et Gutte 1988, Chojnacki 1991, Pyšek et Pyšek 1991) and corresponds to our knowledge of the autecology of particular dominant species.

The lower number of both species and communities in the inner town also corresponds to literary data (Kunick 1974, Sudnik-Wójcikowska 1987, Pyšek et Pyšek 1988, Kowarik 1990). This pattern is usually being explained by higher habitat diversity in peripheral areas which reflects more variable human impact creating more heterogeneous environment. However, the area available to vegetation is another important factor which should be taken into account when analysing the spatial pattern of species and vegetation (in terms of phytosociological units) diversity. In the town under study, this area is remarkably restricted in the inner town zone. When the diversity of flora and vegetation is related to the area available, it appears that more species and communities are concentrated per unit area in the town centre than in both industrial and peripheral zones. This finding reflects that (a) the vegetation in both latter zones is provided with more space which makes it possible to form large stands; consequently, the diversity assessed at smaller scale may be supposed to be lower than that in the historical centre where the vegetation is more fragmented and rather a small scale spatial pattern may be expected to occur. (b) The diversity expressed in absolute terms (i.e. the total number of species or communities in a given zone) is, to a large extent, a function of the area available (Pyšek 1993b).

The community types found at the territory under study are arranged according to the gradients of ecological conditions and their position reflects the demands of dominant species for a given factor (see e.g. Tüllman et Böttcher 1983, Pyšek 1992). Soil nitrogen appears to form a particularly steep gradient. Taking into account that this factor does not differ between particular urban zones and considering the variability of human activities in these zones, one can assume that alternative sources of nitrogen are available in particular parts of the town territory (e.g. deposits, industrial waste, alluvial sources, input from agriculture production and horticulture activities etc.). The differences in relationship to particular factors are more apparent at higher hierarchical levels of the phytosociological system (i.e. alliances) which form more concise and mutually better recognizable units than communities at the association level (Pyšek 1992).

The results yielded by the comparison of the current state of flora with that reported from the past suggest that during the last two decades some thermophilous and basiphilous species disappeared from the flora of Horažďovice, having been replaced by those with lower temperature requirements and more tolerant to acid soils. These trends are opposite to those found for Halle (Klotz 1987); however, it is difficult to compare both sets of data because of different time scale on which the comparisons were made (almost 150 year in the case of Halle compared to 24 years in the present study). As many thermophilous species in the study area are confined to calcium rich soils, their decrease in the course of the last quarter of the century seems to be related to the decrease in number of undisturbed sites harbouring remnants of seminatural calciphilous vegetation (mostly due to building activities and changes in land use management). This result corresponds to the decrease of species typical of soils with a high pH value. However, one must bear in mind that the results may be biased by differences in taxonomical approach between the authors of the compared lists.

Decrease in the proportion of archaeophytes reflects changes in life style and land use management having occurred in the Czech Republic in the last decades (retreat of keeping domestic animals, changes in agricultural technologies, increased effort to keep the town centre clean, use of herbicides etc.) which generally lead to the retreat of traditional weeds (Brandes 1981, Brandes 1983, Pyšek 1993a, Sukopp 1983) among which the archaeophytes represent an important component. However, the economical changes being currently under progress at the territory of the Czech Republic may be expected to act in a direction opposite to that in the past (in terms of coming back, at least in a certain extent, to private farming and traditional land use management). Assessment of forthcoming trends in the development of urban flora and vegetation may thus become a challenge for future research in that kind of environment.

Acknowledgments

Our thanks are due to Jan Lepš for an advice on the statistical analysis.

Souhrn

V příspěvku je analyzováno rozšíření flóry a vegetace na území malého průmyslového města Horažďovic ve vztahu k typům zástavby městského prostředí. Byla rozlišena tři pásma zástavby: historická část města, průmyslová zóna a periférie. Vztah vegetace k faktorům prostředí byl sledován pomocí Ellenbergových indikačních hodnot. Flóra jednotlivých zón se nelišila v zastoupení životních forem, životních strategií ani podle původu (domácí vs. zavlečené druhy). V centru města byl zaznamenán zvýšený výskyt druhů tolerantních vůči suchu a zastínění. Trendy, týkající se složení flóry na gradientu vnitřní město-periférie, uváděné v literatuře pro velká města se zdají být v případě Horažďovic mnohem méně vyhraněné.

Výskyt jednotlivých společenstev je diferencován podle typů zástavby. Společenstva jsou seřazena na gradientu jednotlivých ekologických faktorů, z nichž největší vliv na diferenciaci vegetace má dusík.

Během 24 let se ve flóře Horažďovic zvýšilo zastoupení acidofilních druhů a poklesl podíl druhů teplomilných, což lze dát do souvislosti s mizením stanovišť hostících polopřirozenou vápnomilnou vegetaci (převážně v důsledku stavební činnosti a změn v hospodaření s krajinou). Úbytek archeofytů, k němuž došlo během tohoto období, je způsoben změnami v životním stylu a celkovou urbanizací města.

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