APPROACHES TO STUDYING SPONTANEOUS SETTLEMENT FLORA AND VEGETATION IN CENTRAL EUROPE: A REVIEW

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Abstract

Critical evaluation of methods currently used in the study of spontaneous plant cover in human settlements is presented. Flora and vegetation are discussed from the viewpoint of their (1) recording and description, (2) quantitative assessment, (3) relationships to the environment, and (4) dynamics. Studies on urban vegetation in central Europe are still mostly limited by the traditional phytosociological approach. Research in urban flora is considered to have brought more results of general validity. Further investigations should rely upon new attitudes and ask for general questions. However, reviews and reanalyses of previously published data can also yield results of general validity. Management of urban landscapes can profit considerably from the studies on plant cover. Closer international cooperation is, however, needed since there are still great differences in research efforts, methods and results obtained between central European countries.

1. Introduction: aims and definitions

Flora and vegetation in settlement habitats are recently receiving more attention, especially in central Europe; there is hardly any other region in the world that has been studied so extensively (Sukopp 1972, Bornkamm *et al.*, 1982, Kornaś 1983, Sukopp *et al.*, 1990; see Wittig 1991 for a detailed history of research in cities). This is partially due to their growing importance which is linked with ever increasing synanthropization of vegetation (Sukopp 1969, 1972, Kornaś 1983). The present boom of interest in settlement vegetation has several aspects: (1) It is now known that there is a specific flora and vegetation in cities representing a suitable object to be studied by plant ecologists and geographers. (2) The relationship of the public to spontaneous and cultivated urban flora and vegetation has changed; it is now generally accepted that it is a valuable part of urban environment, an opinion which was not common a few years ago. Moreover, (3) results of such studies are useful for practical purposes such as urban land management (Schulte *et al.*, 1986, Sukopp *et al.*, 1986, Sukopp & Weiler 1988, Rebele 1991).

The term 'urban vegetation' includes all types of both spontaneous and cultivated vegetation occurring in cities (Sukopp & Werner 1983); however, less is known about the latter. The present study thus considers only spontaneous vascular flora and vegetation; for lists of studies on the distribution of planted trees, lichens, mosses and fungi in urban environments see *e.g.*, Sukopp & Werner (1983) and for an updated review of results in this field see Wittig (1991). Areas with a total population exceeding 150,000 and with at least 1000 inhabitants per square km are usually considered urban agglomerations (Sukopp & Werner 1983). The present review is, however, extended to human settlements in general and therefore covers studies on flora and vegetation of small villages as well, since comparisons between settlements of different sizes can yield interesting results (Pyšek & Pyšek 1990, 1991b).

Flora and vegetation are treated separately in the following sections but 'plant cover' is

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used as a general term to include both of them (Kornaś 1983). There is an extensive body of papers on plant cover in human settlements. Only the important references are mentioned in this review, with preference being given to papers which cover certain topics in detail. The list of references is therefore far from complete and more information may be obtained from the studies cited. Instead, this text is focused on critical evaluation of methods currently used in studies on plant cover of human settlements.

2. Recording flora and vegetation

2.1. Floristic lists and species numbers

Compiling floristic lists in human settlements started as long ago as the last century (Scholz 1960, Klotz 1987); the earliest investigations were concerned with introduction of aliens (*e.g.*, Scheuermann 1928, see Wittig 1991). Nowadays, many data are availabe. Pyšek (1993) summarized species numbers reported for 56 central European cities from which 22 were located in Germany and 29 in Poland (for other summarizing studies see Krawiecowa & Rostanski 1976, Kunick 1982, Kowarik 1985, Pyšek 1989a, Klotz 1988, 1990). This list is, however, not considered complete.

The species number reported for a given city may vary considerably, not only due to environmental conditions but also according to the approaches of the respective authors (Pyšek 1989a, Brandes & Zacharias 1990). These can differ in the choice of study area, *i.e.*, whether the fringe area between city and its surroundings is included or not (Haeupler 1974, Sukopp & Werner 1983). A taxonomic approach involved and considering or omitting particular chorological groups may further bias the resulting species number. It appears to be particularly important whether the species escaping from cultivation, garden weeds and ephemerophytes are recorded or not. Moreover, complicated terminology linked with immigration processes (Holub & Jirásek 1967, Schroeder 1969, Sudnik-Wójcikowska & Kozniewska 1988) can sometimes make the comparison of individual lists more difficult. It should be therefore always clearly stated which plant groups were excluded from the list (Sukopp & Weiler 1988). It is also necessary to consider the differences in the area studied; for example the study of Kunick (1974) in which 994 species were reported from Berlin, covered 18 km^2, whereas including the city area of 580 km^2 yielded 1432 species (Kowarik 1990a). The importance of research duration is demonstrated by the following example: investigations over several years on the flora of Warszawa (Sudnik-Wójcikowska 1987, 1988) recorded more than double (1416) the species number of 604 obtained in the 1960's. Some increase in the absolute species numbers reported for the analysed cities might be expected if more thorough and long-term investigations are carried out. However, in those cities where a detailed research has been conducted for a long time, the numbers seem to be near reality and further enrinchment of species lists would be mainly due to ephemeral occurrences of randomly introduced aliens or species escaped from cultivation. One should bear in mind that reported species numbers are usually derived by simply adding the new records to those of previous years, and are thus the cumulative number of species over the research period. This means that the number of species present at a given moment within the territory of the city would be somewhat lower. Nevertheless, these details are not expected to affect the general relationships between flora richness and settlement features.

City size, whether expressed in terms of population or area, is the environmental factor to which species number is most closely related (Klotz 1988, 1990, Pyšek 1989a, 1993, Brandes & Zacharias 1990). Habitat heterogeneity and increased possibilities of immigration of new species are the main causes of flora enrichment (Sukopp *et al.*, 1979a, Sukopp & Werner 1983). Floristic richness of a given surrounding geographical area may also influence the number of urban species (Pyšek 1989a). The species number in European cities shows a log linear increase with the city size and approaches a maximum of about 1500 in cities with 1.5–2 million inhabitants (Pyšek 1989a, 1993, Klotz 1990). A total of 2061 species was recorded by Kunick (1982) in 9 large cities located on a longitudinal gradient. In villages, the effects of climate on species richness are more apparent than in cities (Pyšek 1993).

A higher species number in cities in comparison to the surrounding countryside was first pointed out by Walters (1970). Haeupler (1974), by dividing the countryside (Lower Saxony, Germany) into 5 × 5 km squares, found a higher species number in those squares containing a town. Pyšek (1992b) confirmed this pattern by considering more studies (Wittig & Durwen 1982, Kunick 1983, Kowarik 1985, Brandes 1987, Pyšek & Pyšek 1988a) but concluded that it is necessary to compare the given city with an area of surrounding landscape of approximately the same size. Unfortunately, this condition is not always kept. An alternative method is to document the changes by using transects running from the city centre to the adjacent landscape; it is then not necessary to compare complete cities with adjacent areas of equal size.

Kornaś (1983) pointed out that floristic data have been mostly collected without even the simplest quantitative methods, which he considered especially troublesome in attempts to assess historical changes. It is useful to characterize the occurrence of a species in a given settlement with some quantitative parameter. Mutual comparison of floristic lists containing such data usually provides more precise results and often reveals relationships that would otherwise be overlooked (Bornkamm 1987b, Pyšek & Pyšek 1988b, Kowarik & Seidling 1989).

Frequency, *i.e.*, the percentage of equal squares in which the species was recorded, can be used (Kunick 1974, Sudnik-Wójcikowska 1987); an alternative measure is the proportion of investigated localities in which the species occurred (Pyšek & Pyšek 1988a). When flora in a large number of villages is studied, the percentage of villages in which the species was found is a convenient measure of its commonness or rarity (Wittig 1984, Wittig & Wittig 1986, Pyšek & Pyšek 1988b, 1991b).

2.2. Description of vegetation and its quantitative assessment

Description of vegetation in central Europe is almost exclusively linked with the phytosociological approach (Mueller-Dombois & Ellenberg 1974). There was an extensive discussion on the merits of phytosociology during the last few years (*e.g.*, Feoli 1984, Herben 1986, Wiegleb 1986, Eliáš 1988, Krahulec & Lepš 1989, Moravec 1989, Klimeš 1989, Pyšek 1991). In general, the current opinion is often critical concerning mostly (1) the subjective choice of sampling plots, (2) sometimes untrustworthy or even obscure classification process, (3) the unconvincing concept of 'characteristic' species, (4) the overlooking of lower hierarchical levels and ignoring of underlying mechanisms, (5) the extensive body of special terminology and different understanding of terms (see Herben 1986, Wiegleb 1987, Krahulec & Lepš 1989 for details). This apparent subjectivity together with an insistence on treating phytosociological units as objective biological entities (see *e.g.*, Mucina 1982 cited by Eliáš 1988, Moravec 1989) has resulted in a deep misunderstanding between phytosociology and contemporary vegetation science (Herben 1986, Krahulec & Lepš 1989). The advantages of methods of numerical syntaxonomy (see Mucina & van der Maarel 1989 for review) appear to have been rather overestimated. Despite their usefulness (analysis of large data sets, brief presentation of results, relating vegetation features to the environment) they have failed in solving classification problems (Klimeš 1989).

General classification troubles are even more pronounced in studies of settlement vegetation because of spatial and temporal variability (Klimeš 1989, Pyšek 1991). This vegetation is composed mostly of species with wide ecological amplitudes and develops towards more uniform forms without recognizable characteristics. It is therefore increasingly more difficult to classify (Kopecký & Hejný 1978, Sukopp & Werner 1983). Relations of characteristic species to the units of phytosociological systems are very vague and classification of ruderal communities is mostly based on prevailing (so-called dominant) species (Pyšek 1991). Many vegetation types, even some of the commonest, are simply ignored due to classification problems (Klimeš 1989, Pyšek 1991).

The consequences of these problems are in some cases almost comical: Klimeš (1989) showed that two phytosociological systems covering the same area (southern Slovakia), compiled by different authors (Mucina 1982, Eliáš 1984, 1986) were completely unable to be compared because of each author's subjectivity and strong preference for units of their own creation. Such a decisive influence of a particular author's approach can be further seen in the relation between number of communities[1] recorded which may be expected to increase with the size of the area. However, the correlation found by Klimeš (1989) who plotted data from 30 studies was only at the border of significance. Similarly, Pyšek (1991) pointed to a conspicuous increase in the number of reported communities in both settlements and open landscape habitats during the last decade. There is no meaningful ecological explanation for such a trend and instead the gradual depauperation of settlement vegetation has been reported elsewhere (Brandes 1981, Pyšek 1983, Sukopp 1983, Kornaś 1990). Subjectivity of authors' approaches and resulting different understanding of basic phytosociological units are thus mainly involved; *e.g.*, Wittig (1973) gives 32 communities for Münster, whereas Gödde (1986) having used different classification methods recorded 110 communities in the same city.

Currently, ruderal phytosociology is mostly identified with syntaxonomy and it is frequently understood as being rather a means of classifying communities. This is reflected by the publishing of extensive surveys of phytosociological units (*e.g.*, Eliás 1984, 1986, Mucina & Maglocký 1985, Višňák 1986) without assessment of their ecology and dynamics. Many studies are of a purely descriptive nature and lack any attempt to reveal the relationships between vegetation and its environment. Description of environmental factors is often vague. Nowadays, this holds especially for Czech Republic, Slovakia and Poland. However, examples of phytosociological studies involving a more ecological approach do exist in these countries (*e.g.*, Kopecký 1980-84).

Attempts to cope with classification problems resulted in modifications of classification attitudes, such as the 'synsociological concept' used *e.g.*, by Kienast (1978, 1980), Hüllbusch (1978), Hard (1982) – see Klotz *et al.* (1984) for the list of references. Of these attempts, the so-called deductive method (Kopecký & Hejný 1974, 1978) may be considered the most promising. It has been used quite frequently (see Kopecký 1988 for review) and its strengths were demonstrated especially in the series of papers by Kopecký (1980-84, 1986). The method makes it possible to classify most of the stands found in the field; this is particularly important because those communities which can be considered as associations (*i.e.*, those having their association characteristic species) are diminishing (Pyšek 1992a). It is clearly seen when quantitative data are available: *e.g.*, in the factories of Prague such communities contributed only 10% to the total area covered by vegetation (Pyšek & Pyšek 1988c) and in the villages of the Bohemian Karst the value was 18% (Pyšek 1992a). Furthermore, the deductive method is much more able to record vegetation dynamics as exemplified by description of the gradual spread of native species to man-made habitats (so-called 'apophytization process') (Kopecký 1984b). The method allows the recognition of a large number of units (although this increase is not necessarily linked with its introduction, see Pyšek 1991, Kopecký 1990a), which may lead to the loss of clarity of the phytosociological system.

The final product of phytosociological research of a given area is therefore a survey of communities. This may, however, range from a simple list of units recorded in a single vil-

[1]Understood here as basic hytosociological units recognized by respective author, *e.g.*, associations and units of corresponding level.

lage to the extensive survey critically evaluating vegetation over a large area. The former case is nothing more than 'vegetation floristics' but the latter one is undoubtedly of great value (*e.g.*, Passarge 1964, Gutte 1972, Hejný *et al.*, 1979, Oberdorfer 1983, Kopecký & Hejný 1990). A comprehensive review on phytosociological research in the cities of former eastern Europe, was published by Mucina (1990), and other summarized information regarding this issue may be found in Klotz *et al.* (1984), Sukopp & Köstler (1986), Sowa & Olaczek (1987), Klotz (1987).

Concerning the quantitative assessment of vegetation, the number of communities in a given settlement was shown to be a rather unreliable character. It is less correlated with the city size than is the species number (Pyšek 1993). However, results gathered by the same author or by a group of people using a similar approach are expected to be more comparable. Pyšek (1993) gives numbers of communities for 39 European towns, of which 12 are in Czech and Slovak Republics, 9 in Germany and 18 in Poland, and for 85 Czech villages (Pyšek 1981, Pyšek & Pyšek 1985). Large sets of villages have been studied in Germany as well (Wittig & Wittig 1986, Dechent 1988, Brandes *et al.*, 1990).

To express the occurrence of a community in a given settlement, the same relative measures as for evaluation of individual species can be used (frequency, number of localities). However, phytosociological papers mostly express the quantity by terms such as 'common' or 'rare'. A method of estimating the area covered by an individual community has been thus proposed (Pyšek 1978, Pyšek & Pyšek 1987a). Carrying out this estimation directly in the field, it is possible to obtain quantitative data on the proportional contribution of each community to the total vegetation cover (*e.g.*, Pyšek 1978, Pyšek & Pyšek 1985, 1988c, Pyšek 1992a). Such data allow (1) more precise comparison between areas or settlements of different type and size (Pyšek & Pyšek 1990), (2) recording of vegetation dynamics over time (Pyšek & Pyšek 1987b), (3) calculating of vegetation diversity indices (Pyšek & Pyšek 1987a), and (4) using multivariate analysis in processing data on vegetation cover (Pyšek & Pyšek 1985).

3. Relationships between plant cover and its environment

Specific features of urban environment have been described with respect to climate (Miess 1979), soil (Sukopp *et al.*, 1979a) and in general (Horbert 1978, Laurie 1979, Sukopp *et al.*, 1980, Bornkamm *et al.*, 1982, Gilbert 1989, Wittig 1991, for summarizing of relevance to vegetation see Sukopp & Werner 1983). Ecological conditions of several cities have been described (see Sukopp *et al.*, 1979a for references).

3.1. Species level

Flora of a given area can be analysed with respect to various biological and ecological characteristics; a useful compilation of such traits concerning most species in the central European flora was published by Frank & Klotz (1990). Comparisons between cities (Saarisalo-Taubert 1963, Kunick 1982), between city and open landscape (Wittig & Durwen 1981, 1982, Pyšek 1992b), between cities and villages (Pyšek & Pyšek 1991b) and within a city (Kunick 1974, Sudnik-Wójcikowska 1987, 1988, Pyšek & Pyšek 1988a, Pyšek 1992b) represent a convenient method to analyse the impact of urbanization (Sukopp & Werner 1983).

Data on species origin and time of immigration are frequently used to analyse species lists (for review see Pyšek 1989b, for analysis Kowarik 1985b, 1988, 1990a). We are quite well informed about the invasion of aliens (review on both general principles and examples of case studies see in Kornaś 1983, classification in Holub & Jirásek 1967, Schroeder 1969). A complete species list with information on the time of origin and the degree of naturalization for aliens has been presented for Berlin (Böcker & Kowarik in Kowarik 1991b). A study of Kunick (1991) was focused upon spread of alien species escaping from cultivation.

Sorting out species into the classification categories may however cause difficulties, because we are often not able to distinguis the alien from natives among early man-accompanying plants (Kornas 1983). Moreover, the opinions on species origin may differ between local sources (compare Rothmaler 1986 with Zajac 1979, Opravil 1980).

The proportion of aliens is generally higher in large cities (Sukopp *et al.*, 1979a, 1981, Sukopp & Werner 1983, Pyšek 1989b, Pyšek & Pyšek 1991b) although some trends reported (Falinski 1971) seem to be rather simplistic (Pyšek 1989b). Nevertheless, they were frequently used as examples in later reviewing papers (Sukopp *et al.* 1979a, Sukopp & Werner 1983). Occurrence of aliens increases from outskirts to the city centre (Kunick 1974, Kowarik 1990). Of the species which prefer urban settlements, the majority appear to be of southern European origin (Saarisalo-Taubert 1963). Sukopp *et al.* (1979) pointed out that of the West Berlin aliens, 60% originated from areas warmer than central Europe. This may be quantified using indicator values for temperature (Ellenberg 1979): higher mean values and shifts in frequency distributions were recognized in alien species, especially neophytes, compared to the native ones in the Czech village vegetation (Pyšek 1989b). This seems to be valid not only for settlements but for the central European landscape in general (Kornaś 1983).

Sukopp & Werner (1983) concluded that most of the present-day neophytes spread best in cities and industrial areas whereas many archeophytes, having been introduced as weeds do better in rural areas. They considered the limitation of these species to human settlements to be more pronounced the further they were from their place of origin. The importance of climate selection in immigration processes has been emphasized (Kornaś 1983).

Life forms represent another frequently analysed characteristic; it has been repeatedly shown that the proprotion of therophytes is higher in large cities and city centers compared to their outskirts (Kunick 1974, Sukopp *et al.*, 1979a, Sukopp & Werner 1983, Kowarik 1985a, 1988, 1990a, Sudnik-Wójcikowska 1988, Pyšek & Pyšek 1988a, 1991b). Life strategies (Grime *et al.*, 1988), sociological behaviour (Ellenberg 1979, Hejný *et al.*, 1979, Rothmaler 1986), taxonomical groups or mode of dispersal are other characteristics that may be used to evaluate flora.

An insight into the ecological requirements of flora can be obtained by using indicator values (Ellenberg 1979, for a general discussion on their use see Mucina 1985, Klimeš 1987a, Kowarik & Seidling 1989). Frequency distribution of indicator values proved to be better than simply using their means (Kunick 1982, Pyšek 1989b). Wittig & Durwen (1981, 1982) compared cities and their rural surroundings and found that the urban flora required higher nitrogen and temperature and lower moisture. Similar results were obtained from a comparison of the industrial city of Plzeň with villages located in the same region (Pyšek & Pyšek 1991b). Kunick (1982) compared 9 European cities and was able to determine geographic and climatic trends in ecological demands of the floras.

Indices expressing flora synanthropization on the basis of various proportions of native and alien species were proposed by Polish authors (Kornaś 1977, Sowa & Warcholinska 1984). Some of these were dependent on the total number of species in the florula analysed (Pyšek 1989b). Based on more than 5000 vegetational relevés made in West Berlin, the hemeroby concept was used to construct spectra of hemeroby for each species (Kowarik 1990). This approach is particularly valuable relating a species response to the complex measure of human influence. Human impact consists of many partial environmental factors, some of which (stress, disturbance) cannot be directly measured. Wittig *et al.* (1985, also summarized in Wittig 1991) proposed a more intuitively based classification of species relationships to the urban environment with examples from German cities. The relation of individual species to habitat types was considered *e.g.*, by Kunick (1974), Sudnik-Wójcikowska (1987), Pyšek & Pyšek (1988a,b), Brandes *et al.* (1990) and many others.

Species rarity becomes increasingly relevant in the urban environment (Davis 1976, Sukopp *et al.*, 1978, Gemmell 1982, Sukopp & Kowarik 1986, Rebele 1988). At the end of the 1970's, 55% of the native flora of West Berlin was considered threatened (Sukopp *et al.*, 1981) and corresponding data to the loss of some species are available from other cities as well (see Sukopp *et al.*, 1979a). Areas of open space covered with vegetation are important for maintaining species diversity in the inner-urban areas (Sukopp & Werner 1983). The main principles to be considered in compiling red lists of endangered species were proposed by Kowarik (1991). It is especially important to pay attention to the whole spectrum of habitats, including those of heavily disturbed sites, and not only to those traditionally considered in nature conservation. Two main questions should be answered before any species, regardless of its status (*i.e.*, a native or an alien) is put on such a list, (1) Is the population established in the site?, and (2) Is the site endangered? (Kowarik 1991b). The principles of nature conservancy in central European cities were also discussed by Sukopp & Sukopp (1987).

Papers or books analysing adaptations of plant cover to urban environments and relating plant ecological investigations to other topics of urban ecological research have been frequently published in the last decade (Bornkamm *et al.*, 1982, Kowarik 1985a,b, 1990, Sukopp & Kowarik 1986, Gilbert 1989, Sukopp 1990, Wittig 1991).

3.2. Community level

To evaluate the ecology of a particular community, most studies use non-quantitative descriptions of soil conditions, temperature requirements and impact of anthropogeneous factors. This rough assessment is often enough to recognize those environmental factors that determine the occurrence of a community.

Direct measurements of ecological factors are rather rare in ruderal phytosociology (*e.g.*, Grosse-Brauckmann 1953, Grüll & Květ 1978). Because of considerable heterogeneity in substrata, many samples are necessary, so that measurements are frequently replaced by indicator values, those of Ellenberg (1979) being commonly used. The relation of a community to a given factor is then expressed by a mean value calculated for all species present in a given community (Tüllmann & Böttcher 1983, Pyšek 1992a, for discussion see Kowarik & Seidling 1989); semiquantitative data obtained by the relevé method can be included after simple transformation to the numerical scale (Ellenberg 1979). Nitrogen and moisture represent steep gradients in urban habitats and may be thus used for ranking communities according to their requirements (Pyšek 1992a).

In the urban environment, it is sometime more plausible to express community relationship to some complex measurement of human impact, rather than analysing single factors. Methods to express the intensity of human impact have been proposed (Olaczek sec. Sudnik-Wójcikowska 1988); theoretical concepts of the assessment of human impact on vegetation were reviewed by Kowarik (1991a). In such attempts, however, attention should be paid to avoid circular reasoning: vegetation feature (*e.g.*, community type or percentage of area covered by vegetation) is used to assess and classify the zones of different intensity of human impact and subsequently another characteristic of plant cover (*e.g.*, number of species) is related to these zones (Sudnik-Wójcikowska 1987). This may be overcome by describing environment exclusively by its own features (Pyšek 1992b) or by excluding indicator species from the assessment (Kowarik 1990).

Classification of habitat types was first proposed by Hejný using as an example a concrete city (1971a), more detailed and generally applicable studies appeared later (Sukopp & Werner 1983, Klotz 1986, Schulte *et al.*, 1986, Sukopp *et al.* 1986, Blume *et al.*, 1987). Because of different criteria, particular classifications are mostly applicable to given studies and are thus difficult to compare in detail. Hejný (1971a) distinguished 68 habitat types in Prague, whereas Pyšek (1978) only 21 in Plzeň , a difference which can be ascribed to the fineness of scales rather than to real differences in habitat heterogeneity between the cities. Distribution of communities with respect to habitat type was widely studied, sometimes using vegetation mapping (*e.g.*, Kienast 1978, Pyšek 1978, Tüllman & Böttcher 1983, Klotz 1986, Goldberg & Gutte 1988, Tlusták 1990, Chojnacki 1991 in cities, Pyšek & Rydlo 1984 in villages), so that rough generalizations are possible (Pyšek 1992b). Some attention has been paid to the vegetation of specific habitats, *e.g.*, railway sites (Brandes 1983, Jehlík 1986), cemeteries (Graf 1986, Pyšek 1988), road verges (Klimeš 1987b), factories (Rebele 1986, 1988, Pyšek & Pyšek 1988c). Sukopp & Werner (1983) divided West Berlin habitats into main zones of urban land use; they presented characteristics of climate and soil and analysed their consequences for plant vigour, species composition and migration possibilities within each zone. Another detailed study has been carried out in Warsaw by Chojnacki (1991) who mapped the vegetation within the whole city area. According to my knowledge, this map represents the first vegetation map of such a large city based on the basic phytosociological units. This approach made it possible to analyse spatial relationships between communities and habitat types (Chojnacki 1991).

Classification of depositional habitats has been rather unclear so far, because of diversity of substrata and complicated terminology (Gutte 1971a,b, Hejný 1971b). A simplified scheme based on (1) features of accumulated material, (2) its origin, and (3) type of accumulation process was proposed by Prach *et al.* (1994). Mucina (1982) published a broader classification of ruderal habitats covering not only urban environments but open landscape as well.

The comparison between cities and villages of vegetation distribution with respect to the site structure showed that in many communities, there was a preference for either town or village habitats (Pyšek & Pyšek 1990).

An analysis of a particular community carried out within a large geographical region can provide information on the sociological behaviour of the dominant species and changes in community composition on latitudinal/longitudinal gradients. Community response to climate changes can be evaluated (Mucina & Brandes 1985, Mucina 1989a). The problems of geographic, altitudinal and geological vicariance of synanthropic vegetation were reviewed by Mucina (1991).

3.3. Vegetation level

Surprisingly, there have been few attempts to analyse the ruderal vegetation of a certain area as a whole in quantitative terms. This is presumably caused by the lack of quantitative data on the composition of vegetation cover, which is necessary if some synthetic characteristics are to be calculated. Comparisons of different areas have been carried out mostly in terms of community presence/absence or using vague estimations (Hejný *et al.*, 1978, Hadač 1978).

Pyšek & Pyšek (1985) related features of village vegetation and changes in vegetation diversity to the altitude. It was possible to relate the character of ruderal vegetation to the climax vegetation type of the respective region. The comparison of settlements differing in size made it possible to quantify increase of vegetation diversity, expressed as Shannon index, with the city size (Pyšek & Pyšek 1990). The vegetation diversity in great cities shows a regular pattern which can be related to the urban space structure (Pyšek 1992b).

More general interpretations of the vegetation-environment-relationships can be also made using ordination techniques, as shown by Mucina and van Tongeren (1989) who analysed the coenocline of high-ranked syntaxa of ruderal vegetation.

4. Dynamic changes: comparisons in time

Unfortunately, there are few data recorded in the past which can be compared with the present (Kreh 1955, Scholz 1960, Sudnik-Wójcikowska 1987, Klotz 1987). In some cases even these data are not comparable because of unclear area delimitation (Prach *et al.*, 1994). Nevertheless, there is an example illustrating how useful such data are. Having compared floristic lists of Halle from 1848 and 1983, Klotz (1987) found the total number of species almost unchanged, but the floristic similarity between both lists was only 56.5%. The proportion of neophytes changed from 10 to 31% and indicator values for temperature, nitrogen, continentality and soil reaction increased, whereas that for moisture declined. Hence the same consequences of increasing synanthropization in space, shown by comparing flora of the city to its countryside (Wittig and Durwen 1981, 1982, Pyšek & Pyšek 1991b) also held for time (Klotz 1987).

Similarly, an increase in the number of neophytes in the flora of West Berlin during the last two centuries was related to the population explosion after the industrial revolution (Sukopp *et al.*, 1979a, Kowarik 1990). Sukopp (1973) estimated the proportion of species becoming extinct in some European cities between 1850 and 1950 and reported values between 4 and 16% of the total species number. Kowarik & Jirku (1988) reported on the changes in species composition of grasslands and meadows at the territory of ZOO Berlin between 1954-86.

A common approach to vegetation dynamics in human settlements is a phytosociological study at the community level. Research has been focused mostly on newly created deposits (see Pyšek & Pyšek 1991a, Prach *et al.*, 1994 for reviews). Studies in other habitats are rather rare (Krippelová 1972). Pyšek & Pyšek (1991a) summarized 17 studies, most of them using the method of repeating relevés in permanent plots over time (for review of permanent plots see Böttcher 1974). Data can be obtained by (1) following the changes in a site over time, or (2) comparing several currently existing stages of a different age. Combination of both methods is often used; provided that individual stands are followed for a sufficient time to allow overlap, quite a precise picture of the species/community sequence can be obtained. Kornaś (1990) pointed out three possible methods to document precisely temporal changes in vegetation: (1) repeating of phytosociological relevés in permanent plots, (2) collecting new representative sets of relevés within the area formerly studied and comparing this new relevé set with the corresponding old one, and (3) renewed mapping of the actual vegetation in the area formerly mapped.

Two main approaches can be distinguished in phytosociological studies on succession. The first one focuses upon individual communities and describes mutual transitions among them (*e.g.*, Pyšek 1977). The second approach is concerned with particular habitat types and makes it possible to compare successional seres among them (*e.g.*, Kreh 1935, Gutte 1971a,b, Holzner 1972, for references see Prach *et al.*, 1994). Initial stages of vegetation development on rubble waste sites were investigated after the war in numerous cities (Sukopp & Werner 1983). The results of phytosociological studies on succession are mostly presented in the form of syngenetical schemes (Pyšek 1977, Sukopp *et al.*, 1979a, Holzner 1972).

Although the phytosociological approach is not considered to have contributed to theoretical knowledge on succession (Prach *et al.*, 1994), it makes it possible to record main changes in vegetation such as species/community exchange, changes in species diversity, vegetation diversity and life form spectra, etc. Pyšek & Pyšek (1991a) expressed the changes in occurrence of each species in 46 permanent plots during a 6 year period of succession using frequency distribution of differences between initial and final values of the given species in Braun-Blanquet scale. This method allowed the characterization of the successional position of a species numerically and documented general trends, *e.g.*, increase in native species at the expense of aliens during succession.

A deeper insight into the mechanisms of ruderal succession was provided by Bornkamm (1984, 1986, 1987a). Soil type, starting time and nitrogen fertilization were used in experimental studies as variables affecting the course and rate of succession. It was not possible to find a constant series of dominant species exchange. If the process of succession is to be fully described, not only annual changes but also seasonal ones must be taken into account (Bornkamm 1987a).

Investigations of changes over time at the level of vegetation cover or landscape are often linked with diminishing ruderal communities, the decline of which has been mostly attributed to changes in land use and management (Brandes 1981, Pyšek 1983, Sukopp 1983, Kornaś 1990). Of 110 ruderal associations recorded in Czechoslovakia, over 45% are considered retreating (Prach *et al.*, 1994). Changes in contribution of individual communities to the vegetation cover were assessed quantitatively over the period of 15 years and a decrease in diversity of village vegetation was reported (Pyšek & Pyšek 1987b). There is a conspicuous retreat of communities considered typical of village sites, associated with the simultaneous increase of those preferring an urban environment (Pyšek & Pyšek 1990). Changes in agricultural management in south Bohemia were shown to affect the distribution of communities within the settlement area (Hejný 1973).

5. Conclusions: current state of research and future directions

'Ecosystems that have developed in urban conditions may be the prevailing ecosystems of the future.' (Sukopp *et al.*, 1979a). Unfortunately, much of the efforts devoted to studying these ecosystems so far have been concerned with pure phytosociology, repeatedly describing common vegetation types, without any ambition to get deeper under the cover of the issue. The situation is, however, different in particular central European countries. Among those involved most in intense settlement plant cover research, Czech Republic, Slovakia and Poland seem to be still limited by traditional approaches (although there are some exceptions). The field appears to be much more developed in Germany where new methods and approaches have been applied. The research seems to have been stimulated by some influential articles mapping the 'state of the art' at the turn of the 70's and 80's (Sukopp *et al.* 1979a, Sukopp & Werner 1983). In the contemprorary context, a similar starting point may be represented by the book edited by Sukopp *et al.* (1990) which covers both scientific and practical aspects of the field. Correspondingly, the book of Wittig (1991) is a useful summary of current knowledge and may serve as a link between traditional approaches and the recent development in urban ecology.

The subjectivity of phytosociological methods seems to have another general impact. This review indicates that there are more new approaches and methods applicable to the study of flora than of vegetation. The latter are more limited by traditional attitudes. Moreover, the results concerning flora have better general validity because they can be easily compared among settlements and regions. The main problem limiting the comparison of vegetation, *i.e.*, what it is we are working with and what we want thus to compare, has no relevance here. Faced with the contemporary progress in ecology, the role of phytosociology seems to be limited to that of a useful technique for describing vegetation rather than a progressive scientific method.

Research in urban ecology is undoubtedly of increasing practical importance (Sukopp 1990). Urban land management planning and nature conservancy can profit (Hard & Pirner 1985), especially from the method of habitat mapping (Sukopp *et al.*, 1979b, Schulte *et al.*, 1986, Sukopp & Werner 1987, Sukopp & Weiler 1988). Provided that the recommendations of the Working Group for Habitat Mapping are accepted by a wide range of researchers in different regions, results of general validity could be obtained by comparisons. As it has been widely applied only in Germany till now (see Sukopp and Weiler 1988 for survey), it is plausible to encourage use of the method in other central European countries.

Using synanthropic plants as bioindicators (Trepl 1983, Sukopp & Werner 1987) in monitoring the quality of urban environment represents another example of practical application. Furthermore, the use of urban vegetation research for health care was suggested; knowledge on the distribution of the main pollen producers can be used in preventing pollen allergies (Kopecký 1990b). A specific area in which the knowledge on ruderal flora and vegetation is being successfully used is the management of industrial wastelands (see Rebele 1991 for assessment and the outlook for the future). This habitat type can harbour highly diverse wildlife and is becoming increasingly relevant for nature conservancy, amenity and recreation (Gemmell 1982, Rebele 1988, 1991). Generally, considerable attention is being paid to the management of urban free space (see *e.g.*, Hüllbusch 1983, Hard 1984, Hard & Pirner 1985 for examples).

Further research of plant cover in human settlements should be of deeper scientific interest. Experimental methods can be successfully used in this type of environment as well (Bornkamm 1984, 1986, 1987a). Each particular level of study can provide specific results which are not recognizable at another scale (Krahulec & Lepš 1989, Krahulec 1990). Till now, the attention was concentrated mostly at community level. There this certainly much opportunity for studying relationships at landscape level (Prach *et al.*, 1994). Closer relating of plant cover (both spontaneous and planted) to animals, soil and climate in urban environments can yield more general conclusions (*e.g.*, Kowarik 1985a). Wider application of statistical methods, both in data analysis and designing research, is desirable to improve data interpretation.

Extreme ecological conditions in the urban environment provide an opportunity to study plant adaptations to stresses and its evolutionary aspects (*e.g.*, pollution, toxicity of substrata). Large areas of newly exposed land make it possible to study some problems of general ecological interest, *e.g.*, colonization processes and succession (Antonovics *et al.*, 1971, Bradshaw & McNeilly 1981, Rebele 1986, Cornelius 1988, 1990). Complex studies on autecology of alien species may be of great scientific value (Sukopp 1971, Dapper 1971, Zimmermann-Jaeger 1971, De Sante-Virzo 1971, Bornkamm 1971).

Generally speaking, new field methods, change of attitudes and more studies involved with general questions are needed. Close international cooperation may contribute substantially to the development of the field. There is a large body of information in those phytosociological studies carried out so far. This can be used for generalization by (1) application of statistical and computer methods (*e.g.*, Kowarik 1990), (2) careful reevaluation of the data (*e.g.*, Pyšek & Pyšek 1991a), or (3) reviewing and mutual comparing of large numbers of studies (Prach *et al.*, 1994, Pyšek 1992b).

'Modern cities are often deserts of brick, stones and concrete; plants can break this monotony...' (Woodell 1979). The more we know about them the better we can help them to do so.

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References

Antonovics, J., Bradshaw, A.D. & Turner, R.G. 1971. Heavy metal tolerance in plants. Adv. Ecol. Res. 7: 1–85.

Blume, H.-P. *et al.* 1987. Stadtökologische Raumeinheiten. Umweltatlas, 2: 1–5.

Bornkamm, R. 1971. Beiträge zur Ökologie von Chenopodium botrys L. V. Gehalt an organischem Stickstoff, Nitrat und Asche. Verh. Bot. Ver. Prov. Brandenburg, 108: 57-73.

Bornkamm, R. 1984. Experimentell-ökologische Untersuchungen zur Sukzession von ruderalen Pflanzengesellschaften. II. Quantität und Qualität der Phytomasse. Flora 175: 45–74.

Bornkamm, R. 1986. Ruderal succession starting at different seasons. Acta Soc. Bot. Poloniae 55: 403–419.

Bornkamm, R. 1987a. Veränderungen der Phytomasse in den ersten zwei Jahren einer Sukzession auf unterschiedlichen Böden. Flora 179: 179–192.

Bornkamm, R. 1987b. Fragen der Auswertung und Bewertung floristischer Artenlisten. Mitt. der Biol. Bundesanstalt f. Land- u. Forstwirtschaft, Berlin-Dahlem, 234: 16–20.

Bornkamm, R., Lee, J.A. & Seaward, M.R.D. (eds.) 1982. Urban ecology. 2nd European ecological symposium, Berlin. Blackwell, Oxford.

Böttcher, H. 1974. Bibliographie zum Problem der Sukzessionsforschung mit Hilfe von Dauerquadraten und der Vegetationskartierung. Exc. Bot., Stuttgart, Sect. B Sociologica, 141: 35–56.

Bradshaw, A.D. & McNeilly, T. 1981. Evolution and pollution. Edward Arnold, London.

Brandes, D. 1981. Gefährdete Ruderalgesellschaften in Niedersachsen und Möglichkeiten zu ihrer Erhaltung. Gött. Flor. Rundbr., Göttingen, 14: 90–98.

Brandes, D. 1983. Flora und Vegetation der Bahnhöfe Mitteleuropas. Phytocoenologia, Stuttgart, 11: 31–115.

Brandes, D. 1987. Verzeichnis der im Stadtgebiet von Braunschweig wildwachsenden und verwilderten Pflanzen. Braunschweig.

Brandes, D., Griese, D. & Köller, U. 1990. Die Flora der Dörfer unter besonderer Berücksichtigung von Niedersachsen. Braunschw. Naturkdl. Schr. 3: 569–593.

Brandes, D. & Zacharias, D. 1990. Korrelation zwischen Artenzahlen und Flächengrößen von isolierten Habitaten dargestellt an Kartierungsprojekten aus dem Bereich der Regionalstelle 10 B. Flor. Rundbr. 23: 141–149.

Chojnacki, J. 1991. Zroznicowanie przestrzenne roslinnosci Warszawy. Wydaw. Uniw. Warsz., Warszawa.

Cornelius, R. 1988. Plant strategies in relation to urban habitats. In: Zaliberová, M. *et al.* (ed.), Symposium Synanthropic flora and vegetation V, pp. 39–45, Veda, Bratislava.

Cornelius, R. 1990. The strategies of Solidago canadensis L. in relation to urban habitats. I.-III. Acta Oecol. 11: 19–34, 145–153, 301–310.

Dapper, H. 1971. Beiträge zur Ökologie von Chenopodium botrys L. II. Produktion an Ruderalstandorten. Verh. Bot. Ver. Prov. Brandenburg 108: 26–28.

Davis, B.N.K. 1976. Wildlife, urbanisation and industry. Biol. Conserv. 10: 249–291.

Dechent, H.-J. 1988. Wandel der Dorfflora – gezeigt am Beispiel einiger Dörfer Rheinhessens. KTBL-Schrift, Darmstad, 326: 1–162.

De Santo-Virzo, A. 1971. Beiträge zur Ökologie von Chenopodium botrys L. IV. Wasserhaushalt. Verh. Bot. Ver. Prov. Brandenburg 108: 37–55.

Eliáš, P. 1984, 1986. A survey of ruderal plant communities of Western Slovakia I., II. Feddes Repert., Berlin, 95: 251–276, 97: 197–221.

Eliáš, P. 1988. Inflácia syntaxónov vyššieho rangu teplomilnej ruderálnej vegetacie, skutočnosť ci konfúzia? Preslia, Praha, 60: 59–71.

Ellenberg, H. 1979. Zeigerwerte der Gefäßpflanzen Mitteleuropas. Scr. Geobot., Göttingen 9: 1–122.

Falinski, J.B. 1971. Synanthropization of plant cover. II. Synanthropic flora and vegetation of towns connected with their natural conditions, history and function. Mater. Zakl. Fitosocjol. Stos. UW, Warszawa-Bialowieza 27: 1–317.

Feoli, E. 1984. Some aspects of classification and ordination of vegetation in perspective. Studia Geobot., Trieste 4: 7–21.

Frank, D. & Klotz, S. 1990. Biologisch-ökologische Daten zur Flora der DDR. Halle.

Gemmell, R.P. 1982. The origin and botanical importance of industrial habitats. In: Bornkamm, R. *et al.*, Lee, J.A. & Seaward, M.R.D. (eds.), Urban ecology. 2nd European ecological symposium, Berlin, pp. 33–39, Blackwell, Oxford.

Gilbert, O.L. 1989. Ecology of urban environment. Chapman & Hall, London.

Gödde, M. 1986. Vergleichende Untersuchung der Ruderalvegetation der Großstädte Düsseldorf, Essen und Münster. Düsseldorf.

Goldberg, A. & Gutte, P. 1988. Phytosoziologische Charakterisierung städtischer Flachennutzungsstrukturen, dargestellt an einem Transekt durch die Großstadt Leipzig. In: Zaliberová, M. (ed.), Symposium Synanthropic flora and vegetation V, pp. 59–66. Veda, Bratislava.

Graf, A. 1986. Flora und Vegetation der Friedhöfe in Berlin (West). Verh. Berliner Bot. Ver. 5: 1–210.

Grime, J.P., Hodgson, J.G. & Hunt, R. 1988. Comparative plant ecology. Unwin & Hyman, London.

Grosse-Brauckmann, G. 1953. Untersuchungen über die Ökologie, besonders den Wasserhaushalt von Ruderalgesellschaften. Vegetatio 4: 245–283.

Grüll, F. & Květ, J. 1978. Charakteristik der Bodentemperaturen in Ruderalzönosen der Stadt Brno. Preslia, Praha 50: 361–373.

Gutte, P. 1971a. Die Vegetation der Aschenhalde Rositz bei Altenburg. Abh. u. Ber. Naturkdl. Mus. 'Mauritianum' Altenburg 7: 7–16.

Gutte, P. 1971b. Die Wiederbegrünung städtischen Ödlandes, dargestellt am Beispiel Leipzigs. Herzynia, Leipzig, ser.n. 8: 58–81.

Gutte, P. 1972. Ruderalpflanzengesellschaften West- und Mittelsachsens. Feddes Repert., Berlin 83: 11–122.

Hadač, E. 1978. Ruderal vegetation of the Broumov basin. Folia Geobot. Phytotax., Praha 13: 129–163.

Haeupler, H. 1974. Statistische Auswertung von Punktrasterkarten der Gefäßpflanzenflora Süd-Niedersachsens. Scr. Geobot., Göttingen 8: 1–141.

Hard, G. 1982. Die spontane Vegetation der Wohn- und Gewerbequartiere von Osnabrück (I.). Osnabrück. Naturw. Mitt. 9: 151–203.

Hard, G. 1984. Spontane und angebaute Vegetation an der Peripherie der Stadt. In: Über Plannung. Eine Sammlung planungspolitischer Ansätze. GH Kassel, FB Stadtplannung u. Landschaftsplannung, p. 77–113.

Hard, G. & Pinter, J. Stadtvegetation und Freiraumplannung am Beispiel der Osnabrücker Kinderspielplätze. Osnabr. Stud. Geogr. 7: 1–84.

Hejný, S. 1971a. Metodologicky příspěvek k výzkumu synantropní květeny a vegetace velkoměsta (na příkladu Prahy). Zborn. predn. Zjazdu Slov. bot. spoloč., Tisovec 1970, 2: 545–567, Bratislava.

Hejný, S. 1971b. The characteristic features of vegetation of slag and flue dust substrates in Prague. In: Bioindicators of landscape deterioration, pp. 39–42, Praha.

Hejný, S. 1973. Beitrag zur Charakteristik der Veränderung der Ruderalgesellschaften in Südböhmen. Acta Bot. Acad. Sci. Hungaricae 19: 129–138.

Hejný, S. Husák, S. & Pyšek, A. 1979. Vergleich der Ruderalgesellschaften in erwählten Gesamtheiten südböhmischer und südmährischer Dörfer. Acta Bot. Slov. Acad. Sci. Slov., Bratislava, ser. A. 3: 271–281.

Hejný, S. *et al.* 1979. Přehled ruderálních rostlinných společenstev Československa. Rozpr. Čs. Akad. Věd, Praha, ser. math.-nat. 89: 2.1–100.

Herben, T. 1986 Problém využití fytocenologických znalostí v ČSSR – pokus o rozbor. Preslia, Praha 58: 223–229.

Holub, J. & Jirásek, V. 1967. Zur Vereinheitlichung der Terminologie in der Phytogeographie. Folia Geobot. Phytotax., Praha 2: 69–113.

Horbert, M. 1978. Klimatische und lufthygienischer Aspekte der Stadt- und Landschaftsplanung. Natur u. Heimat 38.

Holzner W. 1972. Einige Ruderalgesellschaften des oberen Murtales. Verh. Zool. Bot. Ges., Wien 112: 67–83.

Hüllbusch, K.H. 1978. Kartierung der Vegetation in Siedlungsgebieten. In: Tüxen, R. (ed.), Assoziationskomplexe, pp. 321–327, Vaduz.

Hüllbusch, K.H. 1983. Arbeitskreis: Biotopkartierung – Wissenschaft und Alibi. Jahrbuch f. Natursch. u. Landschaftspfl. 33: 143–145.

Jehlík, V. 1986. The vegetation of railways in northern Bohemia (eastern part). In: Vegetace ČSSR, Praha, ser. A 14: 1–366.

Kienast, D. 1978. Die spontane Vegetation der Stadt Kassel in Abhängigkeit von bau- und stadtstrukturellen Quartierstypen. Urbs et Regio 10: 1–414.

Kienast, D. 1980. Sigma-Gesellschaften der Stadt Kassel. Phytocoenologia, Stuttgart 7: 65–72.

Klimeš, L. 1987a. Použití tabelovaných indikačních hodnot v gradientové analýze vegetace. Preslia 59: 15–24.

Klimeš, L. 1987b. Succession in road bank vegetation. Folia Geobot. Phytotax., Praha 22: 435–440.

Klimeš, L. 1989. Příspěvek k ruderálním společenstvům Novosibirska (SSSR) a k obecným problemům syntaxonomie ruderální vegetace. Preslia, Praha 61: 259–277.

Klotz, S. 1986. Die Pflanzengemeinschaften des Ballungsraumes Halle – ihre Geschichte, Gefährdung und Bindung an die ökologischen Raumeinheiten der Stadt. Wiss. Z. Karl-Marx-Univ. Leipzig, ser. math.-natur. 35: 673–680.

Klotz, S. 1987. Floristische und vegetationskundliche Untersuchungen in Städten der DDR. Düsseldorf Geobot. Kolloq. 4: 61–69.

Klotz, S. 1988. Flora und Vegetation in der Stadt, ihre Spezifik und Indikationsfunktion. Landschaftsarchitektur 17: 104–107.

Klotz, S. 1990. Species/area and species/inhabitants relations in European cities. In: Sukopp, H., Hejný, S. & Kowarik, I. (eds.), Urban ecology, pp. 99–104, SPB Academic Publ., The Hague.

Klotz, S., Gutte, P. & Klausnitzer, B. 1984. Literaturübersicht, Charakterisierung und Gliederung urbaner Ökosysteme. Hercynia 21: 218–234.

Kopecký, K. 1980–1984. Die Ruderalpflanzengesellschaften im südwestlichen Teil von Praha (1)–(6). Preslia, Praha 52: 241–267; 53: 121–145; 54: 67–89; 54: 123–139; 55: 289–298; 56: 55–72.

Kopecký, K. 1984b. Der Apophytisierungsprozeß und die Apophytengesellschaften der Galio-Urticetea mit einigen Beispielen aus der südwestlichen Umgebung von Praha. Folia Geobot. Phytotax., Praha 19: 113–138.

Kopecký, K. 1986. Versuch einer Klassifizierung der ruderalen Agropyron repens- und Calamagrostis epigejos Gesellschaften unter Anwendung der deduktiven Methode. Folia Geobot Phytotax., Praha 21: 225–242.

Kopecký, K. 1988. Použití tzv. deduktivní metody syntaxonomické klasifikace ve fytocenologické literatuře. Preslia, Praha 60: 177–184.

Kopecký, K. 1990a. K polemicé o syntaxonomických, syngenetických a synekologických aspektech deduktivní metody syntaxonomické klasifikace. Zpr. Čs. Bot. Společ., Praha 25: 3–13.

Kopecký, K. 1990b. Changes of vegetation and pollen respiratory tract allergies on Prague sample. In: Sukopp, H., Hejný, S. & Kowarik, I. (eds.), Urban ecology, pp. 267–271, SPB Academic. Publ., The Hague.

Kopecký, K. & Hejný, S. 1978. Die Anwendung einer deduktiven Methode syntaxonomischer Klassifikation bei der Bearbeitung der straßenbegleitenden Pflanzengesellschaften Nordostböhmens. Vegetatio, The Hague 36: 43–51.

Kopecký, K. & Hejný, S. 1990. Die stauden- und grasreichen Ruderalgesellschaften Böhmens unter Anwendung der deduktiven Methode syntaxonomischer Klassifizierung. Folia Geobot. Phytotax., Praha 25: 357–380.

Kornaš, J. 1977. Analiza flor synantropijnych. Wiadom. Bot., Warszawa 21: 85–91.

Kornaš, J. 1983. Man's impact on the flora and vegetation in Central Europe. In: Holzner, W. *et al.* (eds.), Man's impact on vegetation, p. 277–286, Junk, Hague.

Kornaš, J. 1990. Jak i dla czego gina nasze zespoly roślinne. Wiadom. Bot. 34: 7–16.

Kowarik, I. 1985a. Grundlagen der Stadtökologie und Forderungen nach ihrer Berücksichtigung bei der Stadtgestaltung am Beispiel Berlins. Schr.-Reihe DBV-Jugend 3: 22–39.

Kowarik, I. 1985b. Zum Begriff 'Wildpflanzen' und zu den Bedingungen und Auswirkungen der Einbürgerung hemerochorer Arten. Publ. Naturhist. Gen., Limburg 35(3-4.8-25).

Kowarik, I. 1988. Zum menschlichen Einfluß auf Flora und Vegetation. Theoretische Konzepte und ein Quantifizierungsansatz am Beispiel von Berlin (West) Landschaftsentw. u. Umweltforsch., Berlin 56: 1–280.

Kowarik, I. 1990. Some responses of flora and vegetation to urbanization in Central Europe. In: Sukopp, H. *et al.* (eds.), Urban ecology, pp. 45–74, SPB Academic Publ., The Hague.

Kowarik, I. 1991a. Unkraut oder Urwald? Natur der vierten Art auf dem Gleisdreieck. In: Bundesgartenschau 1995. pp 45–55, Berlin.

Kowarik, I. 1991b. Berücksichtigung anthropogener Standort- und Florenveränderungen bei der Aufstellung Roter Listen. In: Auhagen, A.R. *et al.* (eds.), Rote Listen der gefährdeten Pflanzen und Tiere in Berlin. Landschaftsent. u. Umweltforsch. 6: 25–56.

Kowarik, I. & Jirku, A. 1988. Rasen im Spannungsfeld zwischen Erholungsnutzung, Ökologie und Gartendenkmalpflege. Analyse von Nutzungskonflikten in Parkanlagen am Beispiel des Berliner Tiergartens. 1. Untersuchungskonzeption und Vegetationsanalysen. Gartenamt 37: 645–654.

Kowarik, I. & Seidling, W. 1989. Zeigerwertberechnungen nach Ellenberg – zu Problemen und Einschränkungen einer sinnvollen Methode. Landschaft u. Stadt 21: 132–143.

Krahulec, F. 1990. Introduction. In: Krahulec, F. *et al.* (eds.), Spatial processes in plant communities, pp. xi–x, Academia Praha/SPB Academic Publ., The Hague.

Krahulec, F. & Leps, J. 1989. Fytocenologie a soucasná veda o vegetaci. Preslia, Praha 61: 227–244.

Krawiecowa, A. & Rostanski, K. 1976. Zaleznosc flory synantropijnej wybranych miast polskich od ich warunkow przyrodniczych i rozwoju. Acta Univ. Wratislaw., Pr. Bot. 303/21,5–61.

Kreh, W. 1935. Pflanzensoziologische Untersuchungen auf Stuttgarter Auffüllplatzen. Jhr. Ver. Vaterl. Naturk. Wurttemberg. Schwabisch Hall 91: 59–120.

Kreh, W. 1955. Das Ergebnis der Vegetationsentwicklung auf dem Stuttgarter Trümmerschutt. Mitt. Flor.-Soz. Arb. Gemeinsch., N.F. 5: 69–75.

Krippelová, T. 1972. Ruderálne spoločenstvá mesta Malaciek. Biol. Pr., Bratislava, 18/1,1–117.

Kunick, W. 1974. Veränderungen von Flora und Vegetation einer Großstadt, dargestellt am Beispiel von Berlin (West). Diss. Techn. Univ. Berlin.

Kunick, W. 1982. Comparison of the flora of some cities of the Central European lowlands. In: Bornkamm, R., Lee, J.A. & Seaward, M.R.D. (eds.), Urban ecology. 2nd European ecological symposium, Berlin, pp. 13–22, Blackwell, Oxford.

Kunick, W. 1983, Köln. Landschaftsökologische Grundlagen. T3, Biotopkartierung. Köln.

Kunick, W. 1991. Ausmaß und Bedeutung der Verwilderung von Gartenpflanzen. NAA-Berichte 4/1, 6–13.

Laurie, I.C. (ed.) 1979. Nature in cities. J. Wiley, Chichester.

Miess, M. 1979. The climate of cities. In: Laurie, I.C. (ed.), Nature in cities, pp. 91–114, J. Wiley, Chichester.

Moravec, J. 1989. Influences of the individualistic concept of vegetation on syntaxonomy. Vegetatio, Dordrecht 81: 29–39.

Mucina, L. 1982. Ku klasifikácii ruderálnych stanovíšť severozápadnej časti Podunajskej nížiny. Preslia, Praha 54: 349–367.

Mucina, L. 1985. Používať alebo nepoužívať Ellenbergove indikačné hodnoty? Biológia, 40: 511–516.

Mucina, L. 1989. Syntaxonomy of the Onopordum acanthium communities in temperate and continental Europe. Vegetatio, Dordrecht 81: 107–115.

Mucina, L. 1990. Urban vegetation research in European COMECON countries and Yugoslavia, a review. In: Sukopp, H., Hejný, S. & Kowarik, I. (eds.), Urban ecology, pp. 23–43, SPB Academic. Publ., The Hague.
Mucina, L. 1991. Variance and clinical variation in synanthropic vegetation. In: Nimis, P.L. & Crovello, T.J. (eds.), Quantitative approaches to phytogeography, pp. 263–276, Kluwer, The Hague.
Mucina, L. & Brandes, D. 1985. Communities of Berteroa incana in Europe and their geographical differentiation. Vegetatio, The Hague 59: 125–136.
Mucina, L. & Maglocký, S. (eds.) 1985. A list of vegetation units of Slovakia. Doc. Phytosoc., Camerino, N.S. 9: 175–220.
Mucina, L. & van der Maarel, E. 1989. Twenty years of numerical syntaxonomy. Vegetatio, Dordrecht 81: 1–15.
Mucina, L. & van Tongeren, O.F.R. 1989. A coenocline of the high-ranked syntaxa of ruderal vegetation. Vegetatio, Dordrecht 81: 117–125.
Mueller-Dombois, D. & Ellenberg, H. 1974. Aims and methods of vegetation ecology. J. Wiley, New York.
Oberdorfer, E. 1983. Süddeutsche Pflanzengesellschaften. 2 ed. Pflanzensoziologie, Jena 10: 1–455.
Opravil, E. 1980. Z historie synantropní vegetace 1–3. Živa, Praha 28(66): 4–5, 53–55, 88–90.
Passarge, H. 1964. Pflanzengesellschaften des Norddeutschen Flachlandes 1. Pflanzensoziologie, Jena 13: 1–324.
Pignatti, S. 1968. Die Inflation der höheren Pflanzensoziologischen Einheiten. In: Tüxen, R. (ed.), Pflanzensoziologische Systematik, pp. 85–97, The Hague.
Prach, K., Pyšek, P., Bartha, S. & Krahulec, F. 1994. Succession in man-made habitats. In: Mucina, L. (ed.), Synanthropic vegetation, Kluwer Publ. [in press].
Pyšek, A. 1977. Sukzession der Ruderalpflanzengesellschaften von Groß-Plzeň. Preslia, Praha 49: 161–179.
Pyšek, A. 1978. Ruderální vegetace Velké Plzně. Diss. Bot. Inst. Czechoslovak Acad. Sci., Průhonice.
Pyšek, A. 1981. Übersicht über die westböhmische Ruderalvegetation. Folia Mus. Rer. Natur. Bohem. Occid., Plzeň. ser. bot. 15: 1–24.
Pyšek, A. 1983. Gefährdete Ruderalpflanzengesellschaften Westböhmens. In: Zippelius, A. (ed.), Aus Liebe zur Natur, Bonn 3: 52–54.
Pyšek, A. & Pyšek, P. 1987a. Die Methode der Einheitsflächen beim Studium der Ruderalvegetation. Tuexenia, Göttingen 7: 479–485.
Pyšek, A. & Pyšek, P. 1987b. Quantitative Bewertung der Vegetationsdynamik in westböhmischen Siedlungsgebieten in den letzten 15 Jahren. In: Schubert, R. & Hilbig, W. (eds.), Erfassung und Bewertung anthropogener Vegetationsveränderungen 1, pp. 176–188, Halle/Saale.
Pyšek, A. & Pyšek, P. 1988a. Ruderální flóra Plzně. Sborn. Západočes. Muz., Plzeň, Přír. 68: 1–34.
Pyšek, A. & Pyšek, P. 1988b. Standörtliche Differenzierung der Flora der westböhmischen Dörfer. Folia Mus. Rer. Natur. Bohem. Occid., Plzeň, ser. bot. 28: 1–52.
Pyšek, P. 1988. Floristische- und Vegetationsverhältnisse des Zentralen Friedhofs in der Stadt Plzeň. Folia Mus. Rer. Natur. Bohem. Occid., Plzeň, ser. bot. 25: 1–46.
Pyšek, P. 1989a. On the richness of Central European urban flora. Preslia, Praha 61: 329–334.
Pyšek, P. 1989b. Archeofyty a neofyty v ruderální flóře některých sídlišť v Čechách. Preslia, Praha 61: 209–226.
Pyšek, P. 1991. Die Siedlungsvegetation des Böhmischen Karsts. 1. Syntaxonomie. Folia Geobot. Phytotax., Praha 26: 225–262.
Pyšek, P. 1992a. Die Siedlungsvegetation des Böhmischen Karsts. 2. Ökologische Charakteristik. Folia Geobot. Phytotax., Praha 27: 1–23.
Pyšek, P. 1992b. Settlement outskirts – may they be considered as ecotones? Ekológia (ČSFR), Bratislava 11: 273–286.
Pyšek, P. 1993. Factors affecting the diversity of flora and vegetation in central European settlements. Vegetatio, The Hague, 106: 89–100.
Pyšek, P. & Pyšek, A. 1985. Die Ausnutzung der Ruderalvegetation zur quantitativen Indikation von Standortverhältnissen mit Hilfe von Einheitsflächen (am Beispiel westböhmischer Siedlungen). Folia Mus. Rer. Natur. Bohem. Occid., Plzeň, ser. bot. 22: 1–35.
Pyšek, P. & Pyšek, A. 1988c. Die Vegetation der Betriebe des östlichen Teiles von Praha. 2. Vegetationsverhältnisse. Preslia, Praha 60: 349–365.
Pyšek, P. & Pyšek, A. 1990. Comparison of the vegetation and flora of the West Bohemian villages and towns. In: Sukopp, H., Hejný, S. & Kowarik, I. (eds.), Urban ecology, pp. 105–112, SPB Academic Publ., The Hague.
Pyšek, P. & Pyšek, A. 1991a. Succession in urban habitats: an analysis of phytosociological data. Preslia, Praha 63: 125–138.
Pyšek, P. & Pyšek, A. 1991b. Vergleich der dörflichen und städtischen Ruderalflora, dargestellt am Beispiel Westböhmens. Tuexenia, Göttingen 11: 121–134.

Pyšek, P. & Rydlo, J. 1984. Vegetace a flóra vybraných sídlišť v území mezi Kolínem a Poděbrady. Bohemia Centralis, Praha 13: 135–181.
Rebele, F. 1986. Die Ruderalvegetation der Industriegebiete von Berlin (West) und deren Immissionsbelastung. Landschaftsentw. und Umweltforsch., Berlin 43: 1–224.
Rebele, F. 1988. Ergebnisse floristischer Untersuchungen in den Industriegebieten von Berlin (West). Landschaft und Stadt 20: 49–66.
Rebele, F. 1991. Ecology on industrial wasteland. Symp. New nature on industrial sites, International Building Exhibition Emscher Park 1991, 17 pp. [ms.].
Rothmaler, W. *et al.* (eds.) 1976. Exkursionsflora für die Gebiete der DDR und der BRD. Berlin.
Saarisalo-Taubert, A. 1963. Die Flora in ihrer Beziehung zur Siedlung und Siedlungsgeschichte in den südfinnischen Städten Porvoo, Loviisa und Hamina. Ann. Bot. Soc. Vanamo 351: 1–90.
Scheuermann, R. 1928. Die Pflanzenwelt der Kehrichtplätze des rhein.-westf. Industriegebietes. Sitzungsber. Naturhist. Ver. Preuss. Rheinl. Westfalen 86: 256–342.
Scholz, H. 1960. Die Veränderungen in der Ruderalflora Berlins. Ein Beitrag zur jüngsten Florengeschichte. Willdenowia 2: 379–397.
Schulte, W., Sukopp, H., Voggenreiter, V. & Werner, P. 1986. Flächendeckende Biotopkartierung im besiedelten Bereich als Grundlage einer ökologisch bzw. am Naturschutz orientierten Plannung. Natur und Landschaft, Stuttgart 10: 371–389.
Sowa, R. & Olaczek, R. 1978. Stan badan szaty roślinnej miast polski. Wiad. Ekol. 24: 25–42.
Sowa, R. & Warcholinska, A.V. 1984. Flora synantropijna Sieradza i Zdunskej Woli. Acta Univ. Lodziensis, Fol. Bot 3: 151–207.
Sudnik-Wójcikowska, B. 1987. Dynamik der Warschauer Flora in den letzten 150 Jahren. Gleditschia, Berlin 15: 7–23.
Sudnik-Wójcikowska, B. 1988. Flora synanthropization and anthropopressure zones in a large urban agglomeration (exemplified by Warsaw). Flora, Jena 180: 481–496.
Sudnik-Wójcikowska, B. & Kozniewska, B. 1988. Slownik z zakresu synantropizacji szaty roslinnej. Warszawa.
Sukopp, H. 1969. Der Einfluß des Menschen auf die Vegetation. Vegetatio 17: 360–371.
Sukopp, H. 1971. Beiträge zur Ökologie von Chenopodium botrys L. I. Verbreitung und Vergesellschaftung. Verh. Bot. Ver. Prov. Brandenburg 108: 3–25.
Sukopp, H. 1972. Wandel von Flora und Vegetation in Mitteleuropa unter dem Einfluß des Menschen. Ber. Landw. 50: 112–139.
Sukopp, H. 1973. Die Großstadt als Gegenstand ökologischer Forschung. Schriften d. Vereins. z. Verbreitung naturwissensch. Kenntnisse in Wien 113: 90–140.
Sukopp, H. 1983. Die Bedeutung der Freilichtmuseen für den Arten- und Biotopschutz. In: Zippelius, A. (ed.), Aus Liebe zur Natur, Bonn 3: 34-42.
Sukopp, H. 1990. Urban ecology and its application in Europe. In: Sukopp, H., Blume, H.-P. & Kunick, W. 1979a. The soil, flora and vegetation of Berlins waste lands. In: Laurie, I.E. (ed.), Nature in cities, pp. 115–131, J. Wiley & Sons, Chichester.
Sukopp, H., Hejný, S. & Kowarik, I. (eds.) 1990. Urban ecology. SPB Academic. Publ., The Hague.
Sukopp, H. & Kowarik, I. 1986. Berücksichtigung von Neophyten in Roten Listen gefährdeter Arten. Schr. Reihe Vegetationsk., Bad Godesberg 18: 105–113.
Sukopp, H. & Köstler, H. 1986. Stand der Untersuchungen über dörfliche Flora und Vegetation in der Bundesrepublik Deutschland. Natur und Landschaft, Stuttgart, 7-8: 264–267.
Sukopp, H., Kunick, W. & Schneider, Ch. 1979b. Biotopkartierung in der Stadt. Natur u. Landschaft 54: 66–68.
Sukopp, H. & Sukopp, U. 1987. Leitlinien für den Naturschutz in Städten Zentraleuropas. In: Miyawaki, A. *et al.* (eds.), Vegetation ecology and creation of new environments, pp. 347–355, Tokyo Univ. Press.
Sukopp, H., Trautmann, W., Korneck, D. 1978. Auswertung der Roten Liste gefährdeter Farn- und Blütenpflanzen in der Bundesrepublik Deutschland für den Arten- und Biotopschutz. Schriftenreihe Vegetationskd. 12: 1–138.
Sukopp, H., Weiler, S. 1988. Biotope mapping and nature conservation strategies in urban areas of the Federal Republic of Germany. Lansc. Urban Plan. 15: 39–58.
Sukopp, H. & Werner, P. 1983. Urban environment and vegetation. In: Holzner, W., Werger, M.J.A., Ikusima, I. (eds.), Man's impact on vegetation, pp. 247–260, Junk Publ., The Hague.
Sukopp, H. & Werner, P. 1987. Development of flora and fauna in urban areas. European Committee for the Conservation of Nature and Natural Resources, Strassbourg.
Sukopp, H. *et al.* (1980). Contributions to urban ecology. Berlin (West). 2nd European Ecol. Symp., Excursionguide, Techn. Univ. Berlin.
Sukopp, H. *et al.* 1981. Liste der wildwachsenen Farn- und Blütenpflanzen von Berlin (West). Landesbeauftragter f. Natursch. Landschaftspfl. Berlin.
Sukopp, H. *et al.* 1986. Flächendeckende Biotopkartierung im besiedelten Bereich als Grundlage einer ökologisch bzw. am Naturschutz orientierten Planung. Natur u. Landschaft 61: 371–389.

Tlusták, V. 1990. Ruderální společenstva Olomouce. Diss. Bot. Inst. Czechoslovak Acad. Sci., Průhonice.
Trepl, L. 1983. Zum Gebrauch von Pflanzenarten als Indikatoren der Umweltdynamik. Sitzungsber. Ges. Naturforsch. Freunde zu Berlin 23: 151–171.
Tüllman, G. & Böttcher, H. 1983. Synanthropic vegetation and structure of urban subsystems. Coll. Phytosoc. Bailleuil 12: 481–523.
Višňák, R. 1986. Příspěvek k poznání antropogenní vegetace v severních Čechách, zvláště v měste Liberci. Preslia 58: 353–368.
Walters, S.M. 1970. The next twenty years. In: Perring, F. (ed.), The flora of changing Britain, pp. 136–141, Hampton,
Wiegleb, G. 1986. Grenzen und Möglichkeiten der Datenanalyse in der Pflanzensoziologie. Tuexenia, Göttingen 6: 365–377.
Wittig, R. 1973. Die ruderale Vegetation der Münsterschen Innenstadt. Natur u. Heimat, Heft 4: 100–110.
Wittig, R. 1984. Sterben die Dorfpflanzen aus? Der Gemeinderat 27 (6): 36–37.
Wittig, R. 1991. Ökologie der Großstadtflora. G. Fischer, Stuttgart.
Wittig, R., Diesing, D. & Gödde, M. 1985. Urbanophob – Urbanoneutral – Urbanophil. Das Verhalten der Arten gegenüber dem Lebensraum Stadt. Flora, Jena 177: 265–282.
Wittig, R. & Durwen, K.J. 1981. Das ökologische Zeigerwertspektrum der spontanen Flora von Großstädten im Vergleich zum Spektrum ihres Umlandes. Natur. u. Landsch. 56: 12–16.
Wittig, R. & Durwen, K.-J. 1982. Ecological indicator values spectra of spontaneous urban floras. In: Bornkamm, R., Lee, J.A. & Seaward, M.R.D. (eds.) 1982. Urban ecology. 2nd European ecological symposium, Berlin. Blackwell, Oxford.
Wittig, R. & Wittig, M. 1986. Spontane Vegetation in Westfalen. Decheniana, Bonn 139: 99–122.
Woodell, S. 1979. The flora of walls and pavings. In: Laurie, I.C. (ed.), Nature in cities, pp. 135–157, J. Wiley, Chichester.
Zajac, A. 1979. Pochodzenie archeofitow wystepujacych w Polsce. Rozpr. Habilit. Univ. Jagiel., Krakow 29: 1–213.
Zimmermann-Jaeger, S. 1971. Beiträge zur Ökologie von Chenopodium botrys L. III. Substanzproduktion und Wuchsfrom in Abhängigkeit von Beleuchtungsstärke, Feuchtigkeit und Substrat. Verh. Bot. Ver. Prov. Brandenburg 108: 29–36.