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Synanthropization of riparian plant communities in the Ojców National Park (Southern Poland)

Anna Sołtys-Lelek[1], Beata Barabasz-Krasny*[2] & Katarzyna Możdżeń[3]

[1]Ojców National Park, Ojców 9, 32-045 Sułoszowa, Poland
[2]Department of Botany, Institute of Biology, Pedagogical University, Podchorążych 2, 30-084 Kraków, Poland
[3]Department of Plant Physiology, Institute of Biology, Pedagogical University, Podchorążych 2, 30-084 Kraków, Poland
* corresponding author (e-mail: bbk@up.krakow.pl)

Abstract. Although riparian forests are still common in Europe, their variants – similar to natural forests – are rare. They are, as communities, early stages of forest-shrub succession, particularly vulnerable to the expansion of neophytes for which they are an important type of vegetation that enables their spread. In the Ojców National Park (ONP), these types of phytocoenoses are heavily influenced by anthropogenic pressure. The preservation of their biodiversity is particularly difficult because of the fragmentation and small area occupied by the Park – just 2.89 ha. There have been no data on synanthropization of ONP riparian forests until now. The 'conservation status' of these communities was determined by examining the degree of anthropophyte participation in their floristic composition. This determination is necessary to take effective preventive measures. In 2012-2014, phytosociological studies were carried out on the ONP riparian communities. A particular attention was paid to the presence and quantitative participation of alien species in research plots. The obtained results revealed that there were 189 plant species in alluvial forests of the ONP, including 80 synanthropic species. The group of synanthropes comprised 32 anthropophytes: 5 diaphytes, 9 archaeophytes and 18 kenophytes.

Key words: riparian forests, *Alno-Ulmion* alliance, human impact, synanthropization, kenophytes, Ojców National Park, Poland

1. Introduction

Riparian plant communities are found in Europe at different locations, from lowlands to mountains. They are typical azonal groups showing characteristics of eutrophic habitats, which are very hygrophilous, with lush undergrowth of herbaceous plants (Matuszkiewicz 2007). Currently, riparian forests in natural or semi-natural states are increasingly rare. It is the result of anthropogenic changes of the environment of valleys, river engineering, construction of dam reservoirs and levees (Borysiak 1990; Macicka & Wilczyńska 1993; Matuszkiewicz *et al.* 2000, 2012; Kowalska 2012).

Riparian areas, as forest communities with loose stands periodically flooded or waterlogged, are particularly vulnerable to expansion of neophytes, for which they become an important way of spreading (Matuszkiewicz *et al.* 2012; Tokarska-Guzik *et al.* 2014). In the Ojców National Park (ONP), due to the presence of a farm building, as well as a large village situated just off the northern border of the ONP, those phytocoenoses show signs of strong human pressure, although these communities were formed here in a natural way. As disturbed ecosystems, they are often colonized by different groups of anthropophytes, including neophytes (Sołtys-Lelek & Barabasz-Krasny 2010). Continuous penetration of the area by residents and tourists favours the spread of invasive plants. Construction and engineering works connected with strengthening of the banks of the Prądnik stream are just a few examples of activities that contribute to soil exposure and allow encroachment of alien invasive species (Klasa & Sołtys-Lelek 2013). Riparian forest habitats occur mainly at low streamside and floodplain terraces of the Prądnik and the Sąspówka rivers in the ONP. They occupy a total of 4.02 hectares, including a community of riverside terraces, left to natural succession, while riparian forests cover only 2.89 ha in the ONP (Plan ochrony 2014).

So far, there have not been any comprehensive studies of riparian plant communities in the ONP, especially the ones related to their synanthropization. Fragmentary

data on the subject came from the research works on the flora of the ONP of 1960s. (Michalik 1978). Later, a few references to the subject appeared in other research works: Sołtys (2002-2003), Medwecka-Kornaś (2008), Sołtys-Lelek & Barabasz-Krasny (2010, 2011). For those reasons, it was decided to undertake a study of riparian plant communities. Its aim was to determine the state of preservation of riparian communities occurring within the ONP.

2. Study area

The ONP was established in 1956. It is situated 22 km north of Kraków, in the southern part of Kraków-Częstochowa Upland (50°12′24″N, 19°49′45″E). At present, the Park covers the area of 2 146 ha. There are two main karst valleys of streams within the Park: the Prądnik and the Sąspówka. Prądnik Valley, which is approx. 12 km long, runs from north-west to south-east. The village of Ojców is located in its centre. In its northern part, there are dispersed buildings of two hamlets: Pieskowa Skała and Młynnik and the village of Prądnik Korzkiewski is located in the south. The main hiking trails and transit routes of the Park run along the bottom of the valley. Sąspówka Valley is 5 km long and stretches in the east-west direction. It is free of rural housing and there are only a few scattered farms in its upper part. There is a hiking trail running along

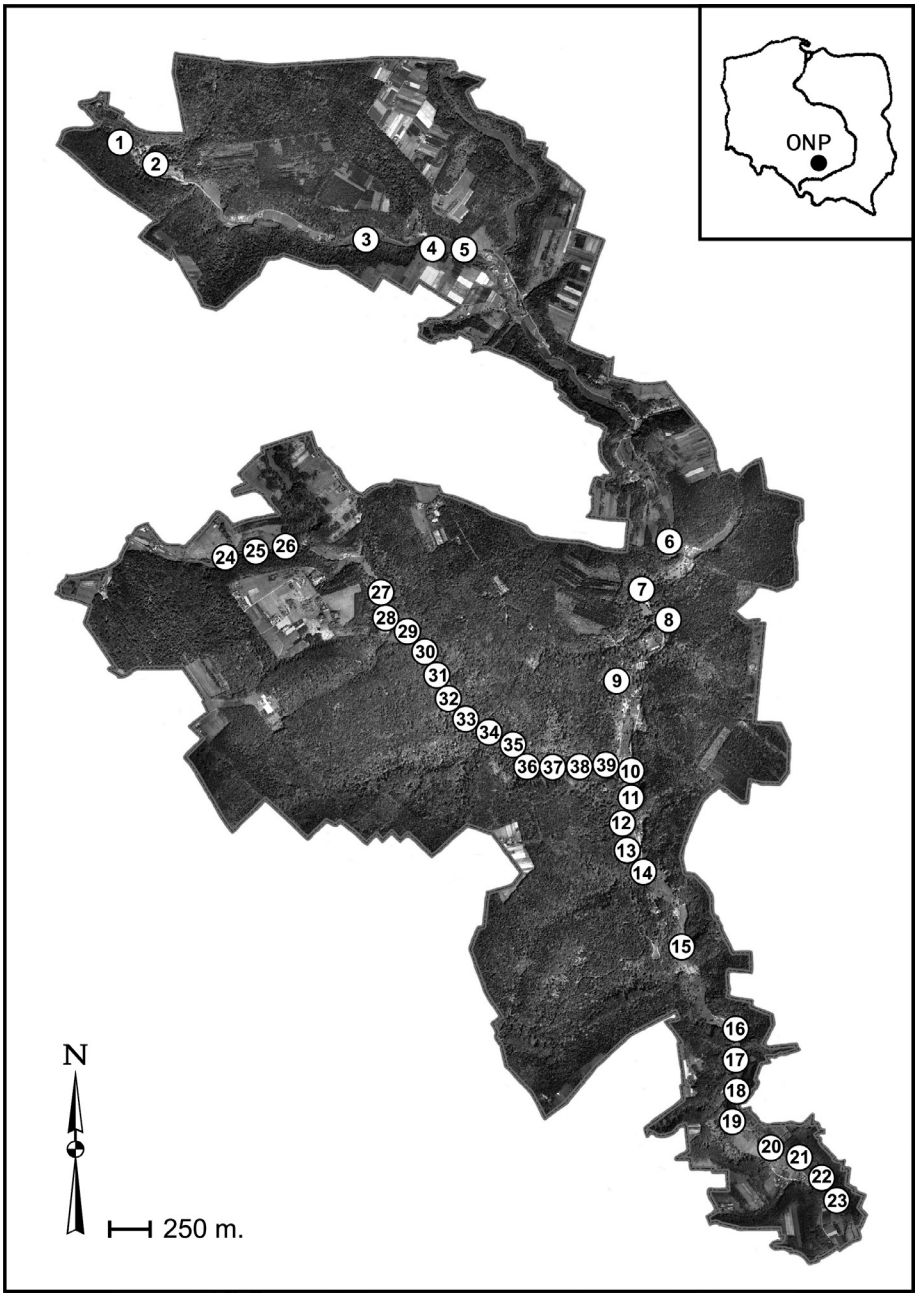

Fig. 1. Distribution of research plots in the Ojców National Park (Southern Poland)
Explanations: Prądnik Valley (1-23), Sąspowska Valley (24-39)

the bottom of the valley but it is much less frequented than the one in Prądnik Valley (Partyka 2005).

All that territory is built of Upper Jurassic limestone. The activity of the karst water in the Pliocene created a unique landscape: V-shaped valleys, with steep canyons up to 120 meters deep (Aleksandrowicz & Wilk 1962). The climate of the Ojców National Park is that of central uplands and distinguished by pronounced continental characteristics. Mean annual temperature is equal to ca. 8°C. Mean annual precipitation amounts to 625 mm at the bottom of the valley and to 689 mm on the top surface (Klein 1977).

In the ONP, about 35 plant associations have been established. Of all the plant communities in the ONP, forests occupy the largest area (about 1631.61 ha) growing in the uplands, on steep slopes and in some places on stream banks. Patches of *Pino-Quercetum* Mat. et Polak. 1955 (=*Querco roboris-Pinetum* (W. Mat. 1981) J.Mat. 1988) association prevail on uplands, on northern slopes – *Dentario glandulosae-Fagetum* W. Mat. 1964 ex Guzikowa et Kornaś 1969, and on southern slopes – *Tilio-Carpinetum* Tracz. 1962. On bottoms of the valleys, alluvial forests of *Alno-Ulmion* Br.-Bl. et R.Tx. 1943 alliance occur (Michalik 2008; Plan ochrony 2014).

3. Material and methods

The field work was conducted on 39 research plots in 2012-2014. The area of each plot was 800 m^2. One phytosociological relevé was taken in every plot following the methodological guidelines of Braun-Blanquet. Only those parts of forests where density of the stand exceeded 30% were chosen for the study. They were located in Prądnik Valley (relevés No. 1-23, Fig. 1), and in Sąspówka Valley (relevés No. 24-39, Fig. 1).

The collected phytosociological material was numerically classified. The classification was carried out in two ways: based on species abundance according to 6-grade Braun-Blanquet scale (the value of 0.5 was assumed as +) and according to species presence/absence (binary scale 0, 1). In both cases, to vectors representing relevés, the van der Maarel coefficient of similarity was applied according to the formula:

$$r(x\text{-}y) = \frac{\sum xy}{\sum x^2 + \sum y^2 - \sum xy}$$

The method of "Minimum Variance Clustering" was used for grouping. The MULVA-5 package was applied for the classification (Wildi & Orlóci 1996). The comparison of dendrograms obtained from the classification made it possible to distinguish groups of relevés homogeneous in terms of species abundance and the species presence/absence in communities (Dzwonko & Loster 1990, 1992).

Based on the obtained phytosociological table, a detailed analysis of the floristic composition, with particular emphasis on anthropophytes, was conducted. The analyses also included the relevés that differed in terms of abundance and composition from the selected sociological groups. The geographical-historical division of species was adopted by the following approach:

- Sn – native species (non-synanthropic sponthaneophytes), associated with natural and semi-natural habitats,
- Ss – synanthropic sponthaneophytes (=apophytes), native species mainly associated with anthropogenic and semi-natural habitats,
- Ar – archaeophytes, permanently established alien species which appeared before the discovery of America,
- Kn – kenophytes, permanently established alien species, which appeared after the discovery of America; among them:
  - Ep – epecophytes, occurring in anthropogenic habitats,
  - He – hemiagriophytes, occurring in semi-natural habitats,
  - Ho – holoagriophytes, invading in natural habitats),
- D – diaphytes, alien species appearing periodically, or escaping from crop to anthropogenical habitats (=ergasiophygophytes Er) (Kornaś 1968; Sudnik-Wojcikowska & Koźniewska 1988; Jackowiak 1990; Chmiel 1993).

For the purpose of the study, species belonging to geographical-historical groups were classified after Kornaś (1968, 1972), Michalik (1978), Urbisz (2004) and Tokarska-Guzik *et al*. (2014), while phytosociological membership was given after Matuszkiewicz (2007). The nomenclature of vascular plants was used according to the one given by Mirek *et al.* (2002).

Apart from that, values of the following indices from the analysed plots in the valleys and two groups of relevés of dendrograms (A and B) were compared:

- Index of synanthropization I_S – as the ratio of the number of synanthropic species to the total number of species recorded in the phytosociological relevés, presented in percent (Jackowiak 1990; Chmiel 1993; Dyderski & Jagodziński 2014);
- Index of anthropophytization I_A – as the ratio of the number of anthropophyte species and the total number of species recorded in the phytosociological relevés, presented in percent (Jackowiak 1990; Chmiel 1993; Dyderski & Jagodziński 2014);
- Index of kenophytization I_K – as the ratio of the number of kenophytes to the total number of species

recorded in the phytosociological relevés, presented in percent (Jackowiak 1990; Chmiel 1993; Wysocki & Sikorski 2009);
- Index of general diversity $H = - \sum(n_i/N) \log (n_i/N)$ (Shannon & Weaver 1963), where n_i is the abundance degree of i- species on a 6-point Braun-Blanquet scale (0.25 was assumed as +), and N is the total sum of abundance of all species;
- Index of uniformity $J = H'/\log S$ (Pielou 1975), where H is the value of the Shannon index, and S the number of species for which the H was calculated;
- Index of dominance $C = \sum(n_i/N)$ (Simpson 1949; Shannon & Weaver 1963).

4. Results

Classification of phytosociological relevés showed that two groups could be distinguished in the plots. One with *Alnus glutinosa* dominance (A) in the stand and the other with *Salix fragilis* dominance (B) in the stand and also its occurrence in the shrub layer (Fig. 2). The first group could be divided into four sub-groups. A1 and A2 were quite similar to each other in composition and abundance of species; however, A2 was not as uniform as A1. Both of the sub-groups were characterized by the fact that *Padus avium* occurred there in the shrub layer, with abundance from + to 3. Like the other two

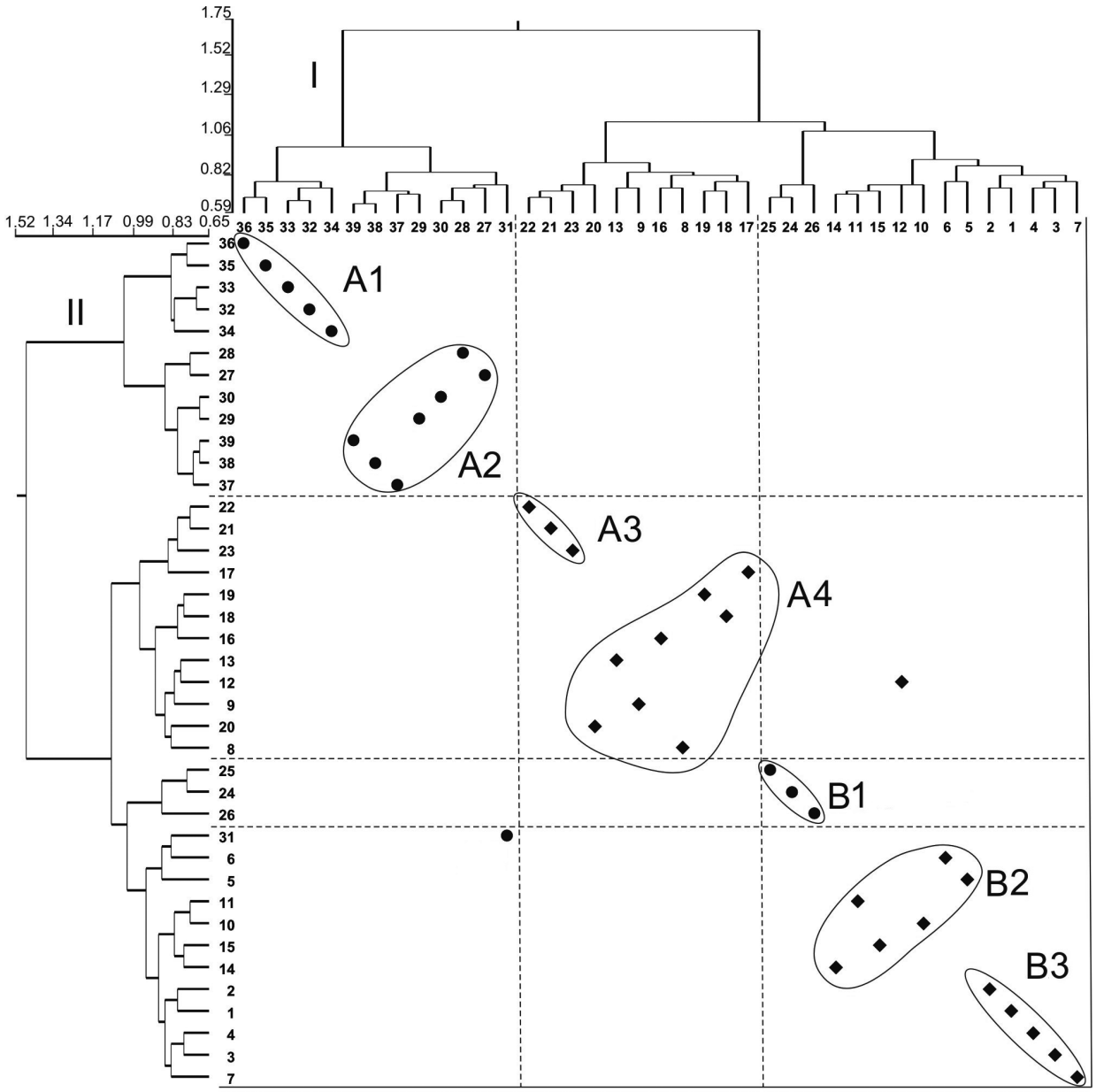

Fig. 2. Classification of the 39 phytosociological relevés of riparian plant communities in the Ojców National Park

Explanations: I – dendrogram based on species abundance; II – dendrogram based on species presence; ◆ – relevés in Prądnik Valley; ● – relevés in Sąspowska Valley; not described plots are outliers; relevé groups, A – plots with the domination of *Alnus glutinosa* in tree layer, B – plots with the domination of *Salix fragilis* in tree and shrub layers

Table 1. Synanthropic species found in the riparian plant communities of the Ojców National Park

Name of species	Number of research plots	Geographical-historical status	Class	Current status in Poland
Achillea millefolium L.	1	Ap	*Mol.-Arrh.*	-
Aesculus hippocastanum L.	5	Ho	-	LE
Alchemilla crinita Buser	1	Ap	-	-
Alchemilla monticola Opiz	1	Ap	*Mol.-Arrh.*	-
Apera spica-venti (L.) P. Beauv.	1	Ar	*St. med.*	-
Arrhenatherum elatius (L.) P. Beauv. ex J. Presl & C. Presl	4	Ap	*Mol.-Arrh.*	-
Artemisia vulgaris L.	2	Ap	*Art. vul.*	-
Avena sativa L.	1	Er	-	-
Barbarea vulgaris R. Br.	1	Ap	-	-
Carduus crispus L.	10	Ap	*Art. vul.*	-
Carex brizoides L.	3	Ap	-	-
Cerastium holosteoides Fr. emend. Hyl.	1	Ap	*Mol.-Arrh.*	-
Chenopodium album L.	1	Ap	*St. med.*	-
Cirsium arvense (L.) Scop.	4	Ap	*Art. vul.*	-
Convolvulus arvensis L.	2	Ar?	*Agr.*	E
Crataegus pedicellata Sarg.	2	He	-	LE
Crepis biennis L.	1	Ap	*Mol.-Arrh.*	-
Dactylis glomerata L.	5	Ap	*Mol.-Arrh.*	-
Echinocystis lobata (F. Michx.) Torr. & A. Gray	1	He	-	E, I
Equisetum arvense L.	1	Ap	*Agr.*	-
Erigeron annuus (L.) Pers.	5	He	-	E, I
Euphorbia helioscopia L.	2	Ar	*St. med.*	E
Fragaria vesca L.	1	Ap	*Epi. ang.*	-
Galinsoga ciliata (Raf.) S. F. Blake	1	Ep	*St. med.*	E, I
Galinsoga parviflora Cav.	3	Ep	*St. med.*	E, I
Galium mollugo L.	1	Ap	*Mol.-Arrh.*	-
Geranium pratense L.	3	Ap	*Mol.-Arrh.*	-
Heracleum sphondylium L. s. str.	3	Ap	*Mol.-Arrh.*	-
Impatiens glandulifera Royle	21	He	*Art. vul.*	E, I
Impatiens parviflora DC.	34	Ho	*Art. vul.*	E, I
Lactuca serriola L.	1	Ar	*St. med.*	E
Lamium album L.	1	Ar	*Art. vul.*	E
Lamium purpureum L.	2	Ar	*St. med.*	E
Lapsana communis L.	10	Ap	*St. med.*	-
Lathyrus pratensis L.	1	Ap	*Mol.-Arrh.*	-
Lolium perenne L.	6	Ap	*Mol.-Arrh.*	-
Matricaria maritima L. ssp. *inodora* (L.) Dostál	3	Ar	*St. med.*	-
Medicago lupulina L.	2	Ap	-	-
Mentha aquatica L.	1	Ap	-	-
Oxalis fontana Bunge	5	Ep	*St. med.*	E, I
Papaver rhoeas L.	1	Ar	*St. med.*	E
Parthenocissus inserta (A. Kern.) Fritsch	1	He	-	E, I
Phleum pratense L.	2	Ap	*Mol.-Arrh.*	-
Plantago lanceolata L.	2	Ap	*Mol.-Arrh.*	-
Plantago major L.	14	Ap	*Mol.-Arrh.*	-
Poa annua L.	6	Ap	-	-
Poa pratensis L.	6	Ap	*Mol.-Arrh.*	-
Poa trivialis L.	2	Ap	*Mol.-Arrh.*	-
Polygonum aviculare L.	1	Ap	*St. med.*	-
Potentilla anserina L.	2	Ap	*Mol.-Arrh.*	-
Pyrus communis L.	1	He	-	E
Ranunculus acris L.	2	Ap	*Mol.-Arrh.*	-
Ranunculus repens L.	19	Ap	*Mol.-Arrh.*	-
Reynoutria japonica Houtt.	5	He	-	E, I
Rubus caesius L.	5	Ap	*Art. vul.*	-
Rubus idaeus L.	16	Ap	*Epi. ang.*	-
Rubus plicatus Weihe & Ness	1	Ap	*Rha.-Prun.*	-
Rudbeckia laciniata L.	1	He	*Art. vul.*	E, I

Name of species	Number of research plots	Geographical-historical status	Class	Current status in Poland
Rumex obtusifolius L.	24	Ap	*Art. vul.*	-
Salix caprea L.	6	Ap	*Epi. ang.*	-
Secale cereale L.	1	Er	-	-
Senecio jacobaea L.	1	Ap	-	-
Senecio viscosus L.	1	Ap	-	-
Senecio vulgaris L.	1	Ap	-	-
Solidago canadensis L.	9	Ho	*Art. vul.*	E, I
Solidago gigantea Aiton	1	Ho	*Art. vul.*	E, I
Sonchus oleraceus L.	3	Ar	*St. med.*	-
Sorbaria sorbifolia (L.) A. Braun	1	He	-	E
Sorbus aucuparia L. emend. Hedl.	1	Ap	-	-
Stellaria media (L.) Vill.	12	Ap	*St. med.*	-
Symphoricarpos albus (L.) S. F. Blake	4	He	-	E
Symphytum officinale L.	3	Ap	-	-
Syringa vulgaris L.	2	Er	-	E
Tanacetum parthenium (L.) Sch. Bip.	1	Er	-	E
Taraxacum officinale F. H. Wigg.	14	Ap	*Mol.-Arrh.*	-
Triticum aestivum L.	1	Er	-	-
Tussilago farfara L.	3	Ap	*St. med.*	-
Veronica chamaedrys L.	5	Ap	-	-
Veronica persica Poir.	3	Ep	*St. med.*	E, I
Viburnum opulus L.	1	Ap	*Rha.-Prun.*	-

Explanations: Ap – apophytes in Poland (synanthropic spontaneophytes), Ar – archaeophytes, Ep – epecophytes, Er – ergasiophygophytes, He – hemiagriophytes, Ho – holoagriophytes; *Agr. – Agropyretea*, *Art. vul. – Artemisietea vulgaris*, *Epi. ang. – Epilobietea angustiifolii*, *Mol.-Arrh. – Molinio-Arrhenatheretea*, *Rha.-Prun. – Rhamno-Prunetea*, *St. med. – Stellarietea mediae*; LE – locally established, E – established, I – invasive

sub-groups – A3 and A4, they had one layer of tree species typical for the oak-hornbeam forest, such as *Acer pseudoplatanus*, *A. platanoides*, or *Carpinus betulus*. Sub-groups A3 and A4 also had a dominant *Alnus glutinosa* in the stand but the herb layer was characterized by the presence of a large group of species from the *Artemisietea* class, also common for group (B), e.g.: *Impatiens glandulifera, Petasites hybridus*, *Geranium robertianum*, *Chaerophyllum temulum Chelidonium majus*, *Carduus crispus*, *Solidago canadensis* and others. Therefore, in dendrograms, they were linked to group (B). Moreover, the species of the *Stellarietea* class occurred in the two sub-groups. Group (B) with *Salix fragilis* dominance in the stand could also be distinguished by *S. purpurea* and *S. caprea* occurrence in the shrub layer of the plots. Although the group was divided into three sub-groups in the classification, floral and quantitative differences between them were relatively insignificant (Fig. 2, Appendix 1).

A total of 189 species of vascular plants were reported in the studied riparian plant communities. The floristic spectrum comprised mainly species of the *Querco-Fagetea* class (24%), with a significant share of meadow species of the *Molinio-Arrhenatheretea* class (16%) and ruderal ones with *Artemisietea vulgaris* (15%) (Fig. 3). 80 species were classified as synanthropic (Table 1). Among them, 48 were classified as apophytes (synanthropic spontaneophytes) and 32 as anthropophytes. Kenophytes – 18 species were the most common among anthropophytes. The others were: archaeophytes (9 species) and diaphytes (5 species). A detailed division of the anthropophytes and their relation to the apophytes is shown in Fig. 4.

The meadow species of the *Molinio-Arrhenatheretea* class, represented by 20 apophytes (25%), dominated in the ecological structure of synanthropic flora of riparian forests. The most common of this group were *Ranunculus repens* (19 records), *Plantago major* and *Taraxacum officinale* (14 records each). The species of nitrophilous habitats and annual plants of cultivated fields with the *Stellarietea mediae* class (16 species – 20%) were also frequent in the flora of this type of forests. Among them, 5 apophytes, 7 archaeophytes and 4 epecophytes were recorded. The most numerous representatives of the class were: *Stellaria media* (12 records) and *Lapsana communis* (10 records). The *Artemisietea vulgaris* class was represented by 11 species (14%); apophytes (5 species) and kenophytes (5 species) dominated among them. *Impatiens parviflora* (34 records) was the most frequent species recorded among the kenpohytes of this class (Fig. 3, Table 1, Appendix 1).

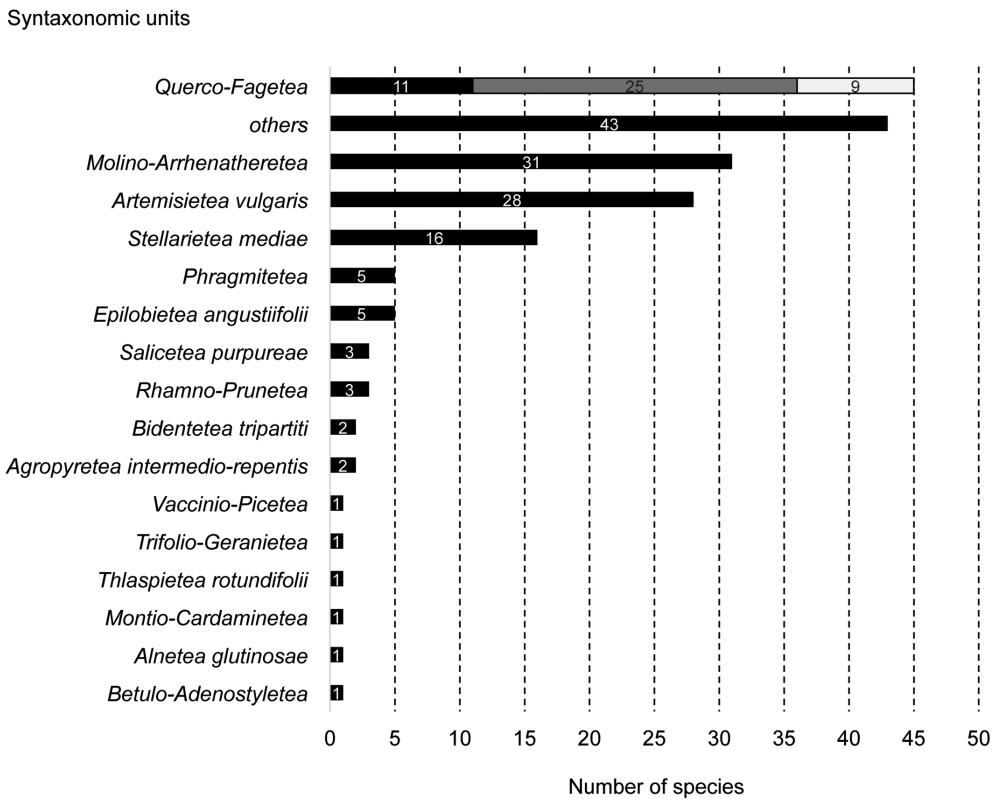

Fig. 3. Participation of species representing particular phytosociological classes in the riparian plant communities of the Ojców National Park
Explanations: *Querco-Fagetea* include species characteristic for the class (11), species characteristic for the *Fagetalia* order (25), species characteristic for the *Alno-Ulmion* alliance (9)

The synanthropization index I_S for all the plots of the surveyed communities amounted to 42.33%. In Prądnik Valley, it reached 43.45% (73 synanthropic species, including: 42 apophytes, 31 anthropophytes – among them 17 kenophytes, 9 archaeophytes and 5 diaphytes), and in Sąspówka Valley – 23.42% (26 synanthropic species, including: 21 apophytes and 5 anthropophytes – among them there were 4 kenophytes and 1 diaphyte). The number of synanthropic species in a single phytosociological relevé was in the range from 0 to 29 in Prądnik Valley from 3 to 29 and in Sąspówka Valley from 0 to 14 (Fig. 5, Table 2). The anthropophytization index I_A of the analysed communities amounted to 16.93% and the kenophytization one I_K reached 9.52%. They were different for the particular valleys. For Prądnik Valley, the anthropophytization index was 18.45%, and the kenophytization one – 10.12%, and for Sąspówka Valley, they were 4.50% and 3.60%, respectively (Table 2).

A comparison of diversity indices showed that all relevés, both within the analysed valleys as well as those distinguished in the classification, had a relatively high value of the H index (from 4.39 to 4.07), which might

Table 2. Comparison of various indicator values of the riparian communities in the Ojców National Park

Name of index	Prądnik Valley	Sąspowska Valley	Group A in dendrograms	Group B in dendrograms	All relevés
	Number of relevés				
	23	16	23	14	39
synanthropization I_S [%]	43.45	23.42	38.96	34.85	42.33
anthropophytization I_A [%]	18.45	4.50	16.23	13.64	16.93
kenophytization I_K	10.12	3.60	8.44	10.61	9.52
general diversity H	4.37	4.07	4.33	4.18	4.39
uniformity J	0.63	0.63	0.63	0.66	0.59
dominance C	0.02	0.03	0.02	0.02	0.02
Average number of synanthropic species in relevé	11.39	4.75	8.56	9.07	8.66

indicate high species abundance. However, it should be taken into consideration that the value of the index depends not only on the total number of species, but also on the number of species with high coverage. The values of the uniformity index J in all groups showed little differences – from 0.59 to 0.66. Similarly, domination indices were at a similar level – from 0.02 to 0.03. They were very low, indicating that there were no clear dominants in the plots (Table 2).

5. Discussion

Due to fragmentary occurrence, riverside riparian plant communities in the ONP were difficult to classify into a particular group of plants. Some of the plots were similar to *Fraxino-Alnetum* W. Mat. 1952 of the *Alno-Ulmion* alliance, which was reported earlier by Michalik (2008). Among the analysed phytosociological relevés, the similarity corresponded to plots which were classified as Group A in the classification dendrograms (Fig. 2, Appendix 1). *Alnus glutinosa* with admixture of *Fraxinus excelsior* was a dominant component of the stand there. In the undergrowth, there was a significant share of species from the *Fagetalia* order and nitrophytes, such as *Urtica dioica*, *Impatiens noli-tangere, Geum urbanum* and, in some plots, *Padus avium* was abundant in the understory layer. According to Matuszkiewicz (2007), such features may indicate that they are really *Fraxino-Alnetum* plots. In the area of Poland, such communities are often adjacent to meadows and oak-hornbeam forests, hence it is not unusual that species penetrating from those phytocoenoses occur in their species composition.

Group B distinguished in the classification dendrograms had *Salix fragilis* as a dominant species in the stand (Fig. 2, Appendix 1). The species, along with *S. purpurea* and *S. caprea*, was quite abundant in the understory of those plots. The phytosociological relevés related to this group were characterized by a lower quantitative share of species of the *Fagetalia* order, with quite abundant occurrence of taxa from the *Molinio-Arrenatheretea* class. Such species as *Calystegia sepium, Phalaris arundinacea,* distinctive for the *Salicion albae* alliance, were also present there. Willow occurrence in the stand and the understory and other features listed above may indicate that the plots resembled the *Salicetum albo-fragilis* R.Tx. 1955 association, of the *Salicetea purpureae* class. Phytocoenoses of that association are usually fragmentary in Poland. Typical *Salicetum albo-fragilis* plots are very rare (Matuszkiewicz 2007).

Due to the aforementioned fragmentary occurrence of riparian plant communities in the ONP and a specific character of the Park, where Ojców village is located in its central part and farm buildings are scattered, the phytocoenoses are shaped by the anthropogenic impact. Therefore, most of the plots had more or less disturbed floristic composition (Appendix 1, Fig. 5). The phytosociological relevés presented recorded species from various places such as: ecotones, fields, ruderal habitats and invasive alien taxa, including neophytes (Figs. 3-4). Occurrence of such floristic components weakens

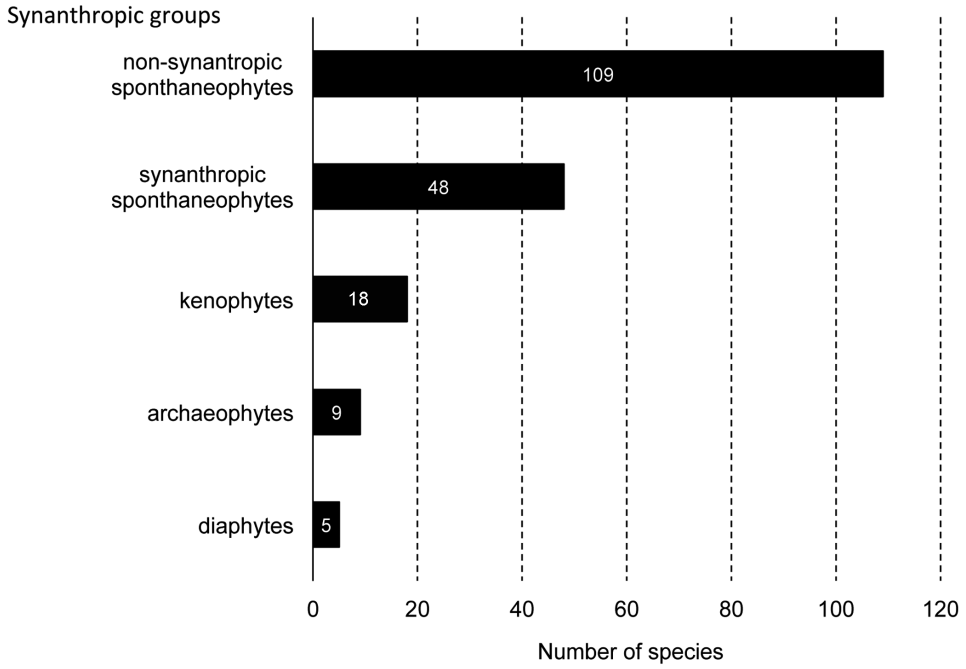

Fig. 4. Geographical and historical division of synanthropic species occurring in the riparian plant communities of the Ojców National Park
Explanations: kenophytes includes hemiagriophytes (10), epecophytes (4), holoagiophytes (4)

the degree of naturalness and stability of communities (Kryszak *et al.* 2011). As it was observed by Matuszkiewicz (2002), plots of riparian plant communities are usually disturbed, making it difficult to determine values of floristic indices typical for them.

The general index of synanthropization of the riparian communities in the ONP was not high (I_S = 42.33% – Table 2). About 80% of synanthropic species recorded in the ONP belonged to the lowest class of frequency and had from 1 to 5 stands (Table 1). Quite frequently, they penetrated from the neighbouring communities. This concerned mainly taxa typical for hay-growing meadows of the *Molinio-Arrhenatheretea* class and species of cultivated fields of the *Stellarietea mediae* class (Appendix 1). Bottoms of Prądnik and Sąspówka Valleys have been intensively used for agricultural purposes since the nineteenth century. Only since the 1970s, conversion of farmlands to forests and grasslands has been observed (Partyka 2005). Riparian communities are adjacent to communities of semi-natural grasslands in the landscape of Prądnik and the Sąspówka Valleys, for example: *Arrhenatheretum elatioris* or *Phalaridetum arundinaceae* and in the forest areas – mainly to oak-hornbeam *Tilio-Carpinetum* forests (Michalik 1978; Medwecka-Kornaś 2008). Due to the penetration of species, the anthropophytization index I_A was slightly

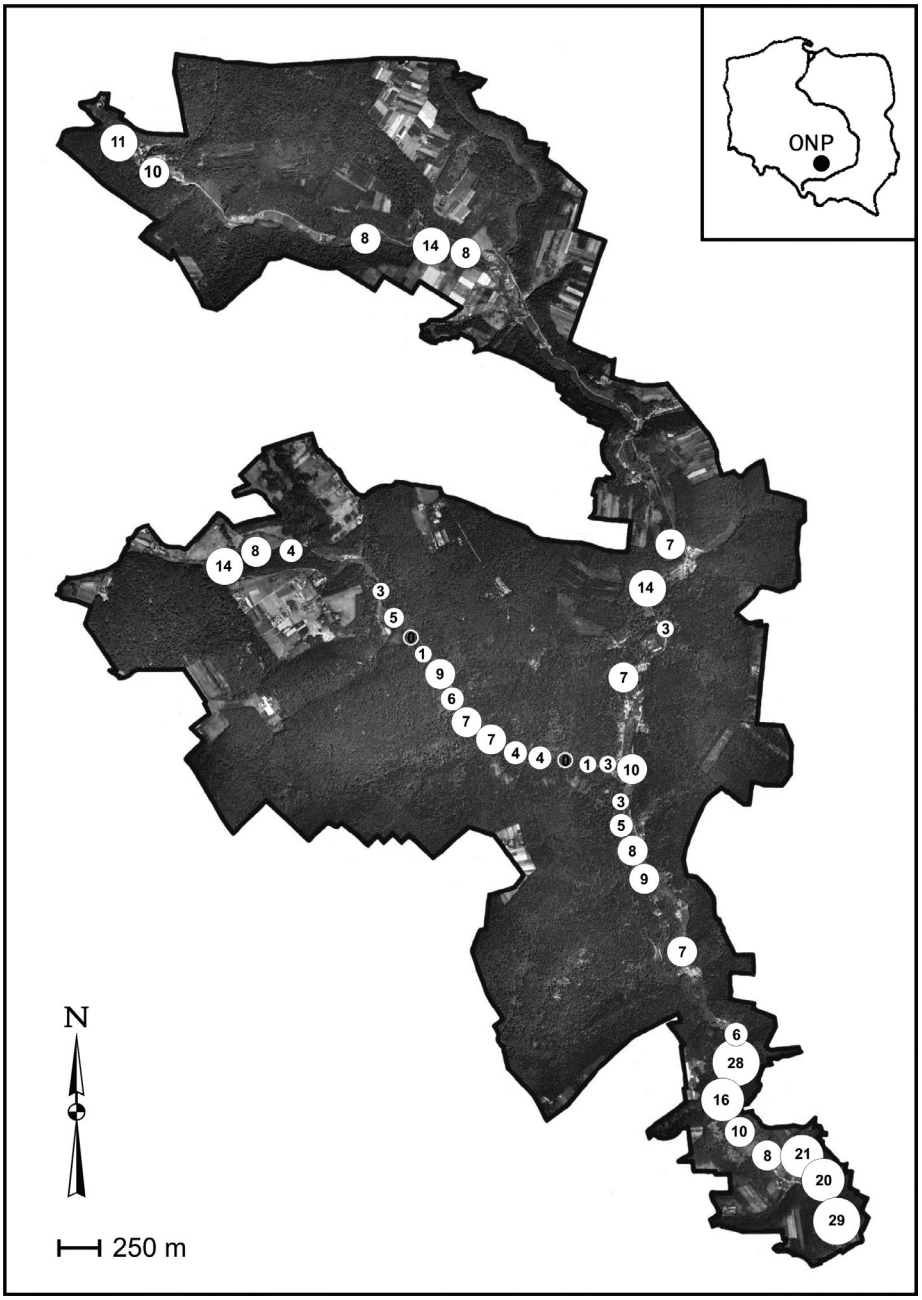

Fig. 5. The comparison of the number of synanthropic species in the individual research plots
Explanations: the arrangement and numbering of plots in accordance with Fig. 1

higher in the plots similar to *Fraxino-Alnetum* (group A in the dendrograms) (Table 2).

Migrating species from neighbouring habitats made plots of the analysed communities very rich in species. 27 to 76 species were found there in the phytosociological relevés (Appendix 1). On the other hand, the average number of species of *Salicetum albo-fragilis* from the Warta riverside is 22.4 (Borysiak *et al*. 1993), and from 6 to 25 species were recorded in the phytosociological relevés of riparian communities in the vicinity of Poznań (Dyderski & Jagodziński 2014). Significant abundance of species in the riparian communities of the ONP was confirmed by a high index value of the general diversity H. It proved dynamic changes of the species composition of riparian communities in the ONP and lack of their stability as a result of various anthropogenic impacts (Kryszak *et al.* 2011; Barabasz-Krasny 2011). This is also confirmed by the distribution of photos within groups distinguished in the dispersion diagram (Fig. 2). A large floristic variety with no clear dominants was a characteristic feature of the plots. It was also reflected by very low indices of dominance C (Table 2).

Despite strong human pressure, riparian communities in the ONP had a relatively low overall index of anthropophytization (I_A = 16.93%), and kenophytization (I_K = 9.52%) – Table 2. This was probably the result of protective measures which had been taken in the Park. For example, specimens of *Impatiens glandulifera* and *Echinocystis lobata* were removed along the whole Prądnik Valley in 2012. The procedure was repeated in 2015 and it is also planned to carry it on in 2016. In this way, *E. lobata* has been almost completely eliminated and the number of specimens of *I. glandulifera* and the area occupied by it have been significantly reduced. Of course, such measures require systematic activities, financial resources and they are time consuming. Therefore, they can be carried out only in areas under partial or landscape protection.

Comparing values of all indices related to synanthropization within groups distinguished in the classification dendrograms, it can be observed that the value of kenophytization index I_K was slightly higher in group B, resembling the *Salicetum albo-fragilis* association (Table 2). This was probably due to the fact that the plots of that type were located directly along the streams and they were prone to frequent flooding and reclamation works exposing the soil which allowed formation of neophyte diasporas. Especially, the Prądnik stream flowing through the ONP is a major ecological corridor for all propagules which are transported to the southern border of the Park (Sołtys-Lelek & Barabasz-Krasny 2010, 2011). It can be also confirmed by more frequent occurrence of species of the *Artemisietea* class from disturbed sites in plots of the B group (Appendix 1).

Significant differences in synanthropization index values concerned mostly the analysed valleys (Figs. 1, 5; Tables 1-2). For example, four times more kenophytes were reported in Prądnik Valley than in Sąspówka Valley. It was associated with different intensity of the anthropogenic impact. Prądnik Valley is a place where the main tourist traffic is concentrated and there are also numerous farm buildings there. On the other hand, except for a few farms, there are no buildings in Sąspówka Valley. Some of the synanthropic plants recorded in Prądnik Valley were introduced as ornamental species into gardens or parks of castles and then they penetrated into riparian communities. *Aesculus hippocastanum*, *Crataegus pedicellata*, *Echinocystis lobata*, *Impatiens glandulifera*, *Parthenocissus inserta*, *Syringa vulgaris*, *Sorbaria sorbifolia*, *Solidago canadensis* and *S. gigantea*, *Symphoricarpos albus* and *Reynoutria japonica are examples of such species*, while others spread spontaneously there, for example *Impatiens parviflora*. Such synanthropic species as *Pyrus communis, Syringa vulgaris* or *Aesculus hippocastanum* are remnants of ancient settlements in Sąspówka Valley.

The most abundant kenophytes in the ONP riparian communities were: *Impatiens parviflora* (34 records), *I. glandulifera* (21 records) and *Solidago canadensis* (9 records) (Table 1). High frequency of *I. parviflora* occurrence in the investigated alluvial communities may be the result of numerous factors, including periodic drying up of the habitat, along with the increasing pressure of tourism and uncontrolled penetration of forests. It is related to treading the soil and formation of gaps in the undergrowth, which are easily colonized by this invasive species. Similarly, gaps in stands facilitate expansion of that species (Chmura 2014; Tokarska-Guzik *et al.* 2014). According to Piskorz (2005), *I. parviflora* bears fruit more abundantly in gaps than in dense stands. It should be remembered that riparian forest stands in the ONP are not very dense, which is another advantage supporting expansion of the species.

Riverside riparian areas form an ecosystem which is very sensitive to changes in habitat conditions, especially hydrographic conditions (Olaczek 1972; Borysiak 1990). In the case of drying up, the undergrowth may take on an oak-hornbeam character. Some of the investigated plots in the ONP were abundant in broadleaved species (group A – Appendix 1). Tree species typical of oak-hornbeam and beech forests occurred in some of the plots: *Tilia platyphyllos*, *Carpinus betulus*, *Fagus sylvatica*. According to Matuszkiewicz *et al.* (2012), the more rapid the process is, the more synanthropic species invade riparian communities. Loss of characteristic features of the ecosystem is treated as an important risk factor for riparian areas in Poland. In many parts of our country, drying of habitats, in the result of a general fall of the ground water horizon or accelerated deep erosion

of watercourses, for example, following engineering works, can be observed (Kornaś 1972).

Preserving the diversity of riverside riparian zones in the ONP is particularly difficult due to their small areas. When considering biodiversity of the whole Park, those communities are particularly endangered and they are under protection not only within the National Park, but also, since 2009, their protection has been provided through special areas of habitat protection 'Natura 2000', called "The Valley of Prądnik" (PLH120004, habitat code 91E0). Maintaining natural hydrological conditions is essential for habitats, which can be achieved by means of passive protection in the ONP. However, in the case of plots invaded by species of foreign origin, active protective measures are necessary to repel the invasive taxa. Therefore, measures are being considered to implement active protection measures against the most expansive neophytes, such as *Aesculus hippocastanum*, *Crataegus pedicellata*, *Echinocystis lobata*, *Impatiens glandulifera*, *Parthenocissus inserta*, *Pyrus communis*, *Syringa vulgaris*, *Sorbaria sorbifolia, Solidago canadensis, S. gigantea* and *Symphoricarpos albus*. Those treatments would include removing them by cutting and digging before their flowering period. However, it requires financial outlays and necessity to raise funds from various external sources by the Park Administration.

6. Conclusions

Riparian communities in the ONP were found to be in a fragmentary form. Among them, there were two groups of plots: (*i*) resembling a *Fraxino-Alnetum* association from the *Alno-Ulmion* alliance and (*ii*) resembling *Salicetum albo-fragilis* from the *Salicion albae* alliance. High values of biodiversity indices confirmed dynamic changes in species composition and lack of their stability. Due to a small area of those phytocoenoses, their species composition was significantly influenced by their direct neighbourhood. In spite of increased human pressure, riparian communities in the ONP showed relatively low indices of synanthropization, anthropophytization and kenophytization. This was probably a result of their protection within the National Park and additional protective measures which were carried out.

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Appendix 1.

Differentiation of riparian plant communities in the Ojców National Park

Successive No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Date (day/month/year)	27.6.12	27.6.12	27.6.12	27.6.12	27.6.12	27.6.12	27.6.12	27.6.12	06.7.12	06.7.12	06.7.12	09.6.12	22.7.14	28.7.14	22.7.14	28.7.14	05.7.12	05.7.12	04.9.12	18.7.12	18.7.14	18.7.14	04.9.12
Slope (degrees)	40	30	20	20	20	30	40	40	10	10	30	40	40	40	40	35	30	40	0	20	30	10	20
Cover tree layer [%]	50	50	50	50	50	70	60	60	75	75	65	80	80	80	80	70	60	60	70	50	75	60	40
Cover shrub layer [%]	30	30	20	20	40	50	50	30	30	30	40	60	30	30	40	10	30	20	10	20	30	10	20
Cover herb layer [%]	80	80	85	85	80	65	65	70	65	70	75	70	75	75	85	80	70	70	85	75	80	90	90
Number of species in relevé	41	34	38	41	32	36	37	32	33	32	40	37	64	65	57	32	51	45	33	36	46	50	76
No. group in dendrograms	A1						A2						A3			A4							
Layer of trees and shrubs																							
Alnus glutinosa (a_1)	1	2	2	2	2	2	2	2	2	2	2	4	3	3	3	3	2	2	3	2	2	3	2
**Salix fragilis* (a_1)	.	.	.	.	.	.	.	.	1	1	.	.	+	.	+	.	+	+	.	.	.	.	.
Fraxinus excelsior (a_1)	.	.	.	.	+	+	.	.	+	.	.	.	.	+	.	.	+	+	+	.	+	+	+
Acer pseudoplatanus (a_1)	1	+	.	.	.	+	+	1	+	.	+	.	+	+	.	.	1	1	.	.	2	+	+
A. platanoides (a_1)	.	+	.	.	.	.	1	.	.	.	+	.	.	.	+	.	+	+	+	+	+	+	.
Carpinus betulus (a_1)	.	.	.	.	.	1	1	1	+	.	+	+	+	.	.	.	.	+	.	+	+	.	.
Fagus sylvatica (a_1)	+	.	.	.	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.
Sambucus nigra (b_1)	+	+	.	.	.	+	+	+	+	+	+	+	2	1	+	.	+	+	+	+	+	+	+
Acer pseudoplatanus (b_1)	+	1	+	+	+	+	+	+	+	+	+	1	+	+	+	+	+	.	.	.	+	.	+
****Padus avium* (b_1)	1	1	+	+	1	3	3	2	2	1	2	+	.	+	.	.	.	.	.	.	+	.	.
Corylus avellana (b_1)	.	.	.	+	+	+	+	+	+	+	+	2	+	.	+	.	+	+	.	.	+	.	.
Acer platanoides (b_1)	+	+	.	.	+	+	+	+	+	.	.	+	+	+	.	.	.	.	+	+	+	+	+
**Salix fragilis* (b_1)	.	.	.	.	.	.	.	.	.	1	+	.	+	+	+	.	+	.	.	.	.	.	+
Rubus idaeus (b_2)	.	.	+	.	+	.	.	.	.	.	.	.	1	+	+	.	.	.	.	.	.	.	.
Alnus glutinosa (b_1)	.	+	.	.	+	+	+	+	+	.	.	.	.	+	.	.	.	.	+	.	.	.	.
Fraxinus excelsior (b_1)	.	+	.	.	+	.	.	.	+	+	.	+	+	.	.	.	.	.	.	+	.	.	+
**Salix purpurea* (b_1)	.	.	+	+	.	.	.	.	.	.	.	.	.	+	.	.	.	+	.	.	.	+	.
Ribes alpinum (b_2)	.	.	.	.	.	.	+	.	.	+	.	+	+	.	.	.	.	.	+	.	+	+	.
Euonymus europaea (b_2)	.	.	+	.	.	.	+	.	.	.	.	.	+	+	.	+	.	.	.	+	.	.	.
Ribes uva-crispa (b_2)	.	.	.	.	.	.	+	+	+	+	+	.	.	.	.	.	+	.	.	.	.	.	.
Salix caprea (b_1)	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
Cornus sanguinea (b_2)	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	+	.	.	.	.	.	.	+
Lonicera xylosteum (b_1)	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	+	.	.	+	.	.	.
Symphoricarpos albus (b_1)	.	.	.	.	.	.	.	.	.	.	.	.	+	+	1	.	.	.	.	.	.	.	.
Lianas and climbing plants																							
Galium aparine	.	+	+	+	.	+	.	+	.	1	+	.	1	+	+	1	+	+	.	+	3	2	1
Solanum dulcamara	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	.	+	.	+
Ch. Cl. *Salicetea purpureae, D. All. *Salicion albae*****																							
***Rubus caesius* (b_2)	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	+	.	.	.	.	.	2	.
***Phalaris arundinacea*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	1	+	2	2	1
***Calystegia sepium*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ch. All. *Alno-Ulmion****																							
Chrysosplenium alternifolium	1	1	1	1	1	1	1	2	1	3	3	2	1	2	1	1	2	1	.	2	1	.	2
Stellaria nemorum	.	+	+	+	+	+	+	+	+	+	+	+	1	.	.	2	+	1	2	1	1	+	2
Geranium phaeum	+	+	+	+	.	+	+	1	1	+	1	+	1	1	+	1	+	+	+	1	.	1	1
Festuca gigantea	.	.	+	+	.	.	.	.	.	.	+	+	2	2	1	2	+	+	2	1	2	3	3
Circaea lutetiana	+	+	+	+	.	+	+	+	.	.	.	.	+	+	+	+	+	+	.	.	+	.	.
Elymus caninus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
Ch. O. *Fagetalia*																							
Galeobdolon luteum	2	1	+	+	1	3	2	2	1	+	+	3	3	2	2	3	+	+	1	1	+	2	3

2	2	2	2	2	2	3	3	3	3	3	3	3	3	
4	5	6	7	8	9	0	1	2	3	4	5	6	7	
0	0	0	0	0	0	0	1	0	0	0	0	0	1	
6	5	7	4	5	4	5	8	5	5	5	5	5	5	
8	8	8	9	7	9	7	7	9	9	9	9	9	7	
1	1	1	1	1	1	1	1	1	1	1	1	1	1	
4	4	4	2	2	2	2	2	2	2	2	2	2	2	
2	3	2				2	1		4	3	4	4	3	Constancy (S)
5	0	0	5	0	0	0	0	0	0	0	0	0	0	
8	7	8	6	4	3	4	6	5	5	6	8	4	3	
0	5	5	0	0	0	0	0	0	0	0	0	0	0	
4	4	4	3	1	1	2	4	6	2	3	6	6	1	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	
7	9	6	9	8	7	7	7	8	8	9	7	8	7	
0	5	0	0	5	0	5	0	0	0	0	0	5	5	
4	3	3	4	3	3	4	3	2	4	3	4	3	5	
1	9	6	3	2	9	6	4	7	1	9	2	2	5	
B1			B2						B3					

.	.	.	3	1	+	+	1	1	2	2	.	2	.	V
3	3	3	2	1	1	1	2	3	1	1	4	1	1	III
+	+	1	+	.	+	+	.	.	.	+	+	+	+	III
.	.	.	.	.	.	.	.	.	+	.	+	.	+	III
.	.	.	.	.	.	+	.	.	.	.	.	.	.	II
.	.	+	.	.	.	+	.	.	.	.	.	.	.	II
+	.	.	.	.	.	.	.	.	+	.	.	.	.	I
1	1	2	+	.	+	+	+	.	.	+	+	+	+	IV
+	1	+	.	.	+	.	+	+	.	+	.	1	.	IV
1	.	1	.	+	.	+	1	.	+	1	.	.	+	III
3	1	3	.	.	.	.	.	.	+	+	+	+	+	III
.	.	.	+	+	.	.	+	.	.	.	.	.	+	III
2	.	+	2	+	+	+	1	3	+	.	1	2	.	III
+	.	.	+	+	+	+	+	.	+	.	+	+	+	II
.	.	.	.	.	+	.	.	+	.	+	.	.	.	II
.	.	.	.	.	.	.	.	.	.	.	+	1	.	II
1	1	.	.	.	+	.	.	1	.	.	2	.	+	II
+	.	+	.	.	.	.	.	.	.	.	.	.	.	II
.	.	+	.	.	.	.	.	.	.	.	.	.	.	I
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.	.	.	.	.	.	.	.	.	.	.	+	.	.	I
1	+	.	2	+	3	.	1	2	1	1	2	2	1	IV
.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
.	.	.	.	.	.	+	.	.	.	.	.	.	.	I
.	.	.	1	1	3	1	.	.	+	.	+	.	+	II
.	.	.	.	.	+	.	.	.	+	+	1	.	.	I
2	1	3	2	1	1	1	+	1	1	1	2	1	1	V
1	1	.	2	1	.	1	1	+	+	+	2	2	+	V
1	2	1	1	+	1	.	1	.	+	1	.	1	.	V
.	.	+	2	+	+	2	.	1	.	.	+	2	2	IV
.	.	.	+	.	.	.	.	.	.	.	.	.	+	III
.	.	.	+	.	+	.	.	.	.	.	.	.	+	I
.	+	1	.	.	+	1	.	.	1	.	+	+	+	V

Successive No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
No. group in dendrograms	A1						A2						A3			A4							
Ranunculus lanuginosus	1	+	+	+	.	2	+	+	+	+	+	+	+	+	.	.	.	+	.	.	+	+	.
Impatiens noli-tangere	1	2	3	2	2	1	3	.	+	+	+	+	+	.	.	.	.	.	+	.	.	.	+
Dryopteris filix-mas	+	.	.	.	.	+	+	+	+	+	+	.	.	+	.	.	+	+	.	+	+	.	.
Stachys sylvatica	+	+	+	+	.	+	+	.	.	.	.	.	+	+	+	+	+	.	+	.	3	+	+
Pulmonaria obscura	.	.	.	+	.	+	+	+	+	+	+	+	+	.	+	.	+	.	.	+	.	.	+
Carex sylvatica	+	+	+	+	+	+	+	.	+	+	1	+	.	.	.	.	.	+	.	.	.	.	.
Asarum europaeum	+	.	.	.	.	+	+	.	+	+	+	+	+	.	.	+	+	+	.	.	+	.	.
Primula elatior	+	.	.	.	.	.	.	+	+	+	.	+	.	+	.	.	.	.	.	.	.	.	+
Scrophularia nodosa	.	.	.	.	.	.	.	.	.	.	+	+	.	+	+	.	.	.	+	.	.	.	+
Galium odoratum	.	.	.	.	.	+	.	+	+	.	.	.	.	.	.	.	+	.	.	.	.	.	+
Mercurialis perennis	+	.	.	.	.	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ch. Cl. *Querco-Fagetea*																							
Aegopodium podagraria	2	2	1	1	2	2	1	2	2	2	2	2	1	1	2	+	2	3	+	1	1	2	2
Poa nemoralis	+	.	+	1	+	+	+	+	+	+	1	.	1	1	+	.	.	+	.	.	.	1	.
Campanula trachelium	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+
Ch. Cl. *Molinio-Arrhenatheretea*																							
Cirsium oleraceum	.	+	+	+	.	+	.	.	.	.	.	.	+	+	+	+	+	+	+	.	+	1	+
Myosotis palustris	+	+	+	+	+	.	.	.	.	.	+	+	.	+	.	.	+	.	+	+	.	+	+
Mentha longifolia	+	+	+	+	+	.	.	.	.	.	+	+	.	+	.	.	.	.	.	.	.	+	+
Ranunculus repens	.	+	1	+	+	.	.	.	.	.	+	+	1	1	1	.	.	.	.	.	.	2	2
Geranium palustre	.	+	.	+	+	.	.	.	.	+	+	.	+	+	.	.	+	.	.	.	.	.	.
Lysimachia nummularia	.	.	.	.	.	.	.	.	+	.	+	.	.	+	+	.	.	+	+	.	.	+	1
Plantago major	+	+	.	+	+	+	.	.	.	.	.	+	+	+	.	.	+	.	.	.	.	.	+
Taraxacum officinale	.	.	.	.	.	+	.	.	.	.	.	.	+	+	+	+	+	+	.	.	.	+	1
Filipendula ulmaria	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.
Poa pratensis	+	.	1	.	.	.	.	.	.	.	.	.	+	1	+	+	.	.	.	.	.	.	.
Lolium perenne	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	.	.	.	.	.	+	+	.
Dactylis glomerata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.
Deschampsia cespitosa	.	.	+	.	+	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.
Arrhenatherum elatius	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	.	.	.	.	.	.	+	+
Ch. Cl. *Artemisietea*																							
Urtica dioica	2	2	1	1	2	2	1	2	+	1	1	2	3	3	3	3	2	1	3	2	2	3	3
Chaerophyllum aromaticum	+	+	.	+	+	+	+	+	+	1	+	+	+	+	+	+	.	1	1	+	1	1	1
Impatiens parviflora	3	2	2	2	1	2	1	.	.	2	2	+	1	1	2	+	2	2	+	+	+	+	+
Geum urbanum	+	+	+	+	.	1	+	.	1	+	1	2	2	1	2	2	1	+	.	+	1	1	.
Galeopsis pubescens	.	.	+	.	+	+	.	+	.	.	.	.	+	+	+	+	+	.	+	+	+	+	1
Lamium maculatum	+	+	+	+	+	1	+	+	.	.	.	.	+	.	+	+	.	1	+	+	2	1	.
Rumex obtusifolius	.	+	+	+	.	.	.	.	.	.	+	.	+	+	+	.	+	.	+	.	+	+	+
Epilobium roseum	+	.	+	+	.	.	.	.	.	.	+	+	+	+	+	+	+	.	+	.	+	+	1
Alliaria petiolata	+	.	.	+	+	+	+	+	+	+	+	.	+	+	.	+	+	+	.	.	+	.	.
Impatiens glandulifera	.	.	.	.	.	.	.	.	.	.	.	.	1	+	2	1	+	+	+	+	+	.	+
Petasites hybridus	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	1	+	+	+	.	+	+
Geranium robertianum	.	.	.	+	.	.	.	.	.	.	.	+	+	+	+	.	.	.	.	+	.	.	1
Chaerophyllum temulum	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	+	1	+	+	+
Chelidonium majus	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	.	+	.	.	.	+	+	+
Carduus crispus	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	+	+	+
Solidago canadensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
Myosoton aquaticum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	+
Anthriscus sylvestris	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	+	+	.	.	.	+	+	.
Glechoma hederacea	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.
Epilobium hirsutum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cirsium arvense	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+
Ch. Cl. *Stellarietea*																							
Stellaria media	.	.	.	.	+	.	.	.	.	.	+	.	1	.	1	1	+	.	.	.	.	1	1
Lapsana communis	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	.	.	.	+	+	.	+
Oxalis fontana	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	.	.	.	.	.	+	+

24	25	26	27	28	29	30	31	32	33	34	35	36	37	
B1			B2						B3					
.	.	.	+	.	.	+	+	.	.	.	.	.	+	III
.	.	.	+	.	.	.	.	.	.	1	+	.	.	III
+	.	+	.	.	.	.	.	.	+	+	+	.	+	III
.	.	+	+	.	.	+	.	.	.	.	.	.	.	III
+	+	.	.	.	.	.	.	.	.	.	.	.	+	III
.	.	.	.	.	.	.	.	.	.	.	.	.	.	II
.	.	+	.	.	.	.	.	.	.	.	.	.	.	II
+	.	+	.	.	.	.	+	.	.	.	.	.	.	II
.	.	.	.	.	+	.	.	.	.	.	.	+	+	II
.	.	.	.	.	.	.	+	.	.	.	.	.	.	I
+	.	+	.	.	.	.	.	.	.	.	.	.	.	I
3	3	3	+	1	+	2	2	2	1	1	2	1	2	V
1	1	+	.	.	.	.	.	.	1	.	.	.	.	III
.	.	+	.	.	.	.	.	.	.	.	.	.	.	I
+	.	.	1	+	+	+	+	1	+	+	+	+	1	IV
+	+	.	.	+	+	+	.	.	.	+	2	1	1	III
+	+	.	1	+	1	+	+	1	+	+	.	.	+	III
.	+	.	1	.	.	1	+	.	.	.	+	+	1	III
+	+	.	1	1	1	1	.	.	.	.	.	.	+	III
.	.	.	.	+	+	+	.	.	.	+	1	.	+	II
.	.	.	+	.	.	.	.	.	.	.	.	.	+	II
.	+	.	.	.	.	.	.	.	.	.	+	.	+	II
.	.	.	.	+	1	+	.	.	.	.	.	.	1	I
.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
+	+	.	.	.	.	.	.	.	.	.	.	.	.	I
+	.	.	.	.	+	.	.	1	.	.	.	.	.	I
.	.	.	+	.	.	.	.	.	.	.	.	.	.	I
.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
3	3	2	4	2	4	2	2	3	3	4	3	3	2	V
2	2	2	1	1	+	1	.	2	1	+	1	1	2	V
+	+	1	+	+	+	+	.	.	2	1	+	1	1	V
2	2	+	.	+	.	+	+	.	+	+	.	+	+	IV
+	.	.	+	+	+	+	+	+	+	+	+	1	.	IV
.	.	.	+	+	+	+	+	+	+	+	.	.	.	IV
+	+	+	+	.	+	.	+	+	+	.	+	+	+	IV
+	+	.	+	+	.	+	.	.	+	.	+	+	+	III
.	.	+	.	+	.	+	+	.	.	.	.	.	.	III
.	.	.	1	+	+	+	+	.	+	1	+	+	+	III
.	.	.	1	2	2	1	.	.	+	.	.	.	.	II
+	+	1	.	.	.	.	.	.	.	+	.	.	.	II
+	+	.	1	1	.	+	.	.	.	.	.	.	.	II
.	.	.	.	.	.	+	.	.	.	.	+	.	+	II
.	+	.	+	.	.	+	.	.	+	.	.	.	.	II
+	+	.	+	.	+	.	.	.	+	+	+	+	.	II
.	+	.	+	.	.	.	.	.	+	.	.	.	+	I
.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
.	.	.	.	.	.	.	+	.	.	+	.	.	.	I
.	+	.	+	.	+	.	+	+	.	.	.	.	.	I
.	+	.	.	.	.	.	.	+	.	.	.	.	.	I
.	.	.	.	.	.	.	+	.	.	+	.	+	+	II
+	+	+	.	.	.	.	.	.	.	.	.	.	.	II
.	.	.	.	.	.	.	.	.	.	.	.	.	.	I

Successive No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
No. group in dendrograms	A1						A2						A3			A4							
Others																							
Chaerophyllum hirsutum	.	.	+	.	.	.	.	.	.	.	.	.	1	+	.	.	+	1	2	2	2	1	1
Oxalis acetosella	+	+	.	.	.	.	+	+	+	+	.	1	+	.	.	.	+	+	.	1	.	.	.
Glyceria notata	+	+	+	+	+	.	.	.	.	.	.	.	.	+	.	.	.	+	.	.	.	.	.
Ajuga reptans	.	.	.	.	.	+	+	.	.	.	.	+	+	+	.	.	.	+	.	+	.	.	+
Poa annua	.	.	.	.	.	.	.	.	.	.	.	.	2	+	1	.	+	.	.	.	.	1	1
Mycelis muralis	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+	.	.	+
Erigeron annuus	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	.	.	.	.	.	.	.
Reynoutria japonica	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	+	.	.	+	.	1
Veronica beccabunga	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	+	.	.	.
V. chamaedrys	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.
Equisetum sylvaticum	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.

Sporadic species: Layer of trees and shrubs – *Tilia cordata* (a_1) 22, 21, 35: 1; *Aesculus hippocastanum* (a_1) 25, 32; *Tilia platyphyllos* (a_1) 29, 9; **Salix alba* (a_1) 16, 17; *Corylus avellana* (a_2) 21; ***Padus avium* (a_2) 18; *Picea abies* (a_1) 25; *Betula pendula* (a_2) 4; *Carpinus betulus* (b_1) 30, 28, 17; *Ulmus glabra* (b_1) 32, 9; *Aesculus hippocastanum* (b_1) 28, 13; *Crataegus pedicellata* (b_1) 9, 26; *Sorbus aucuparia* (b_1) 36; *Sambucus racemosa* (b_1) 33; *Tilia platyphyllos* (b_1) 38; *Syringa vulgaris* (b_1) 23; *Viburnum opulus* (b_1) 9; *Rubus plicatus* (b_2) 19; *Ulmus laevis* (b_1) 17; *Euonymus verrucosa* (b_2) 25; *Pyrus communis* (b_1) 24; *Quercus robur* (b_1) 3, *Fagus sylvatica* (b_1) 7; **Lianas and climbing plants** – *Humulus lupulus* 21, 23, 15; *Hedera helix* 17, 26; *Convolvulus arvensis* 17, 4; *Vicia sepium* 10; *Echinocystis lobata* 6; *Parthenocissus inserta* 1; **Trees and shrubs in herb layer** – *Alnus glutinosa* (c) 13, 9, 11; *Acer pseudoplatanus* (c) 23, 26; ***Padus avium* (c) 38; ***Ulmus minor* (c) 27; *Fraxinus excelsior* (c) 26; *Tilia platyphyllos* (c) 26; *Acer platanoides* (c) 11; **Ch. All. *Alno-Ulmion*** – *Ficaria verna* 32: 2, 33: 1; *Gagea lutea* 6; **Ch. O. *Fagetalia*** – *Corydalis solida* 36, 37, 9; *C. cava* 36, 37; *Lunaria rediviva* 35, 38; *Adoxa moschatellina* 10, 6; *Lysimachia nemorum* 22; **Ch. Cl. *Querco-Fagetea*** – *Anemone nemorosa* 29; **Ch. Cl. *Molinio-Arrhenatheretea*** – *Lychnis flos-cuculi* 33, 34, 17; *Geranium pratense* 24, 5, 7; *Heracleum sphondylium* ssp. *sphondylium* 24, 1, 7; *Plantago lanceolata* 32, 24; *Phleum pratense* 22, 5; *Potentilla anserina* 21, 17; *Angelica sylvestris* 13, 1; *Poa trivialis* 18: 1, 17: 1; *Ranunculus acris* 17, 5; *Cerastium holosteoides* 33; *Juncus effusus* 34; *Crepis biennis* 21; *Carex hirta* 13; *Achillea millefolium* 17; *Galium mollugo* 1; *Lathyrus pratensis* 7; **Ch. Cl. *Artemisietea*** – *Artemisia vulgaris* 2, 1; *Rudbeckia laciniata* 23; *Lamium album* 10; *Solidago gigantea* 4; **Ch. Cl. *Stellarietea*** – *Veronica persica* 21, 17, 6; *Matricaria maritima* ssp. *inodora* 23, 20, 17; *Galinsoga parviflora* 23, 16, 17; *Sonchus oleraceus* 23, 17, 4; *Tussilago farfara* 14, 2, 1; *Lamium purpureum* 21, 23; *Euphorbia helioscopia* 16, 17; *Chenopodium album* 23; *Papaver rhoeas* 23; *Polygonum aviculare* 23; *Apera spica-venti* 18; *Lactuca serriola* 1; *Galinsoga ciliata* 4; **Others** – *Carex brizoides* 33: 1, 32: 1, 34: 1; *Athyrium filix-femina* 32, 17, 26; *Polygonum lapatifolium* 22, 17, 7; *Symphytum officinale* 23, 16, 19; *Gymnocarpium robertianum* 36, 35; *Berula erecta* 36, 32; *Gymnocarpium dryopteris* 38, 37; *Omphalodes scorpioides* 37:3, 28, *Medicago lupulina* 23, 17; *Avena sativa* 21; *Barbarea vulgaris* 23; *Secale cereale* 23; *Senecio vulgaris* 23; *Sorbaria sorbifolia* 9; *Arum alpinum* 8; *Tanacetum parthenium* 18; *Cardamine amara* 17; *Triticum aestivum* 17; *Scrophularia umbrosa* 14; *Equisetum arvense* 5; *Aruncus sylvestris* 2; *Epilobium palustre* 4; *Senecio viscosus* 4; *Fragaria vesca* 3; *Mentha aquatica* 7; *Polygonum hydropiper* 7; *Senecio jacobaea* 7

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