

VASCULAR PLANT BIODIVERSITY OF FLOODPLAIN FOREST GEOBIOCOENOSIS IN LOWER MORAVA RIVER BASIN (FOREST DISTRICT TVRDONICE), CZECH REPUBLIC

PETR MADĚRA, RADOMÍR ŘEPKA, JAN ŠEBESTA, TOMÁŠ KOUTECKÝ,
MARTIN KLIMÁNEK

Faculty of Forestry and Wood Technology Mendel University in Brno, Zemědělská 3, 613 00, Brno, Czech Republic, e-mail: petrmad@mendelu.cz

Received: 9th September 2013, **Accepted:** 3rd November 2013

ABSTRACT

This paper presents an evaluation of full-area floristic mapping of floodplain forest in Tvrdonice forest district (Židlochovice Forest Enterprise) based on a single forest stand inventory. The study area encompasses 2,200 ha of forests, where 769 segments were inventoried, and 46,886 single records about presence of vascular plant species were catalogued. We found 612 species (incl. subspecies and hybrids), out of which 514 were herbs, 98 were woody plants, 113 were endangered species and 170 were adventive species. The average area of a segment is 2.86 ha. The mean number of species per segment is 60.97 in a range of 4–151.

Key words: biodiversity, vascular plants, floodplain forest, forest district Tvrdonice, Czech Republic

INTRODUCTION

Formations of floodplain forests in Europe are classified as azonal; however, their vegetation differs in particular parts of Europe both in its physiognomy and species composition (Bohn et al. 2003). Floodplains and floodplain forests in alluvia of large rivers are dynamic ecosystems, which are subject to fast changes in the temporal as well as spatial sense (Klimo et al. 2008). They are relatively young communities, as regards their development, and are affected by two main ecological factors – more or less cyclic flooding and a high level of the groundwater (Maděra et al. 2008). Their genesis and especially florogenesis has also been affected by the broad surroundings of the floodplains, i.e. the entire river drainage basin. The cyclic character of floods and the migration of diaspores of many species by water (Boedeltje 2004) were the factors that have been enriching the flora of floodplain forests for centuries. Considering the ever more frequent deposition of material from the entire drainage basins and global eutrophication on the one hand, as well as the natural fast decomposition of organic mass on the other hand, these sites are very well supplied with nutrients and in recent decades have also been supplied or even oversaturated with nitrogen. The significance of floodplain forests for biodiversity has been mentioned in many studies (Tabacchi et al. 1996, Naiman & Decamps 1997, Schnitzler et al. 2007); however, the condition of river ecosystems in Europe is currently affected by a number of negative anthropogenic factors (Wenger et al. 1990).

The biodiversity of vascular plants in the study area has been affected significantly by the forest management in the area, i.e. the way the landscape in the entire drainage basin has been managed. The floodplain was densely populated in the period of Great Moravia. In the Middle Ages, the forest communities were harvested with very short rotation periods (as frequently as 7 years), managed as coppice forests or coppice with standards. Pasture was created in the floodplain forests in the historical times and the forest was regenerated by agroforestry (Nožička 1956; Hrib 2004) and in the most recent decades by various forms of uniform clear-cutting with broadcast soil preparation. Regeneration has always been achieved using autochthonous woody plants; therefore, nowadays, there are valuable forest stands that can be referred to as man-made natural ecosystems (Maarel 1975).

South-Moravian lowland floodplains, together with the adjacent Slovakian and Lower Austrian floodplains, are the most extensive complex within central Europe; recently, they have been a subject of research of more and more studies. They are significant forest coenoses covering the broad floodplains of lower reaches of large rivers, well-known for their dynamic development (Maděra 2001a, 2001b) and high production of biomass (Klimo & Hager 2000; Penka et al. 1985). The afore-mentioned floodplain forests in the Czech Republic are managed by the Židlochovice Forest Enterprise and are divided into three forest districts (Valtice, Tvrdonice and Soutok). Floristic-oriented studies from the area of the confluence of the Morava and the Dyje rivers have been published only recently. Horák (1961) focused on the typology of floodplain forests, Vicherek et al. (2000) dealt with a floristic inventory in map squares regardless of forest or non-forest biotopes, Danihelka et al. (1995) and Danihelka & Šumberová (2004) described the distribution of selected taxa. Maděra et al. (2011) presented the results of a floristic inventory of floodplain forests within the Valtice forest district.

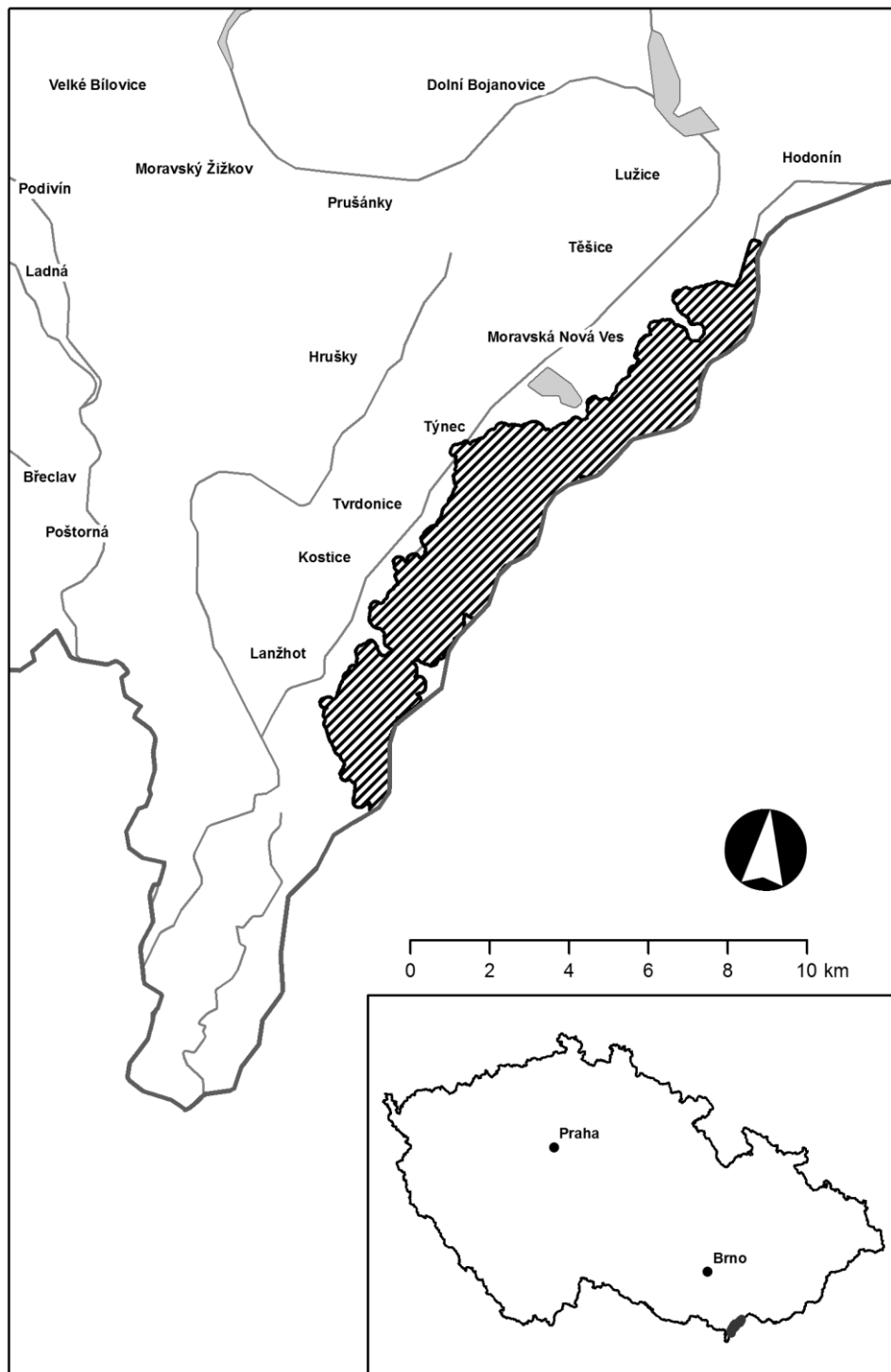
The aims of this paper are to continue the work presented in the last mentioned publication and introduce another stage of the floristic inventory of floodplain forests, this time within the Tvrdonice forest district of the Židlochovice Forest Enterprise, as a model of diversity of vascular plants in floodplain forests of the Lower Morava Basin. The results should serve as a significant source of information for the zonation of Dolní Morava Biosphere Reserve, the studied area being its part.

MATERIAL AND METHODS

Study area

The area of 2,200 ha of floodplain forest along the lower reaches of the Morava river between towns Lanžhot and Hodonín was inventoried. This is the Tvrdonice forest district, Židlochovice Forest Enterprise, which is a part of state forests managed by Lesy ČR s.p. The Morava river in the studied area forms the border between the Czech Republic and Slovakia (Fig.1). A short description of the historical development of the area and its significance for nature conservation was presented in the previous study (Maděra et al. 2011), which concerned the Valtice forest district.

Fig. 1: Study area



Methods

All vascular plants in the area of the Tvrdonice forest district were recorded between 2007 and 2011 down to the level of a segment; each segment corresponds to one stand group (exceptionally, similar groups are put together or non-homogeneous groups are divided). The presence of species in each segment is ticked in a list that includes 263 most common species of herbs in south-Moravian floodplains. Rare species and woody plants are added to the list. We used nomenclature according to Kubát et al. (2002). The occurrence of species growing only at the segment edges (stand adjacent to a forest road, a water current, a clearing, a meadow) and dominant species (species of over 40% cover) are marked differently. The terrain survey needs to be conducted in two aspects: spring (March 20–May 31) and summer (June 1–November 30); also fresh clearings and young plantings were inventoried. The ticking lists are then transferred to a database and further processed. The segment after digitalisation becomes a site (a point in the point map). The digitalisation and creation of the species distribution maps was implemented in the GIS environment (ArcGIS).

RESULTS

The total study area is 2,200 ha of forest; 769 segments were explored and 46,886 records on the presence of vascular plant taxa were taken. According to the records, there are 612 species (and lower taxa, or hybrids) in the area, out of which there are 514 herbs and 98 woody plants. The mean size of a segment is 2.86 ha. On average, there are 60.97 taxa (range of 4–151) per segment (most segments containing 40–59 species). The numbers of species within a segment are distributed slightly unequally – there are more segments with lower numbers of species than average (412) and fewer segments with higher numbers (357) (Fig.2). On average, there are 9.39 species of woody plants and 51.58 species of herbs in a segment. The spatial distribution of the segments with their highlighted significance for biodiversity (the number of species per segment) is illustrated in Fig. 3.

Fig. 2: Frequency of segments according to containing number of species

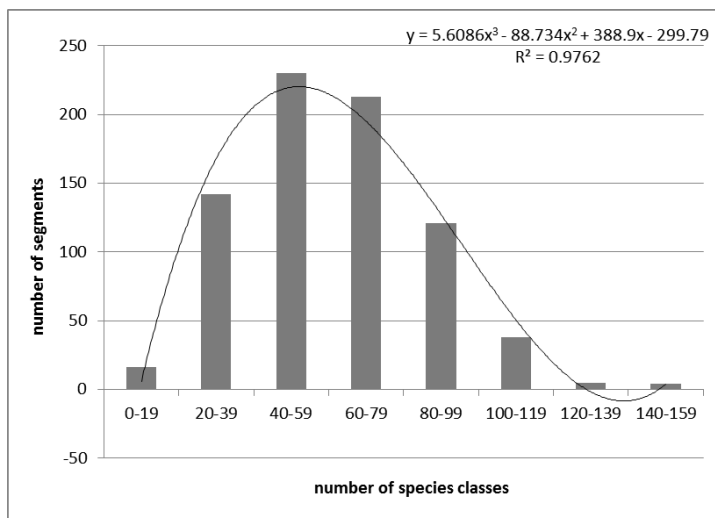
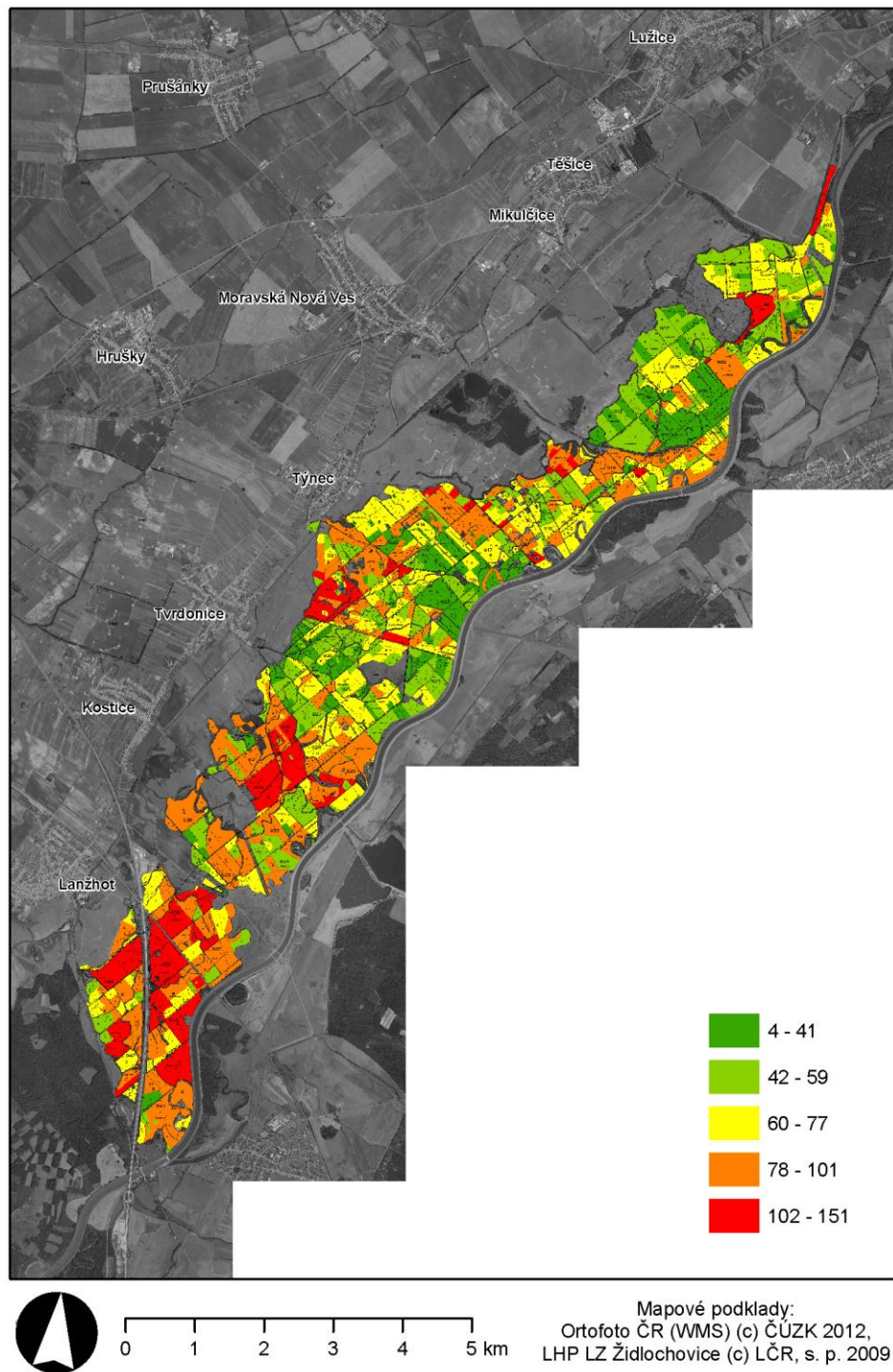


Fig. 3: Map of the number of all vascular plant species per segment



We also examined the frequency of species occurrence (presence of a taxon in segments) in the area (Table 1). The analysis shows that 110 species (i.e. nearly 15%) occur in one segment only, 281 species (i.e. 37%) are present in 1–9 segments; it means that the species scarcely occur in the area and are rare. The table also shows that another 196 species (i.e. 25%) are present in 10–99 segments. These species can be referred to as scattered. 135 species (i.e. 17.5%) are present in over 100 segments – these species are abundant. Only 25 species occur in over 60% of segments (Table 2) – the species with high stability. This group contains most species of the herb layer of floodplain forests considered typical species of subclass *Ulmenion* (Neuhäuslová 2001). Only two adventive species are in this group – invasive neophyte *Aster lanceolatus* and naturalised archeophyte *Arctium lappa*.

Table 1: The frequency of species occurrence

Classes of segments number	Number of species
700 +	2
600-699	8
500-599	12
400-499	13
300-399	17
200-299	26
100-199	57
0-99	477
90-99	0
80-89	9
70-79	14
60-69	17
50-59	16
40-49	14
30-39	23
20-29	36
10-19	67
1-9	281

Table 2: Species with occurrence frequency over 60% of segments

Species	No. of segments
<i>Aster lanceolatus</i>	731
<i>Rubus caesius</i>	708
<i>Urtica dioica</i>	694
<i>Geum urbanum</i>	670
<i>Glechoma hederacea</i>	653
<i>Carex riparia</i>	626
<i>Galium aparine</i>	626
<i>Quercus robur</i>	624
<i>Acer campestre</i>	608
<i>Symphytum officinale</i>	603
<i>Brachypodium sylvaticum</i>	599
<i>Festuca gigantea</i>	594
<i>Rumex sanguineus</i>	594
<i>Arctium lappa</i>	573
<i>Deschampsia cespitosa</i>	569
<i>Torilis japonica</i>	565
<i>Phalaris arundinacea</i>	555
<i>Iris pseudacorus</i>	539
<i>Lysimachia nummularia</i>	534
<i>Fraxinus angustifolia</i>	512
<i>Cirsium arvense</i>	512
<i>Dactylis polygama</i>	509
<i>Taraxacum</i> sect. <i>Ruderalia</i>	493
<i>Ficaria verna</i>	481
<i>Poa palustris</i>	471

From the perspective of nature preservation, it is interesting to evaluate the proportion of adventive species (based on Pyšek et al. 2002) and endangered species (based on Holub & Procházka 2000). Considering merely the number of species (Fig. 4), over a quarter (27.7%, i.e. 170 taxa) are various categories of adventive species and 18.4% (113) taxa are species with various levels of conservation status. However, Fig. 5 has a higher information capacity concerning the role of these groups in the area. It shows the results categorised based on the number of records of the species in the segments. Based on this, the proportion of adventive species drops to 18% (8,455 records) and the proportion of endangered species to 7% (3,478 records). Neither of this is sufficiently informative, as the presence of taxa in segments does not give any idea about their cover. For example, *Aster lanceolatus*, a significant invasive neophyte, is present in over 95% of segments and it is dominant in the

herb layer synusia in 18% of them; the dominance is the most frequent in stands up to 10 years of age (Řepka & Maděra 2009a). By contrast, *Arctium lappa* is present in 74% of segments, but always relatively scarcely.

Fig. 4: Proportion of adventive, threatened and others vascular plant species in the area of study

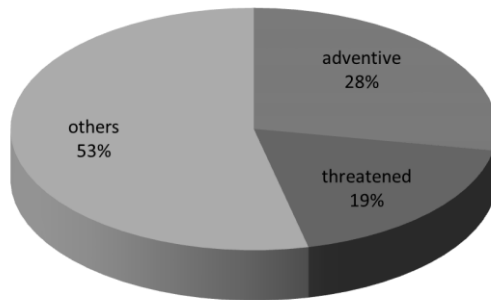
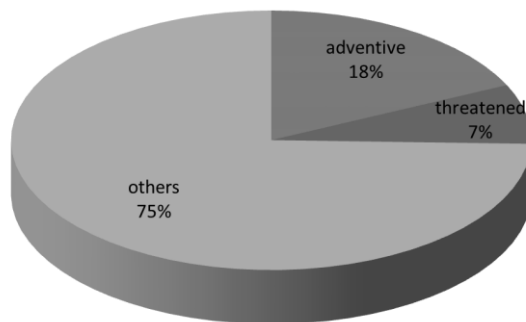


Fig. 5: Proportion of adventive, threatened and others vascular plant species in the area of study according to the number of records



Within the set of adventive species, archeophytes (58.8%) slightly prevail over neophytes (41.2 %); there are 48, i.e. 28% of invasive species in total (Fig. 6, Table 3), according to Pyšek et al. (2002) we distinguish archeophytes (arc) and neophytes (neo), in detail (cas – casual, nat – naturalised and inv – invasive). On average, there are 11 adventive species in a segment (range of 0–46). Only 3 segments contained no adventive species. There were up to 10% of adventive species in 124 segments, 10–20% in 403 segments, 20–30% in 198 segments, 31–40% in 34 segments, and 41–50% of adventive species in 8 segments. Two segments even contains over 50% of adventive species. The loading of individual segments by the presence of adventive species is illustrated in the map, Fig. 7, neophytes especially are pictured in the map, Fig. 8.

Table 3: The abundance of different categories of adventive species
(according to Pyšek et al. 2002)

adventive species category	all species		herbs		woody plants	
	species number	records number	species number	records number	species number	records number
ar cas	8	90	5	8	3	82
ar nat	77	3509	71	3443	6	66
ar inv	15	1665	15	1665	0	0
neo cas	17	142	5	11	12	131
neo nat	20	626	16	590	4	36
neo inv	33	2423	25	2043	8	380

Fig. 6: Proportion of adventive species (according to Pyšek et al. 2002) in the area of study

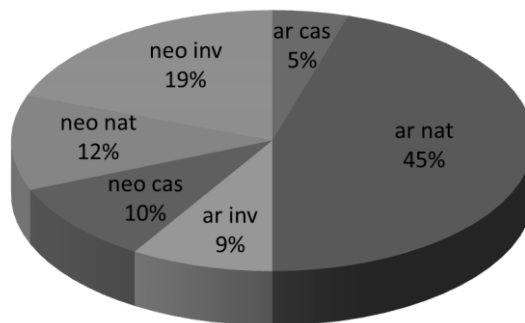


Fig. 7: Map of the number of adventive vascular plant species per segment

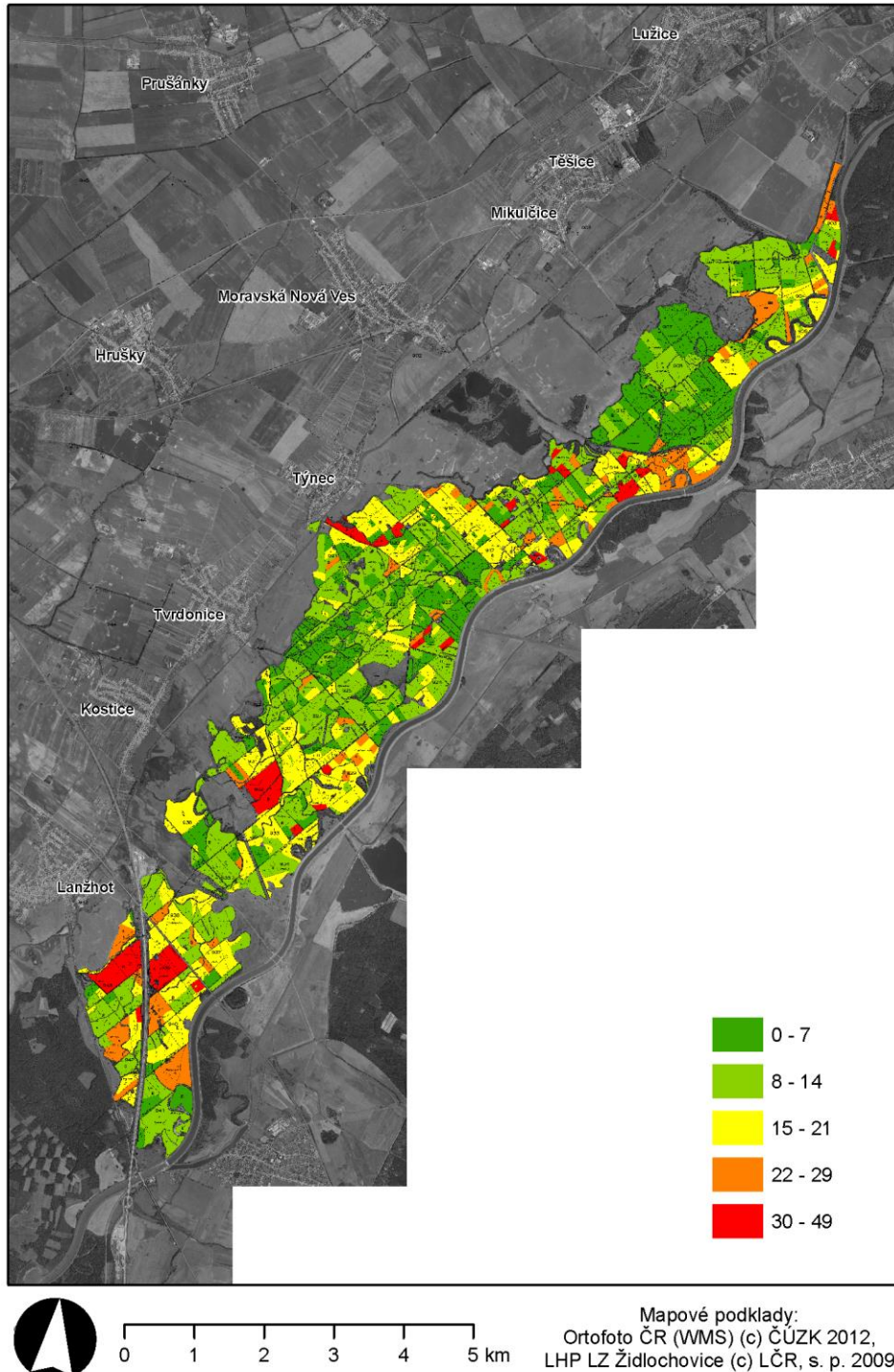
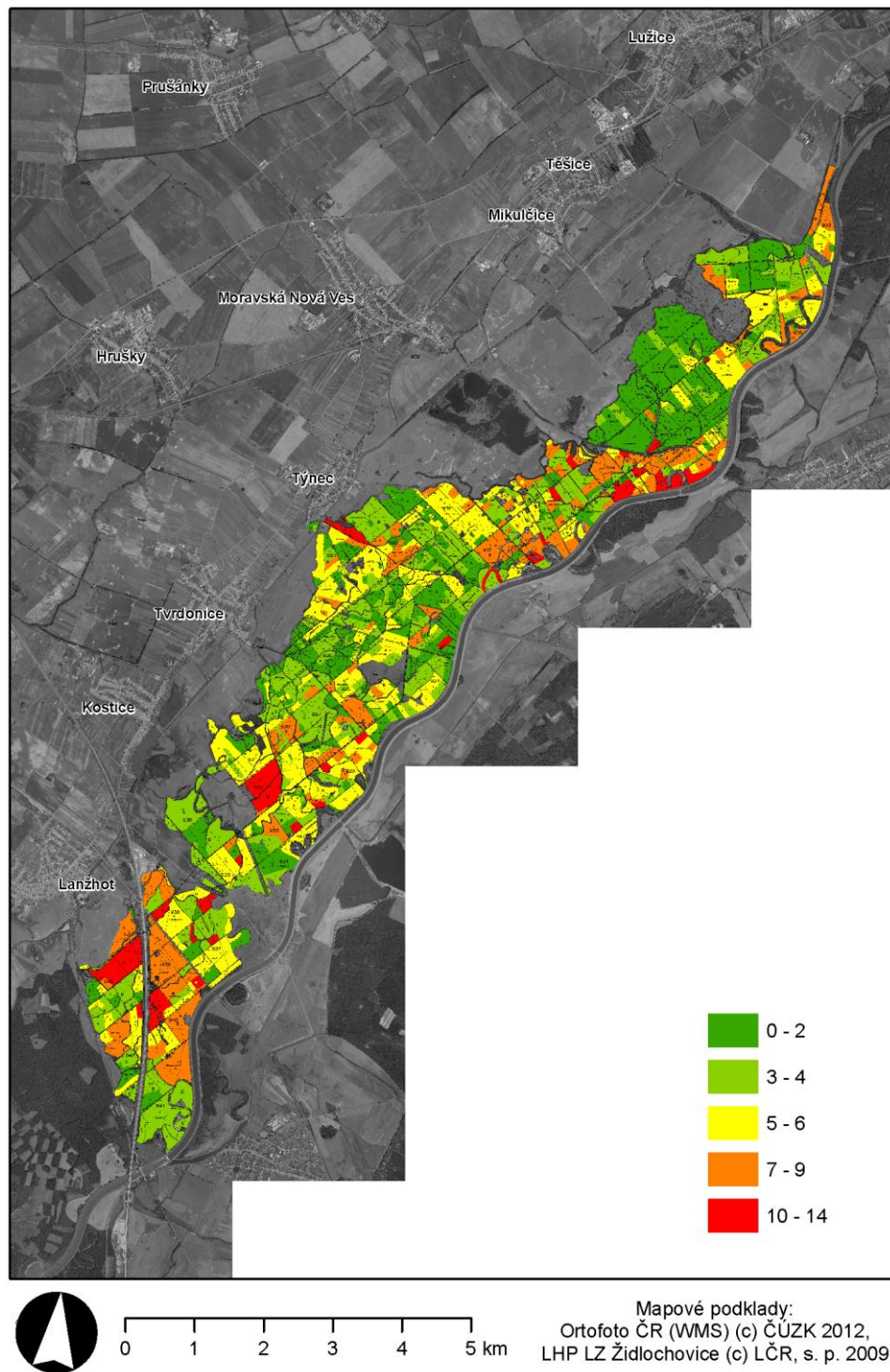


Fig. 8: Map of the number of vascular plant neophytes per segment



As concerns threatened species, 19.46% of species are protected by law, the rest are within various categories of the Red List. There are 8 critically endangered species, 34 strongly endangered and 25 endangered, the other 46 species are within C4 category – requiring further attention (Fig. 9, Table 4). The analysis shows that the mean number per segment is 4.52 species (range of 0–17). Threatened species are not present in 14 segments only; in the others there is at least one threatened species. Most segments (307) contain 6–9% of threatened species; 10 segments even over 15%. The most of threatened species (66%) are present in 1–10 segments and only 7% of threatened species are present in over 100 segments. The spatial distribution of the numbers of threatened species of plants in the segments is shown in the map, Fig. 10. The map in Fig. 11 shows the species of categories C1 (critically endangered) and C2 (strongly endangered).

Table 4: The abundance of threatened vascular plants species
(according to Holub & Procházka 2000)

threat and protection category	all species		herbs		woody plants	
	species number	records number	species number	records number	species number	records number
§1	7	49	7	49	0	0
§2	11	72	11	72	0	0
§3	4	17	3	16	1	1
C1	8	62	8	62	0	0
C2	34	825	31	705	3	120
C3	25	749	23	236	2	513
C4	46	1842	36	1262	10	580

Fig. 9: Proportion of threatened species in the area of study

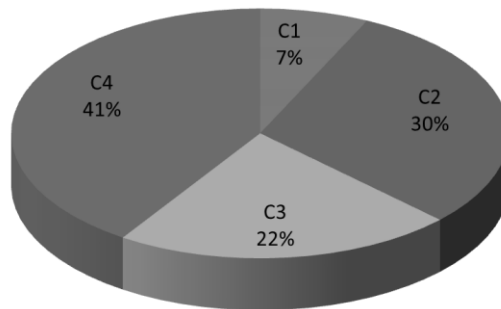


Fig. 10: Map of the number of endangered vascular plant species per segment according to Pyšek et al. (2002)

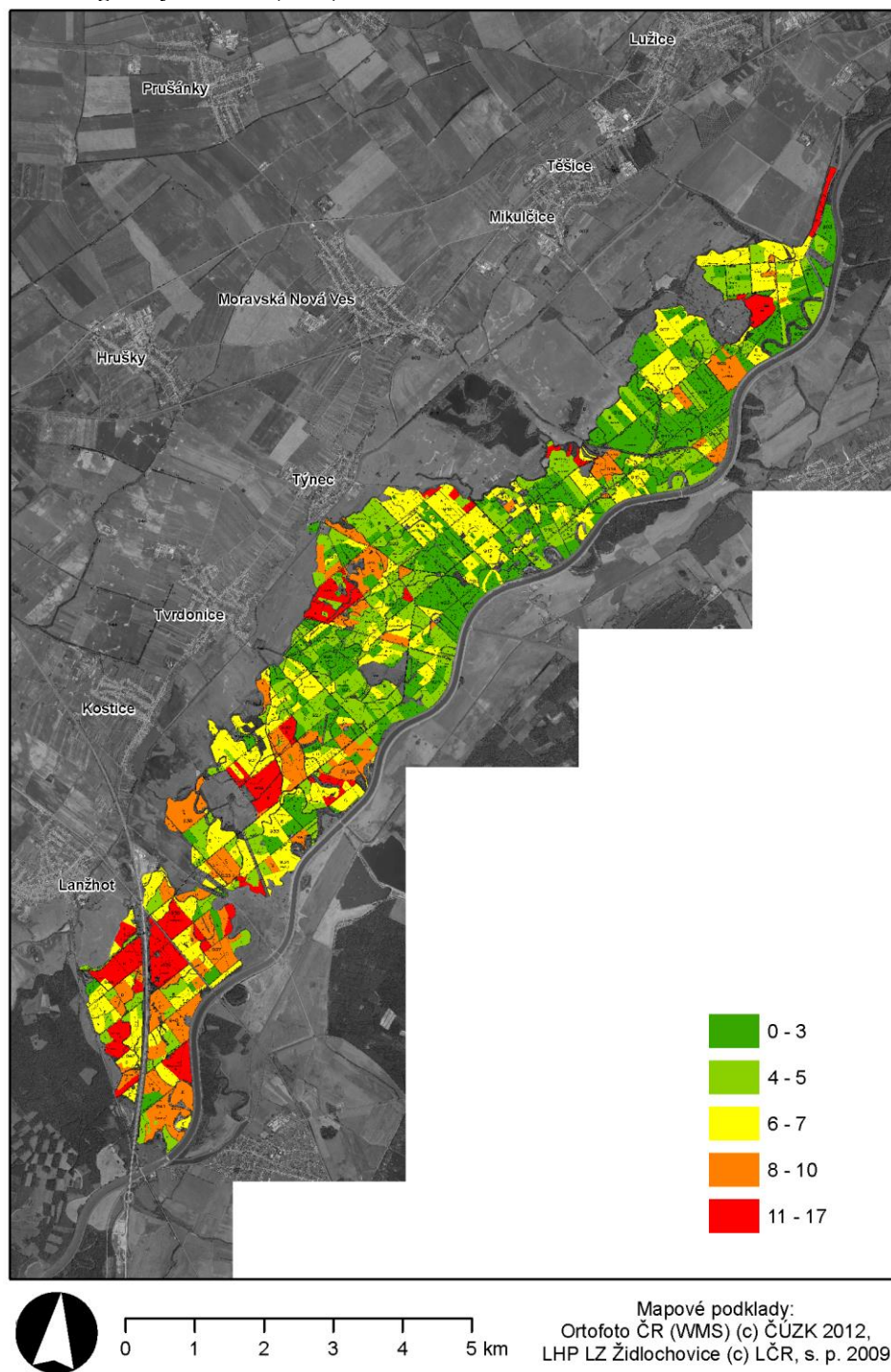
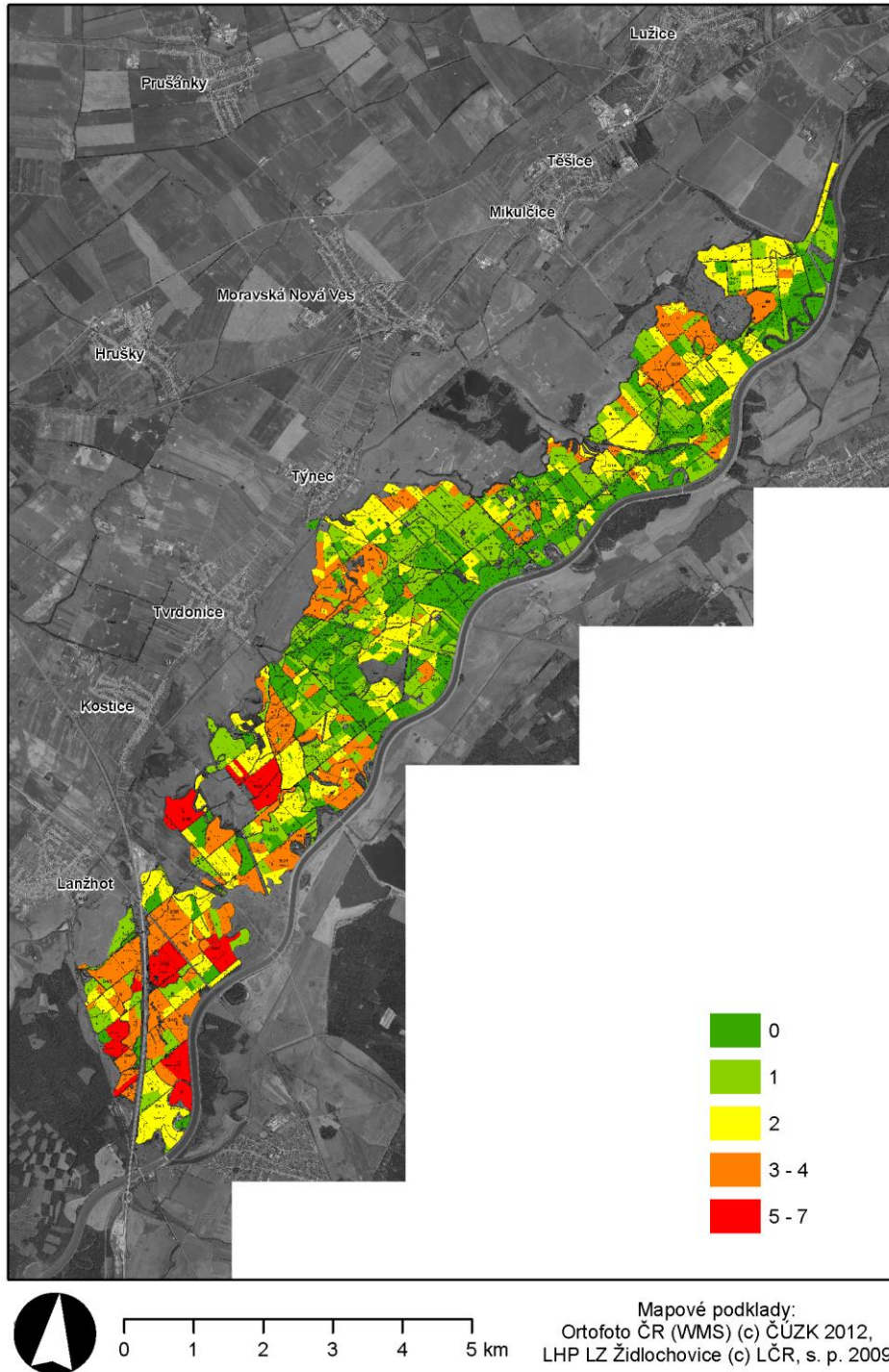


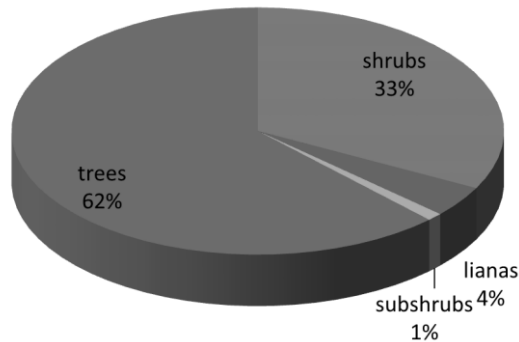
Fig. 11: Map of the number of critical (C1) and strong endangered vascular (C2) plant species per segment according to Holub & Procházka (2000)



Diversity of woody plants in the floodplain forests

As has been mentioned, we found 98 species, subspecies and hybrids of woody plants in the study area. Based on Úradníček et al. (2010), woody plants are not only trees and shrubs but also semi-shrubs (e.g. *Solanum dulcamara*) or woody lianas (e.g. *Hedera helix*) and shrublets, whose representative has not been found in the area (Fig.12).

Fig. 12: Proportion of life form occurrence of woody plants



Out of the total number of woody plants found, there are 25 abundant species (occurrence in over 100 segments), 31 scattered species (10–99 segments) and 42 rare species (1–9 segments) – 23 species were recorded in one segment only.

From the perspective of autochthonous character, 33 recorded species are various types of adventive species (Table 5). There are 8 recorded invasive neophytes, a more significant presence being recorded for *Acer negundo* – in nearly 24% of segments and *Populus x canadensis* – in 18% of segments. The former is the only one that propagates spontaneously, the others are grown (besides hybrid poplars, *Fraxinus pennsylvanica* and *Quercus rubra*) and spread less. Pyšek et al. (2002) also categorised the frequently grown *Juglans nigra* as an occasionally wild-growing neophyte; however, in the conditions of a floodplain we can assume at least a very good naturalisation as it often regenerates naturally – it was recorded in 10% of segments.

Table 5: The presence of adventive woody plants species in segments
(according to Pyšek et al. 2002)

Species	number of segments	proportion of segments	adventive species category	
<i>Malus domestica</i>	73	9.49	cas	ar
<i>Morus alba</i>	5	0.65	cas	ar
<i>Vitis vinifera</i> subsp. <i>vinifera</i>	4	0.52	cas	ar
<i>Pyrus communis</i>	34	4.42	nat	ar
<i>Malus x dasyphylla</i>	13	1.69	nat	ar
<i>Prunus insititia</i>	11	1.43	nat	ar
<i>Juglans regia</i>	5	0.65	nat	ar
<i>Prunus domestica</i>	2	0.26	nat	ar
<i>Prunus cerasus</i>	1	0.13	nat	ar
<i>Juglans nigra</i>	78	10.14	cas	neo
<i>Aesculus hippocastanum</i>	27	3.51	cas	neo
<i>Tilia tomentosa</i>	15	1.95	cas	neo
<i>Populus balsamifera</i>	2	0.26	cas	neo
<i>Juglans x intermedia</i>	2	0.26	cas	neo
<i>Abies grandis</i>	1	0.13	cas	neo
<i>Eleagnus angustifolia</i>	1	0.13	cas	neo
<i>Gleditsia triacanthos</i>	1	0.13	cas	neo
<i>Picea pungens</i>	1	0.13	cas	neo
<i>Pinus jeffreyi</i>	1	0.13	cas	neo
<i>Platanus x hispanica</i>	1	0.13	cas	neo
<i>Thuja occidentalis</i>	1	0.13	cas	neo
<i>Acer negundo</i>	184	23.93	inv	neo
<i>Populus x canadensis</i>	139	18.08	inv	neo
<i>Robinia pseudacacia</i>	25	3.25	inv	neo
<i>Quercus rubra</i>	16	2.08	inv	neo
<i>Fraxinus pennsylvanica</i>	12	1.56	inv	neo
<i>Parthenocissus inserta</i>	4	0.52	inv	neo
<i>Ailanthus altissima</i>	2	0.26	inv	neo
<i>Mahonia aquifolium</i>	1	0.13	inv	neo
<i>Physocarpus opulifolius</i>	1	0.13	inv	neo
<i>Prunus cerasifera</i>	20	2.60	nat	neo
<i>Ribes rubrum</i>	11	1.43	nat	neo
<i>Pinus nigra</i>	1	0.13	nat	neo

15 species of the woody plants fall within threatened species of some category (Table 6) but only *Cornus mas* is protected by law and it was found in one segment only. Floodplain forests are indispensable biotopes of strongly endangered woody species, *Malus sylvestris* (70 segments), *Populus nigra* (33 segments) and endangered *Fraxinus angustifolia* (512 segments). There is also a strong population of elms, both *Ulmus laevis* and *Ulmus minor* (348 and 151 segments, respectively).

Table 6: The presence of threatened woody plant species

Species	threat category	number of segments
<i>Cornus mas</i>	§3 (C4)	1
<i>Malus sylvestris</i>	C2	70
<i>Populus nigra</i>	C2	33
<i>Quercus cerris</i>	C2	17
<i>Fraxinus angustifolia</i>	C3	512
<i>Prunus mahaleb</i>	C3	1
<i>Ulmus laevis</i>	C4	348
<i>Ulmus minor</i>	C4	151
<i>Viscum album</i>	C4	28
<i>Loranthus europaeus</i>	C4	25
<i>Pyrus pyraeaster</i>	C4	20
<i>Euonymus verrucosa</i>	C4	3
<i>Viburnum lantana</i>	C4	2
<i>Berberis vulgaris</i>	C4	1
<i>Sorbus aria</i>	C4	1

It is typical of floodplain woody plants that they grow to vast dimensions within their species (Maděra et al. 2007). Huge specimens can be found both in the stands and the meadows, riparian stands and forest edges with a high density. Their ecological significance is great; they are biotopes for a number of specially protected insects and birds, they form the landscape character, and they often represent the last remnants of local populations. Therefore, they need to be devoted sufficient attention in management (Rychtecká & Dreslerová 2009).

Diversity of herbs in the floodplain forests

We determined 514 species, subspecies and hybrids of herbs in the synusia of floodplain forest herb layer. Out of the total number of herbs found, there are 112 abundant species (occurrence in over 100 segments), 161 scattered species (10–99 segments) and 241 rare species within the area (1–9 segments) – 90 species were found in one segment only.

From the perspective of autochthonous character, 137 recorded species are various types of adventive species (Table 7), out of which there are 91 archeophytes and 46 neophytes, 40 invasive species. The more significant invasive archeophytes are *Cirsium arvense* in 66%

of segments, *Plantago major* (40% of segments), *Tanacetum vulgare* (36% of segments), *Cirsium vulgare* (31% of segments) and *Tripleurospermum inodorum* (24% of segments). Only the first mentioned species is dominant in forest edges and openings. The most significant and highly aggressive invasive neophyte in the area is *Aster lanceolatus*, whose presence in nearly 95% of segments and frequent dominance in younger and older stands of the floodplain forest presents a problem with almost no solution any more (Řepka & Maděra 2009a). The other abundant invasive neophytes in the area are *Impatiens parviflora*, *Bidens frondosa*, *Erigeron annuus*, *Solidago gigantea*, *Conyza canadensis*, *Rudbeckia laciniata*, *Helianthus tuberosus*, *Impatiens glandulifera* and species of genus *Amaranthus*. These species usually grow in clearings and newly established cultures and only the first two mentioned ones penetrate into forest communities.

Table 7: The presence of adventive herb species in segments
(according to Pyšek et al. 2002)

Species	number of segments	proportion of segments	adventive species category	
<i>Avena sativa</i>	3	0.39	cas	ar
<i>Panicum miliaceum</i>	2	0.26	cas	ar
<i>Brassica napus</i>	1	0.13	cas	ar
<i>Cannabis sativa</i>	1	0.13	cas	ar
<i>Hordeum distichon</i>	1	0.13	cas	ar
<i>Cirsium arvense</i>	512	66.49	inv	ar
<i>Plantago major</i>	308	40.00	inv	ar
<i>Tanacetum vulgare</i>	284	36.88	inv	ar
<i>Cirsium vulgare</i>	239	31.04	inv	ar
<i>Tripleurospermum inodorum</i>	188	24.42	inv	ar
<i>Ballota nigra</i>	51	6.62	inv	ar
<i>Viola odorata</i>	35	4.55	inv	ar
<i>Melilotus alba</i>	19	2.47	inv	ar
<i>Melilotus officinalis</i>	13	1.69	inv	ar
<i>Atriplex sagittata</i>	5	0.65	inv	ar
<i>Chenopodium pedunculare</i>	5	0.65	inv	ar
<i>Bryonia alba</i>	2	0.26	inv	ar
<i>Conium maculatum</i>	2	0.26	inv	ar
<i>Atriplex oblongifolia</i>	1	0.13	inv	ar
<i>Cardaria draba</i>	1	0.13	inv	ar
<i>Arctium lappa</i>	573	74.42	nat	ar
<i>Carduus crispus</i>	429	55.71	nat	ar
<i>Lapsana communis</i>	351	45.58	nat	ar
<i>Bromus sterilis</i>	170	22.08	nat	ar
<i>Echinochloa crus-galli</i>	139	18.05	nat	ar
<i>Lactuca serriola</i>	132	17.14	nat	ar
<i>Polygonum aviculare</i>	118	15.32	nat	ar
<i>Chenopodium polyspermum</i>	102	13.25	nat	ar
<i>Mentha arvensis</i>	89	11.56	nat	ar
<i>Sonchus asper</i>	84	10.91	nat	ar
<i>Atriplex patula</i>	79	10.26	nat	ar
<i>Pastinaca sativa</i>	77	10.00	nat	ar
<i>Chelidonium majus</i>	74	9.61	nat	ar
<i>Capsella bursa-pastoris</i>	73	9.48	nat	ar
<i>Sonchus arvensis</i>	67	8.70	nat	ar
<i>Setaria pumila</i>	66	8.57	nat	ar

Species	number of segments	proportion of segments	adventive species category	
<i>Medicago lupulina</i>	62	8.05	nat	ar
<i>Lamium album</i>	58	7.53	nat	ar
<i>Cichorium intybus</i>	57	7.40	nat	ar
<i>Lamium purpureum</i>	50	6.49	nat	ar
<i>Silene latifolia</i>	47	6.10	nat	ar
<i>Fallopia convolvulus</i>	44	5.71	nat	ar
<i>Bromus tectorum</i>	43	5.58	nat	ar
<i>Vicia hirsuta</i>	42	5.45	nat	ar
<i>Sonchus oleraceus</i>	36	4.68	nat	ar
<i>Bromus hordeaceus</i>	31	4.03	nat	ar
<i>Portulaca oleracea</i>	27	3.51	nat	ar
<i>Solanum nigrum</i>	24	3.12	nat	ar
<i>Convolvulus arvensis</i>	23	2.99	nat	ar
<i>Carduus acanthoides</i>	22	2.86	nat	ar
<i>Setaria viridis</i>	22	2.86	nat	ar
<i>Crepis biennis</i>	20	2.60	nat	ar
<i>Bromus commutatus</i>	19	2.47	nat	ar
<i>Linaria vulgaris</i>	18	2.34	nat	ar
<i>Vicia angustifolia</i>	17	2.21	nat	ar
<i>Arctium tomentosum</i>	14	1.82	nat	ar
<i>Sambucus ebulus</i>	12	1.56	nat	ar
<i>Erysimum cheiranthoides</i>	10	1.30	nat	ar
<i>Geranium pusillum</i>	10	1.30	nat	ar
<i>Setaria verticillata</i>	10	1.30	nat	ar
<i>Veronica arvensis</i>	10	1.30	nat	ar
<i>Digitaria sanguinalis</i>	9	1.17	nat	ar
<i>Senecio vulgaris</i>	9	1.17	nat	ar
<i>Verbena officinalis</i>	9	1.17	nat	ar
<i>Crepis capillaris</i>	7	0.91	nat	ar
<i>Tragopogon dubius</i>	6	0.78	nat	ar
<i>Leonurus cardiaca</i>	5	0.65	nat	ar
<i>Armoracia rusticana</i>	4	0.52	nat	ar
<i>Saponaria officinalis</i>	4	0.52	nat	ar
<i>Bromus japonicus</i>	3	0.39	nat	ar
<i>Eragrostis minor</i>	3	0.39	nat	ar
<i>Hordeum murinum</i>	3	0.39	nat	ar
<i>Myosotis arvensis</i>	3	0.39	nat	ar
<i>Synapis arvensis</i>	3	0.39	nat	ar
<i>Vicia villosa</i>	3	0.39	nat	ar
<i>Descurainia sophia</i>	2	0.26	nat	ar
<i>Lathyrus tuberosus</i>	2	0.26	nat	ar
<i>Thlaspi arvense</i>	2	0.26	nat	ar
<i>Vicia sativa</i>	2	0.26	nat	ar
<i>Vicia villosa subsp. varia</i>	2	0.26	nat	ar
<i>Arctium lappa x tomentosum</i>	1	0.13	nat	ar
<i>Avena fatua</i>	1	0.13	nat	ar
<i>Berteroa incana</i>	1	0.13	nat	ar
<i>Crepis tectorum</i>	1	0.13	nat	ar
<i>Cynodon dactylon</i>	1	0.13	nat	ar
<i>Euphorbia peplus</i>	1	0.13	nat	ar
<i>Malva neglecta</i>	1	0.13	nat	ar
<i>Nepeta cataria</i>	1	0.13	nat	ar

Species	number of segments	proportion of segments	adventive species category	
<i>Papaver rhoeas</i>	1	0.13	nat	ar
<i>Parietaria officinalis</i>	1	0.13	nat	ar
<i>Physalis alkekengi</i>	1	0.13	nat	ar
<i>Sagittaria latifolia</i>	6	0.78	cas	neo
<i>Bromus carinatus</i>	2	0.26	cas	neo
<i>Crepis foetida</i>	1	0.13	cas	neo
<i>Helianthus annuus</i>	1	0.13	cas	neo
<i>Zea mays</i>	1	0.13	cas	neo
<i>Aster lanceolatus</i>	731	94.94	inv	neo
<i>Impatiens parviflora</i>	274	35.58	inv	neo
<i>Bidens frondosa</i>	267	34.68	inv	neo
<i>Conyza canadensis</i>	174	22.60	inv	neo
<i>Solidago gigantea</i>	168	21.82	inv	neo
<i>Rudbeckia laciniata</i>	80	10.39	inv	neo
<i>Helianthus tuberosus</i>	66	8.57	inv	neo
<i>Impatiens glandulifera</i>	63	8.18	inv	neo
<i>Arrhenatherum elatius</i>	60	7.79	inv	neo
<i>Amaranthus retroflexus</i>	44	5.71	inv	neo
<i>Amaranthus powellii</i>	30	3.90	inv	neo
<i>Solidago canadensis</i>	27	3.51	inv	neo
<i>Epilobium ciliatum</i>	22	2.86	inv	neo
<i>Echinocystis lobata</i>	14	1.82	inv	neo
<i>Reynoutria japonica</i>	6	0.78	inv	neo
<i>Galinsoga parviflora</i>	3	0.39	inv	neo
<i>Juncus tenuis</i>	3	0.39	inv	neo
<i>Geranium pyrenaicum</i>	2	0.26	inv	neo
<i>Matricaria discoidea</i>	2	0.26	inv	neo
<i>Rumex thyrsiflorus</i>	2	0.26	inv	neo
<i>Aster novi-belgii</i>	1	0.13	inv	neo
<i>Galinsoga quadriradiata</i>	1	0.13	inv	neo
<i>Oenothera biennis</i>	1	0.13	inv	neo
<i>Reynoutria sachalinensis</i>	1	0.13	inv	neo
<i>Veronica persica</i>	1	0.13	inv	neo
<i>Erigeron annuus</i>	255	33.12	nat	neo
<i>Oxalis fontana</i>	141	18.31	nat	neo
<i>Trifolium hybridum</i>	129	16.75	nat	neo
<i>Galega officinalis</i>	20	2.60	nat	neo
<i>Chenopodium strictum</i>	14	1.82	nat	neo
<i>Datura stramonium</i>	7	0.91	nat	neo
<i>Xanthium albinum</i>	6	0.78	nat	neo
<i>Agrostis gigantea</i>	4	0.52	nat	neo
<i>Medicago sativa</i>	4	0.52	nat	neo
<i>Amaranthus albus</i>	2	0.26	nat	neo
<i>Asclepias syriaca</i>	2	0.26	nat	neo
<i>Sisymbrium strictissimum</i>	2	0.26	nat	neo
<i>Acorus calamus</i>	1	0.13	nat	neo
<i>Erechtites hieraciifolia</i>	1	0.13	nat	neo
<i>Oxalis corniculata</i>	1	0.13	nat	neo
<i>Oxalis dillenii</i>	1	0.13	nat	neo

As regards specially protected and threatened species, there are 98 of them in the area (Table 8). 21 species within the total number of 137 records in the segments are protected by law. Floodplain forests are very significant biotopes for species such as *Leucojum aestivum* (37 of segments), *Euphorbia palustris* (29), *Carex strigosa* (241), *Carex divulsa* (47), *Cardamine dentata* (123) and *Carex riparia* (626). Other species, indicating heavy-textured soils with varying humidity or subhalophilous, occur mainly in floodplain meadows and edges or clearings within forests – *Viola elatior*, *Scutellaria hastifolia*, *Carex melanostachya*, *Gratiola officinalis*, *Teucrium scordium*, *Lathyrus palustris*, *Pulicaria dysenterica*, *Leonurus marubiastrum*, *Lycopus exaltatus*, *Sonchus palustris*, *Lythrum virgatum*, *Sonchus palustris*, *Cnidium dubium*, *Silaum silaus*, *Trifolium fragiferum*, *Inula salicina*, and *Galium boreale*. Marshlands, water streams and their edges are important biotopes for species such as *Juncus atratus*, *Cardamine parviflora*, *Ceratophyllum submersum*, *Hottonia palustris*, *Sium latifolium*, *Potamogeton nodosus*, *Hydrocharis morsus-ranae*, *Najas marina*, *Butomus umbellatus*, *Cardamine matthioli*, *Leersia oryzoides*, *Scrophularia umbrosa* or *Veronica scutellata*, *Carex buekii*. Elevated sandy dunes contain species such as *Scilla drunensis*, *Galanthus nivalis*, *Equisetum ramosissimum*.

Table 8: The presence of threatened herb species

Species	threat category	number of segments
<i>Leucojum aestivum</i>	§1, C1	37
<i>Cardamine parviflora</i>	§1, C1	5
<i>Viola elatior</i>	§1, C1	3
<i>Euphorbia lucida</i>	§1, C1	1
<i>Juncus atratus</i>	§1, C1	1
<i>Lathyrus palustris</i>	§1, C2	1
<i>Euphorbia palustris</i>	§2, C2	29
<i>Thalictrum flavum</i>	§2, C2	11
<i>Senecio sarracenicus</i>	§2, C2	8
<i>Scutellaria hastifolia</i>	§2, C2	7
<i>Gratiola officinalis</i>	§2, C2	6
<i>Allium angulosum</i>	§2, C2	5
<i>Carex melanostachya</i>	§2, C2	2
<i>Ceratophyllum submersum</i>	§2, C1	1
<i>Scilla drunensis</i>	§2, C2	1
<i>Teucrium scordium</i>	§2, C2	1
<i>Viola pumila</i>	§2, C2	1
<i>Epipactis albensis</i>	§2, C2	1
<i>Hottonia palustris</i>	§3, C3	8
<i>Galanthus nivalis</i>	§3, C3	7
<i>Equisetum ramosissimum</i>	§3, C3	1
<i>Pulicaria dysenterica</i>	C1	12
<i>Ranunculus sardous</i>	C1	2
<i>Carex strigosa</i>	C2	241
<i>Cardamine dentata</i>	C2	123
<i>Odontites verna</i>	C2	89
<i>Leonurus marubiastrum</i>	C2	64
<i>Carex divulsa</i>	C2	47

Species	threat category	number of segments
<i>Bromus commutatus</i>	C2	19
<i>Sium latifolium</i>	C2	12
<i>Althaea officinalis</i>	C2	6
<i>Cerastium dubium</i>	C2	6
<i>Potamogeton nodosus</i>	C2	5
<i>Hydrocharis morsus-ranae</i>	C2	4
<i>Lycopus exaltatus</i>	C2	4
<i>Sonchus palustris</i>	C2	3
<i>Cnidium dubium</i>	C2	3
<i>Dipsacus laciniatus</i>	C2	2
<i>Centaurium pulchellum</i>	C2	1
<i>Lythrum virgatum</i>	C2	1
<i>Najas marina</i>	C2	1
<i>Parietaria officinalis</i>	C2	1
<i>Lotus tenuis</i>	C3	47
<i>Silaum silaus</i>	C3	36
<i>Pseudolysimachion longifolium</i>	C3	33
<i>Trifolium fragiferum</i>	C3	22
<i>Verbascum blattaria</i>	C3	16
<i>Butomus umbellatus</i>	C3	13
<i>Virga pilosa</i>	C3	12
<i>Verbena officinalis</i>	C3	9
<i>Corydalis pumila</i>	C3	8
<i>Leersia oryzoides</i>	C3	5
<i>Scrophularia umbrosa</i>	C3	5
<i>Cardamine matthioli</i>	C3	4
<i>Carex curvata</i>	C3	2
<i>Lathyrus latifolius</i>	C3	2
<i>Agrimonia procera</i>	C3	1
<i>Cyperus fuscus</i>	C3	1
<i>Lactuca quercina</i>	C3	1
<i>Myosurus minimus</i>	C3	1
<i>Potamogeton lucens</i>	C3	1
<i>Thalictrum lucidum</i>	C3	1
<i>Carex riparia</i>	C4a	626
<i>Senecio erraticus</i>	C4a	154
<i>Aethusa cynapioides</i>	C4a	100
<i>Cerastium lucorum</i>	C4a	69
<i>Cucubalus baccifer</i>	C4a	65
<i>Carex buekii</i>	C4a	59
<i>Epipactis helleborine</i>	C4a	27
<i>Veronica montana</i>	C4a	27
<i>Arum cylindraceum</i>	C4a	17
<i>Vicia dumetorum</i>	C4a	13
<i>Veronica scutellata</i>	C4a	10
<i>Verbascum austriacum</i>	C4a	9
<i>Carex disticha</i>	C4a	8

Species	threat category	number of segments
<i>Serratula tinctoria</i>	C4a	6
<i>Galium boreale</i>	C4a	5
<i>Myosotis sparsiflora</i>	C4a	5
<i>Barbarea stricta</i>	C4a	4
<i>Melica transsilvanica</i>	C4a	4
<i>Bromus japonicus</i>	C4a	3
<i>Carex otrubae</i>	C4a	3
<i>Carex pseudocyperus</i>	C4a	3
<i>Centaureum erythraea</i>	C4a	3
<i>Lemna trisulca</i>	C4a	3
<i>Schoenoplectus lacustris</i>	C4a	3
<i>Inula salicina</i>	C4a	2
<i>Atriplex oblongifolia</i>	C4a	1
<i>Corydalis intermedia</i>	C4a	1
<i>Cynodon dactylon</i>	C4a	1
<i>Elytrigia intermedia</i>	C4a	1
<i>Kohlruschia prolifera</i>	C4a	1
<i>Lavatera thuringiaca</i>	C4a	1
<i>Potentilla arenaria</i>	C4a	1
<i>Veronica verna</i>	C4a	1
<i>Carex chabertii</i>	C4b	21
<i>Xanthium albinum</i>	C4b	6
<i>Cerastium pumilum</i>	C4b	2

DISCUSSION

Professional literature seldom provides results of a full-area inventory of floodplain forests. Trinajstić et al. (2005) present the richness of flora in floodplain forests of northern Croatia with a number of 437 species. Although our study area lies in the northern part of the Pannonian Basin, the total number of found species is higher than in its southern part, i.e. the species diversity of lowland floodplain forests of northern Croatia (612 versus 437 species of vascular plants). Other data come from geographically distant areas: Lyon and Sagers (1998) found 65 families in the floodplain of the Current and Jacks Fork Rivers, North America, and in agreement with our results they ascertained low fidelity of the found species – only fidelity of 42 species out of the 269 recorded ones was over 10%. Tabacchi et al. (1996) found 1,396 plant species along the entire corridor of the Adour River (SW France), which accounts for a fifth of the flora of France. The species diversity of south-Moravian floodplain forests we established also corresponds to about a fifth of the flora of the Czech Republic. The highest biodiversity was found by Pott et al. (2011) in the tropical South American Pantanal wetland, where nearly 2,000 species were recorded in an area of over 150,000 km² in various types of vegetation. The study of Schnitzler et al. (2007) summarised available articles focused on the diversity of riparian forests across the whole of Europe and recorded 1,380 species. Even these sparse data testify to the considerable significance of floodplain forests for the maintenance of diversity of vascular plants.

Most authors examine the species diversity of floodplain forests using sample plots, not full-area terrain surveys, and thus they naturally reach lower numbers than we have

recorded. Ernault et al. (2006) found 334 species of plants in twenty plots of the Seine floodplain forests, each having an area of 1 km². Goebel et al. (2006) used 417 plots of 1 m² in size and determined 162 species of plants in various river systems in NE Wisconsin. Mölder et al. (2011) explored the diversity of flora along the Danube River and found 165 species of higher plants, including 22 graminoids (13%), 100 forbs (61%) and 43 woody species (26%). Only woody plants were examined by Santos (2010). She recorded 53 species, out of which 28 were endemic, in 70 river plots of 2 km in length on the Sado and Guadiana watersheds in southern Portugal. Paal et al. (2007) studied the floodplain forests in Estonia in 79 subnatural stands. The ground vegetation was described using randomly located sample quadrats of 1 x 1 m; their number was 15–20 per stand. The total species list included 372 plant species: 17 species in the tree layer, 17 in the shrub layer, 225 in the herb layer and 100 species in the moss layer. A total of 269 herb and 70 tree species were identified on 94 sample plots by Lyon and Sagers (1998), within the Ozark National Scenic Riverways (ONSR), a forest corridor enclosing a 161 km stretch of the Current River and a 55 km stretch of the Jacks Fork River in southwest Missouri, USA. Similarly, McLane et al. (2012) recorded 193 plant species within the Cypress Creek NWR, Illinois, U.S.A., out of which 56 were woody plants, in 80 plots of 1 m². Archaux et al. (2010) sampled vascular flora in 181 poplar plantations along the Seine and Aube rivers within plots of 200 m² in area. They recorded 211 plant species (32 forest species, 40 tall herbs and 48 meadow plants, 38 ruderal species, 53 other species – aquatic, generalist, field plants). Schnitzler (1997) showed 106–157 plant species (incl. 37–56 woody species) from the Ill, Rhine, Loire and Allier floodplains, Trémolieres et al. (1998) presented only 37 woody species in the Rhine floodplain, but these were bound to the communities of alluvial hardwood forests. Godreau et al. (1999) in their study from the Saone floodplain mentioned 104 plant species in riverine wetlands, 208 plant species in grasslands, unfortunately the number of forest species is not given.

High native plant diversity in riparian biotopes is largely associated with natural disturbance, particularly flooding and scour by seasonal and storm related flood pulses, which create regeneration microsites and mediate resource competition among species (Naiman & Decamps 1997; Naiman et al. 1993, 2005). Frequent natural or anthropogenic disturbances, however, can also create conditions conducive to alien plant establishment (De Ferrari & Naiman 1994; Pyšek & Prach 1994; Planty-Tabacchi et al. 1996; Pyle 1995; Stohlgren et al. 1998).

We found 170 adventive species in the study area, it is 26% of all vascular plants creating the floodplain forest communities. Williams (2010) described forty alien plant species (17.8% of the total surveyed flora) from 42 survey sites across the seven islands of the Allegheny River Islands Wilderness (northwestern Pennsylvania). Košir et al. (2013) presented up to 15% proportion of neophytes in phytocoenological plots along the Mura River (NE Slovenia). Schnitzler et al. (2007) summarised 1,380 species across European riparian forests, 45 (3.3%) of these were exotic species. Many exotics found in their study were introduced intentionally either from North America (51%) or Asia (38%). The exotics belong to various life-forms: approximately 50% are grasses (polycarpic perennials, summer and autumn annuals), while the rest are phanerophytes, equally distributed among trees, shrubs and liana life-forms. Most of the exotics are thermophilous and light-demanding pioneer species from warm temperate floodplains. Thirty-two percent are from the *Asteraceae* family. The distribution of exotics in the 177 communities recorded is highly unequal. Twenty-six are present at low levels in very few communities; seven have an intermediate distribution; and twelve (27%) are abundant in a large range of habitats (in compliance with our results there are for example *Impatiens parviflora*, *Erigeron*

canadensis or *Solidago gigantea*). McLane et al. (2012) recorded a 14.4% proportion of exotic species in the basin of the Cypress Creek NWR, Illinois, U.S.A., and Uowolo et al. (2005) even higher – 30% proportion of exotic species – along the Yampa and Green rivers (northwest Colorado, USA). Concerning neophytes, the Upper Danube flora yielded five species (7%), the Middle Danube Flora nine species (14%) and the Lower Danube Flora eight species (10%). The most important non-native tree species were *Fraxinus pennsylvanica* (Middle and Lower Danube), *Acer negundo* (Middle Danube) and *Robinia pseudoacacia* (Upper Danube), which reached considerable proportions in the tree layer. Frequent non-native herb species were *Impatiens parviflora* and *Solidago gigantea* (Upper and Middle Danube), *Aster parviflorus*, *Oxalis stricta* (Middle Danube) and *Aster lanceolatus* (Lower Danube). The invasive shrub species *Amorpha fruticosa* was very common on the Lower Danube (Mölder & Schneider 2011). Also Chmura & Sierka (2006) in their study of Polish floodplain forests consider *Impatiens parviflora* to be a significant invasive species. Magee et al. (2008) evaluated the importance of alien species in the existing vegetation along Wadeable streams of a large, topographically diverse river basin in eastern Oregon, USA; they identified 60 alien species and 355 native species. Alien species occurred in 93% of sample plots, in all community types, and along all sampled stream reaches, with relative alien cover (RAC) ranging from 0.1% to 47% and 1 to 24 alien species occurring along individual stream reaches. RAC differed among community types: it was the greatest in arid associations (shrubland/grassland), followed by associations with limited tree canopy cover (meadows, dry forest), and the lowest in moist, closed forest associations.

Floodplains are considered vulnerable to exotic species (Hood & Naiman 2000; Harris et al. 2005), due to the combined influence of intensive human exploitation, a high degree of hydrological connectivity that facilitates propagule dispersal and the high spatial and temporal heterogeneity inherent to these systems. Globally, anthropogenic alterations to floodplain hydrological regimes have frequently resulted in riparian species invasions (Richardson et al. 2007). Vegetation changes are partially structured by reduced flood frequency favouring increased abundance of exotic, sexually reproducing annuals at drier sites. Sites of low flood frequency are more sensitive to future exotic weed invasion. Flow restoration is predicted to benefit propagule dispersal of species adopting dual regeneration strategies, which are predominantly natives in this system (Stokes et al. 2010). The invasion by alien plant species is a major challenge to the conservation and management of riparian areas, which can alter ecosystem structure and function in undesirable ways (Hood & Naiman 2000; Stohlgren et al. 1998). The invasive species capable of becoming dominant are the most dangerous, and in the study area it is *Aster lanceolatus* (Řepka et al. 2009). Brewer (2010) described a similar example: a significant negative effect of species richness on invasive grass *M. vimineum* abundance. Altogether, his results suggest that the same factors that reduce biotic resistance have even greater direct positive effects on the abundance of invasive grass and native floodplain specialists. According to investigation of Saccone et al. (2010), *Acer negundo* showed both a high survival in the shade and a high growth in full light. This species could be an example of adaptive plasticity that certainly represents a competitive advantage over native species. Another example is mentioned by Hanula & Horn (2011); they investigated the effects of the invasive shrub Chinese privet (*Ligustrum sinense*) and two methods (mulching or hand-felling) of removing it from riparian forests on butterfly communities. Pyšek & Prach (1993) named four significant invasive species in riparian habitats of central Europe: *Impatiens glandulifera*, *Heracleum mantegazzianum*, *Reynoutria japonica* and *R. sachalinensis*; none of these has caused a significant problem in the study area.

Technical regulations of the water regime within floodplains can also impact on the species diversity of floodplain forests. For example, Trémolières et al. (1998) compared various sections of an alluvial hardwood forest along the Rhine. Using six plots of about 2,000 m², they found 63 species (25 woody species) in a flooded floodplain, 121 species (45 woody species) in a floodplain that had not been flooded for 30 years, and 95 species (47 woody species) in a floodplain not flooded for 130 years. Deiller et al. (2001) mentioned that the species richness of the extant vegetation increases with the duration of interruption of the floods in the Rhine forest as a result of introduction of flood-intolerant species in the unflooded forest. By contrast, Uowolo et al. (2005) recorded a 40% higher number of species in unregulated floodplain of the Yampa river in contrast to the regulated Green River. Other authors also document the changes in species composition and spatial structure of the synusia of floodplain forest herb layer (Vašíček 1985, Vrška 1997, 1998, Maděra 2001a, 2001b; Viewegh 2002, Unar & Šamonil 2008, Santos 2010) or in the tree layer (Schnitzler 1994; Trémolières et al. 1998; Janík et al. 2008, 2011) in dependence on drying of floodplain forests, when flood-intolerant and mesic species can arrive.

Much fewer studies deal with threatened species in floodplains. De Nooij (2006) presented 136 threatened species of vascular plants related to occurrence in river floodplains in Holland. Godreau et al. (1999) found 31 regionally threatened plant species in all biotopes (wetlands, grasslands) in the Saone floodplain; surprisingly, in floodplain forests none such species was found. Similarly, a study by O'ahelová et al. (1992, 1997) mentioned 129 rare or threatened plant and moss species in the Slovakian part of the Morava river polder. Based on their results, the biotope of floodplain forest is insignificant for the threatened species, comprising only 4% of found species. Floodplain meadows, water biotopes, wetlands, acid sands, bare bottoms and even anthropogenic biotopes (dams, road edges, fallows) are more significant as they contain more threatened species. However, our results show that the floodplain forests are significant biotopes for threatened species – we have recorded a total of 113, which is 19.46% of all species. This discrepancy can be perhaps explained by the insufficiently consistent approach of the florists to the full-area forest inventory as the orientation in them is difficult and demanding. A lot of species occur in forests only rarely and they need not be discovered unless the forest is scoured thoroughly.

CONCLUSIONS

From the perspective of species diversity of vascular plants, floodplain forests in the Tvrdonice forest district are a highly valuable area containing many threatened species. However, there is a high proportion of adventive species. The most significant of them is *Aster lanceolatus*, which poses a serious problem due to its presence in nearly 95% of segments as well as its ability to create dominant stands considerably reducing the species diversity.

The high number of adventive species and their relatively high occurrence are caused by a number of factors. The most significant of them are the used ways of stand regeneration with the broadcast soil preparation - agroforestry in history and in more recent decades ploughing, raking of the soil profile with stumps into mounds, or milling (Řepka, Maděra 2009b). The primary vector for the spread of these species is the river and its flooding system; however, stand fragmentation (Dynesius & Nilsson 1994) and their connection by forest roads, clearings, and canals also played their role after the regulation of the Morava river and elimination of regular floods (Penka et al. 1991, Horák 1964).

The full-area floristic inventory provides unique results. It expands our knowledge about the significance of floodplain forests for biodiversity and enables us to create maps of occurrence of particular species, places with high diversity and places with the troublesome occurrence of adventive species. These geographic models can be well used for the management of forest stands or the zonation of Dolní Morava Biosphere Reserve.

ACKNOWLEDGEMENT

The results could be attained thanks to support provided by NAZV (National Agency for Research in Agriculture) project called Harmonization of Forest Management in Floodplains as a Tool to Preserve Species Diversity of Vascular Plants (reg. no. QI92A031).

REFERENCES

- ARCHAUX, F., CHEVALIER, R., BERTHELOT, A., 2010. *Towards practices favourable to plant diversity in hybrid poplar plantations*. Forest Ecology and Management 259: 2410–2417
- BOEDEL TJE, G., BAKKER, J.P., BRINKE, A.T., VAN GROENENDAEL, J.M., SOESBERGEN, M., 2004. *Dispersal phenology of hydrochorous plants in relation to discharge, seed release time and buoyancy of seeds: The flood pulse concept supported*. Journal of Ecology, 92 (5): 786–796.
- BOHN, U., NEUHÄUSL, R., GOLLUB, G., HETTWER, C., NEUHÄUSLOVÁ, Z., SCHLÜTER, H., WEBER, H., 2003. *Map of the Natural Vegetation of Europe*. Scale 1:2 500 000. Federal Agency for Nature Conservation, Bonn, 655 p.
- BREWER, J.S., 2010. *A Potential Conflict between Preserving Regional Plant Diversity and Biotic Resistance to an Invasive Grass, Microstegium vimineum*. Natural Areas Journal, 30(3): 279–293.
- CHMURA, D., SIERKA, E., 2006. *Relation between invasive plant and species richness of forest floor vegetation: A study of Impatiens parviflora DC*. Polish Journal of Ecology, 54 (3): 417–428
- DANIHELKA, J., GRULICH, V., ŠUMBEROVÁ, K., ŘEPKA, R., HUSÁK, Š. ET ČÁP, J., 1995. *O rozšíření některých cévnatých rostlin na nejjižnější Moravě*. Zprávy České Botanické Společnosti, 30 (Suppl.): 29–102.
- DANIHELKA, J., ŠUMBEROVÁ, K., 2004. *O rozšíření některých cévnatých rostlin na nejjižnější Moravě II*. Příroda, Praha, 21: 117–192.
- DE FERRARI, C. M., NAIMAN, R. J., 1994. *A multi-scale assessment of the occurrence of exotic plants on the Olympic Peninsula, Washington*. Journal of Vegetation Science 5: 247–258.
- DEILLER, A.F., WALTER J.M.N., TRÉMOLIÉRES, M., 2001. *Effect of flood interruption on species richness, diversity and floristic composition of woody regeneration in the upper Rhine alluvial hardwood forest*. Regulated Rivers: Research & Management, 17: 393–405
- DE NOOIJ, R.J.W., LOTTERMAN, K.M., VAN DE SANDE, P.H.J., PELSMA, T., LEUVEN, R.S.E.W., LENDERS, H.J.R., 2006. *Validity and sensitivity of a model for assessment of*

impacts of river floodplain reconstruction on protected and endangered species. Environmental Impact Assessment Review 26: 677–695

DYNESIUS, M., NILSSON, C., 1994. *Fragmentation and flow regulation of river systems in the northern third of the world.* Science 266: 753–761.

ERNOULT, A., TREMAUVILLE, Y., CELLIER, D., MARGERIE, P., LANGLOIS, E., ALARD, D., 2006. *Potential landscape drivers of biodiversity components in a flood plain: Past or present patterns?* Biological Conservation, 127: 1–17

GODREAU, V., BORNETTE, G., FROCHOT, B., AMOROS, C., CASTELLA, E., OERTLI, B., CHAMBAUD, F., OBERTI, D., CRANEY, E., 1999. *Biodiversity in the floodplain of Saone: a global approach.* Biodiversity and Conservation, 8: 839–864.

GOEBEL, P.CH., PREGITZER, K.S., PALIK, B.J., 2006. *Landscape hierarchies influence riparian ground-flora communities in Wisconsin, USA.* Forest Ecology and Management 230: 43–54

HANULA, J.L., HORN, S., 2011. *Removing an exotic shrub from riparian forests increases butterfly abundance and diversity.* Forest Ecology and Management 262: 674–680.

HARRIS, M.B., TOMAS, W., MOURAO, G., DA SILVA, C.J., GUIMARAES, E., SONODA, F., FACHIM E., 2005. *Safeguarding the Patanal wetlands: threats and conservation initiatives.* Conservation Biology 19:714–720

HOLUB, J., PROCHÁZKA, F., 2000. *Red List of vascular plants of the Czech Republic.* Preslia, 72: 187–230.

HOOD, G.W., NAIMAN, R.J., 2000. *Vulnerability of riparian zones to invasion by exotic vascular plant species.* Plant Ecology, 148:105–114

HORÁK, J., 1961. *Jihomoravské lužní lesy (typologická studie).* Thesis, VŠZ, Brno, 266 pp.

HORÁK, J., 1964. *Lesní fytoceνόza jako indikátor změn vodního režimu lužních lesů.* In: Vegetační problémy budování vodních děl, ČSAV Praha: 39–53.

HRIB, M., 2004. *Z historie lesního hospodářství.* IN. HRIB M., KORDIOVSKÝ E. (EDS.): Lužní les v Dyjsko-moravské nivě. Moraviapress, Břeclav: 209–226.

JANÍK, D., ADAM, D., VRŠKA, T., HORT, L., UNAR, P., KRÁL, K., ŠAMONIL, P., HORAL, D., 2008. *Tree layer dynamics of the Cahnov-Soutok near-natural floodplain forest after 33 years (1973–2006).* European Journal of Forest Research, 127 (4): 337–345.

JANÍK, D., ADAM, D., VRŠKA, T., HORT, L., UNAR, P., KRÁL, K., ŠAMONIL, P., HORAL, D., 2011. *Field maple and hornbeam populations along a 4-m elevation gradient in an alluvial forest.* European Journal of Forest Research, 130: 197–208.

KLIMO, E., HAGER, H., 2000. *The floodplain forests in Europe.* EFI, Leiden, Boston, Köln, Brill, 215 p.

KLIMO, E., HAGER, H., MATIĆ, S., ANIĆ, I., KULHAVÝ, J. /EDS./ 2008. *Floodplain Forests of the Temperate Zone of Europe.* Lesnická práce, Kostelec nad Černými Lesy, 623 p.

KOŠIR, P., ČARNI, A., MARINŠEK, A., ŠILC, U., 2013. *Floodplain forest communities along the Mura River (NE Slovenia).* Acta Botanica Croatia, 72, 1: 71–95.

KUBÁT, K., HROUDA, L., CHRTEK, J., KAPLAN, Z., KIRSCHNER, J., ŠTĚPÁNEK, J., 2002. *Klíč ke květeně České republiky.* Academia, Praha, 928.

LYON, J., SAGERS, C.L., 1998. *Structure of herbaceous plant assemblages in a forested riparian landscape.* Plant Ecology 138: 1–16.

- NOŽIČKA, J., 1956.** *Z minulosti jihomoravských luhů (Předběžná studie).* Práce výzkumných ústavů lesnických ČSR, sv.10: 169-199.
- MAAREL VAN DER, E., 1975.** *Man-made natural ecosystems in environmental management and planning.* IN: **DOBBEN VAN W.H., LOWE-MCCONELL R. H. (EDS.):** Unifying concepts in ecology. The Hague, Dr W. Junk B. V. Publishers: 263 – 274.
- MADĚRA, P., 2001A.** *Response of floodplain forest communities herb layer to changes in the water regime.* Biológia, Bratislava, **56:** 63-72.
- MADĚRA, P., 2001B.** *Effect of water regime changes on the diversity of plant communities in floodplain forests.* Ekológia (Bratislava), Vol.20, Supplement 1, p.116-129.
- MADĚRA, P. ET AL., 2007.** *100 nejzajímavějších stromů Biosférické rezervace Dolní Morava.* BR Dolní Morava, 120 s.
- MADĚRA, P., VUKELIC, J., BUČEK, A., BARIČEVIC, D., 2008.** *Floodplain forest plant communities.* IN. **KLIMO E. ET AL. (EDS.):** Floodplain forests of the temperate zone of Europe. Lesnická práce, Kostelec nad Černými lesy: 102-159.
- MADĚRA, P., ŠEBESTA, J., ŘEPKA, R., KLIMÁNEK, M., 2011.** *Vascular plants distribution as a tool for adaptive forest management of floodplain forests in the Dyje river basin.* Journal of Landscape Ecology, 4, 2: 18-34.
- MAGEE, T.K., RINGOLD, P.L., BOLLMAN, M.A., 2008.** *Alien species importance in native vegetation along wadeable streams, John Day River basin, Oregon, USA.* Plant Ecology 195: 287–307
- MCLANE, C.R., BATTAGLIA, L.L., GIBSON, D.J., GRONINGER, J.W., 2012.** *Succession of Exotic and Native Species Assemblages within Restored Floodplain Forests: A Test of the Parallel Dynamics Hypothesis.* Restoration Ecology, 20, 2: 202–210.
- MÖLDER, A., SCHNEIDER, E., 2011.** *On the beautiful diverse Danube? Danubian floodplain forest vegetation and flora under the influence of river eutrophication.* River Research and Applications, 27: 881–894
- NAIMAN, R.J., DECAMPS, H., POLLOCK, M., 1993.** *The role of riparian corridors in maintaining regional biodiversity.* Ecological Applications, 3: 209–212
- NAIMAN, R. J., DECAMPS, H., 1997.** *The ecology of interfaces: Riparian zones.* Annual Review of Ecology, Evolution and Systematics, 28: 621–658.
- NAIMAN, R. J., DECAMPS, H., MC CLAIN, M.E., 2005.** *Riparia: Ecology, Conservation, and Management of Streamside Communities.* Elsevier Academic Press, New York.
- NEUHÁUSLOVÁ, Z., 2001.** *L2 Lužní lesy.* IN: **CHYTRÝ M., KUČERA T., KOČÍ M. (EDS.):** Katalog biotopů České republiky, AOPK, Praha: 173-179.
- OŤAHELOVÁ, H., BANÁSOVÁ, V., JAROLÍMEK, I., HUSÁK, Š., ZALIBEROVÁ, M., ZLINSKÁ, J., 1992.** *K výskytu ohrozených druhů flóry Slovenska v inundačnom území dolného toku rieky Moravy.* Bulletin Slovenskej Botanickéj Spoločnosti, Bratislava 14: 34-35.
- OŤAHELOVÁ, H., BANÁSOVÁ, V., JAROLÍMEK, I., ZALIBEROVÁ, M., 1997.** *Zoznam ohrozených druhov rastlín v nivě Moravy.* Bulletin Slovenskej Botanickéj Spoločnosti, Bratislava 19: 107-113.
- PAAL, J., RANNIK, R., JELETSKY, E.M., PRIEDITIS, N., 2007.** *Floodplain forests in Estonia: Typological diversity and growth conditions.* Folia Geobotanica 42: 383-400.
- PENKA, M., VYSKOT, M., KLIMO, E., VAŠÍČEK, F., 1985.** *Floodplain forest ecosystem 1.* Academia, Praha, 466 p.

- PENKA, M., VYSKOT, M., KLIMO, E., VAŠÍČEK, F., 1991. *Floodplain forest ecosystem 2*. Academia, Praha, 632 p.
- PLANTY-TABACCHI, A., TABACCHI, E., NAIMAN, R. J., DE FERRARI, C. M., DECAMPS, H., 1996. *Invasibility of species-rich communities in riparian zones*. Conservation Biology, 10: 598–607.
- POTT, A., OLIVEIRA, A.K.M., DAMASCENO-JUNIOR, G.A., SILVA, J.S.V., 2011. *Plant diversity of the Pantanal wetland*. Brazilian Journal of Biology, 71, 1 (suppl.): 265–273.
- PYLE, L. L., 1995. *Effects of disturbance on herbaceous exotic plant species on the floodplain of the Potomac River*. American Midland Naturalist, 134: 244–253.
- PYŠEK, P., PRACH, K., 1993. *Plant invasions and the role of riparian habitats: a comparison of four species alien to central Europe*. Journal of Biology, 20: 413–420.
- PYŠEK, P., PRACH, K., 1994. *How Important are Rivers for Supporting Plant Invasions?* IN: L. C. DE WAAL, L. E. CHILD, P. M. WADE AND J. H. BROCK, (EDS.): Ecology and Management of Invasive Riverside Plants. John Wiley & Sons Ltd, pp. 19–26.
- PYŠEK, P., SÁDLO, J., MANDÁK, B., 2002. *Catalogue of alien plants of the Czech Republic*. Preslia, 74: 97–186.
- RICHARDSON, D., HOLMES, P.M., ELSE, K.J., GALATOWITSCH, S.M., STROMBERG, J.C., KIRKMAN, S.P., PYŠEK, P., HOBBS, R.J., 2007. *Riparian vegetation: degradation, alien plant invasions, and restoration prospects*. Diversity and Distributions, 13: 126–139.
- RYCHTECKÁ, P., DRESLEROVÁ, J., 2009. *Important woody species in Poodří floodplains (Czech Republic)*. Journal of Landscape Ecology, 2(1): 58–76.
- ŘEPKA, R., MADĚRA, P., 2009. *Rozšíření adventivních druhů v nížinných lužích jižní Moravy – případ hvězdnice kopinaté (Aster lanceolatus)*. IN: MĚKOTOVÁ, J. (ED.): Říční krajina 6. Sborník příspěvků z konference 21.října 2009, Olomouc: 100–106.
- ŘEPKA, R., MADĚRA, P., 2009B. *Diverzita vyšších cévnatých rostlin lužního lesa ve vztahu k jeho věku*. Zprávy České Botanické Společnosti, 44, Materiály 24: 101–110.
- SACCONE, P., BRUN, J.J., MICHALET, R., 2010. *Challenging growth-survival trade-off: A key for Acer negundo invasion in European floodplains?* Canadian Journal of Forest Research, 40, 10: 1879–1886.
- SANTOS, M.J., 2010. *Encroachment of upland Mediterranean plant species in riparian ecosystems of southern Portugal*. Biodiversity and Conservation, 19:2667–2684.
- SCHNITZLER, A., 1994. *Conservation of biodiversity in alluvial hardwood forests of the temperate zone. The example of Rhine valley*. Forest ecology and management, 68:385–398.
- SCHNITZLER, A., 1997. *River dynamics as a forest process: interaction between fluvial systems and alluvial forests in large European river plains*. The botanical review, 63,1:40–64.
- SCHNITZLER, A., HALE, B.W., ALSUM, E.M., 2007. *Examining native and exotic species diversity in European riparian forests*. Biological Conservation, 138: 146–156.
- STOHLGREN, T. J., BULL, K. A., OTSUKI, Y., VILLA, C. A., LEE, M., 1998. *Riparian zones are havens for exotic plant species in the central grasslands*. Plant Ecology, 138: 113–125.
- STOKES, K., WARD, K., COLLOFF, M., 2010. *Alterations in flood frequency increase exotic and native species richness of understorey vegetation in a temperate floodplain eucalypt forest*. Plant Ecology, 211: 219–233.

TABACCHI, E., PLANTY-TABACCHI, A.M., SALINAS, M.J., DECAMPS, H., 1996. *Landscape structure and diversity in riparian plant communities: a longitudinal comparative study.* Regulated Rivers: Research & Management, 12: 367-390.

TREMOLIERES, M., SANCHEZ-PEREZ, J.M., SCHNITZLER, A., SCHMITT, D., 1998. *Impact of river management history on the community structure, species composition and nutrient status in the Rhine alluvial hardwood forest.* Plant Ecology 135: 59–78.

TRINAJSTIĆ, I., FRANJIČ, J., ŠKVORC, Ž., 2005. *The flora of floodplain and marshy forests.* IN: VUKELIĆ J. (ED.): Floodplain Forests in Croatia, p. 93-101, Academy of Forestry Sciences, Zagreb.

UNAR, P., ŠAMONIL, P., 2008. *The evolution of natural floodplain forests in South Moravia between 1973 and 2005.* Journal of Forest Science, 54 (8): 340-354.

UOWOLO, A.L., BINKLEY, D., ADAIR, E.C., 2005. *Plant diversity in riparian forests in northwest Colorado: Effects of time and river regulation.* Forest Ecology and Management 218: 107–114.

ÚRADNÍČEK, L., MADĚRA, P., TICHÁ, S., KOBLÍZEK, J., 2010. *Woody Plants of the Czech Republic.* Lesnická práce, Kostelec nad Černými lesy, 368 s.

VÁŠÍČEK, F., 1985. *Changes in the herbal vegetation along the topographical moisture gradient.* IN: PENKA M., VYSKYT M, KLIMO E., VÁŠÍČEK F.: Floodplain Forests Ecosystem 2: 355-386, Academia, Praha.

VICHEREK, J. ET AL. 2000. *Flóra a vegetace na soutoku Moravy a Dyje.* Masarykova univerzita v Brně, Brno, 368 s.

VIEWEGH, J., 2002. *South-Moravian floodplain forest herb vegetation in the period 1978 – 1997.* Journal of Forest Science, 48: 88–92.

VRŠKA, T., 1997. *Prales Cahnov po 21 letech (1973-1994).* Lesnictví-Forestry 43:155-180.

VRŠKA, T., 1998. *Prales Ranšpurk po 21 letech (1973-1994).* Lesnictví-Forestry, 44:440-473.

WILLIAMS, CH.E., 2010. *Survey of the alien flora of the Allegheny river island wilderness, Pennsylvania.* Rhodora, 112, 950: 142–155

WENGER, E.L., ZINKE, A., GUTZWEILER, K.A., 1990. *Present situation of the European floodplain forests.* Forest Ecology and Management, 33-34: 5–12.