sciendo
10.2478/jlecol-2018-0013 Journal of Landscape Ecology (2018), **Vol: 11 / No. 3.**

VASCULAR PLANT BIODIVERSITY OF FLOODPLAIN FOREST IN MORAVA AND DYJE RIVERS CONFLUENCE (FOREST DISTRICT SOUTOK), CZECH REPUBLIC

PETR MADĚRA*, RADOMÍR ŘEPKA, TOMÁŠ KOUTECKÝ, JAN ŠEBESTA

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

Received: 21th November 2018, **Accepted:** 10th December 2018

ABSTRACT

This paper presents an evaluation of full-area floristic investigation of floodplain forests in Soutok forest district (Židlochovice Forest State Enterprise) based on an individual forest stand inventory. The study area encompasses 5103 ha of forests, where 1186 segments were inventoried, and 71 223 single records about presence of vascular plant species were done. We found 761 taxa (species, subspecies and hybrids), out of which 655 were herbs, 106 woody plants, 156 were endangered species and 177 adventive species. The average area of a segment was 4.3 ha. The mean number of species per segment was 64.42 in a range of 4– 180.

Keywords: biodiversity, vascular plants, floodplain forest, forest district Soutok, Morava and Dyje rivers, Czech Republic

INTRODUCTION

The area under study is composed not only from valuable floodplain forests (Horák, 1961; Klimo *et al*. 2008; Maděra *et al*. 2011, 2013; Řepka *et al*. 2015) but there occur also the continental floodplain meadows (Vicherek *et al*., 2000) with solitary oak trees (Maděra *et al*., 2007) creating famous landscape character of the area. High abundance of many endangered xylophagous species of insect (Miklín *et al*., 2018, 2017; Miklín & Čížek, 2014; Laštůvka *et al*., 2016), many rare bird species (Machar *et al*., 2018; Opluštil & Čupa, 2012), amphibians (Šebela, 2004; Suchomel *et al*., 2017), invertebrates and other organisms (Hrib & Kordiovský, 2004; Suchomel *et al*., 2017) due to the occurrence of well preserved habitats like large old trees, forest pools, riverine lakes, water channels and close nature floodplain forests, were reasons why a few small scale protected areas, NATURA 2000, UNESCO Biosphere Reserve were established in the area during last decades.

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 in detail.

Presented paper is third part of articles concerning to vascular plant biodiversity evaluation in south Moravian floodplain forests. The previous were published by Maděra *et al*. (2011,

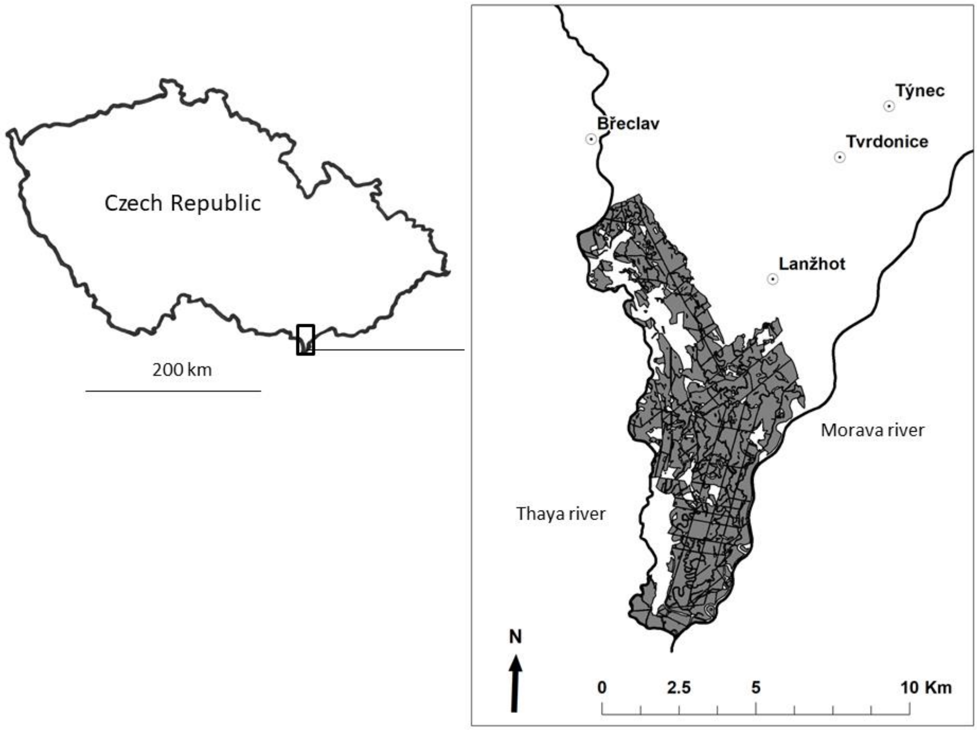
2013) for forest districts Valtice and Tvrdonice. The aim of the work is to describe spatial distribution of vascular plants biodiversity in the area as a tool for both, responsible forest management and conservation efforts.

MATERIAL AND METHODS

Study area

The area of 5103 ha of floodplain forest in confluence of the Morava and Dyje rivers between towns Lanžhot and Břeclav was inventoried. This is the Soutok forest district, Židlochovice Forest Enterprise, which is a part of state forests managed by Lesy ČR s.p. The Morava and Dyje rivers in the studied area forms large alluvium and the border among the Czech Republic, Slovakia and Austria, respectively (Fig. 1).

Fig. 1: Study area



METHODS

All vascular plants in the area of the Soutok 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 followed nomenclature according to Kubát *et al*. (2002). The occurrence of species growing only at the segment edges (stand adjacent to the forest roads, water channels, clearings and meadows) 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. Both, list of alien plant species according to Pyšek *et al.* (2012a) and Red list according to Grulich & Chobot (2017) were used for evaluation of our dataset. The segments after digitalization become a site. The digitalization and creation of the species distribution maps was implemented in the GIS environment (ArcGIS).

RESULTS

The total study area was 5,103 ha of forest; 1,186 segments were explored and 71,223 records on the presence of vascular plant taxa were taken. According to the records, there are 761 species (and infraspecific taxa and hybrids) in the area, out of which there were 655 herbs and 106 woody plants. The mean size of a segment was 4.3 ha. On average, there were 64.42 taxa (range of 4–180) per segment (most segments containing 40–59 species). The numbers of species within a segment were distributed unequally – there were more segments with lower numbers of species than average (703) and fewer segments with higher numbers (483) (Fig. 2). On average, there were 8.94 species of woody plants and 55.48 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

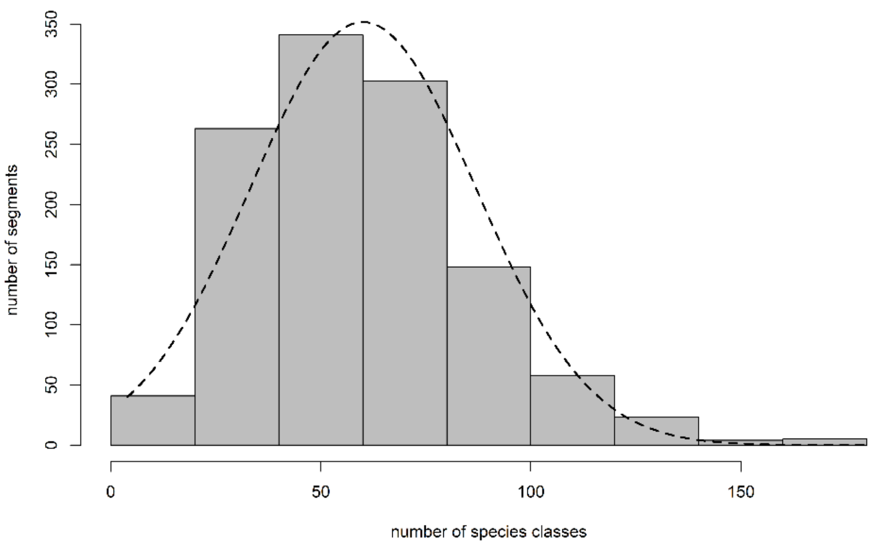
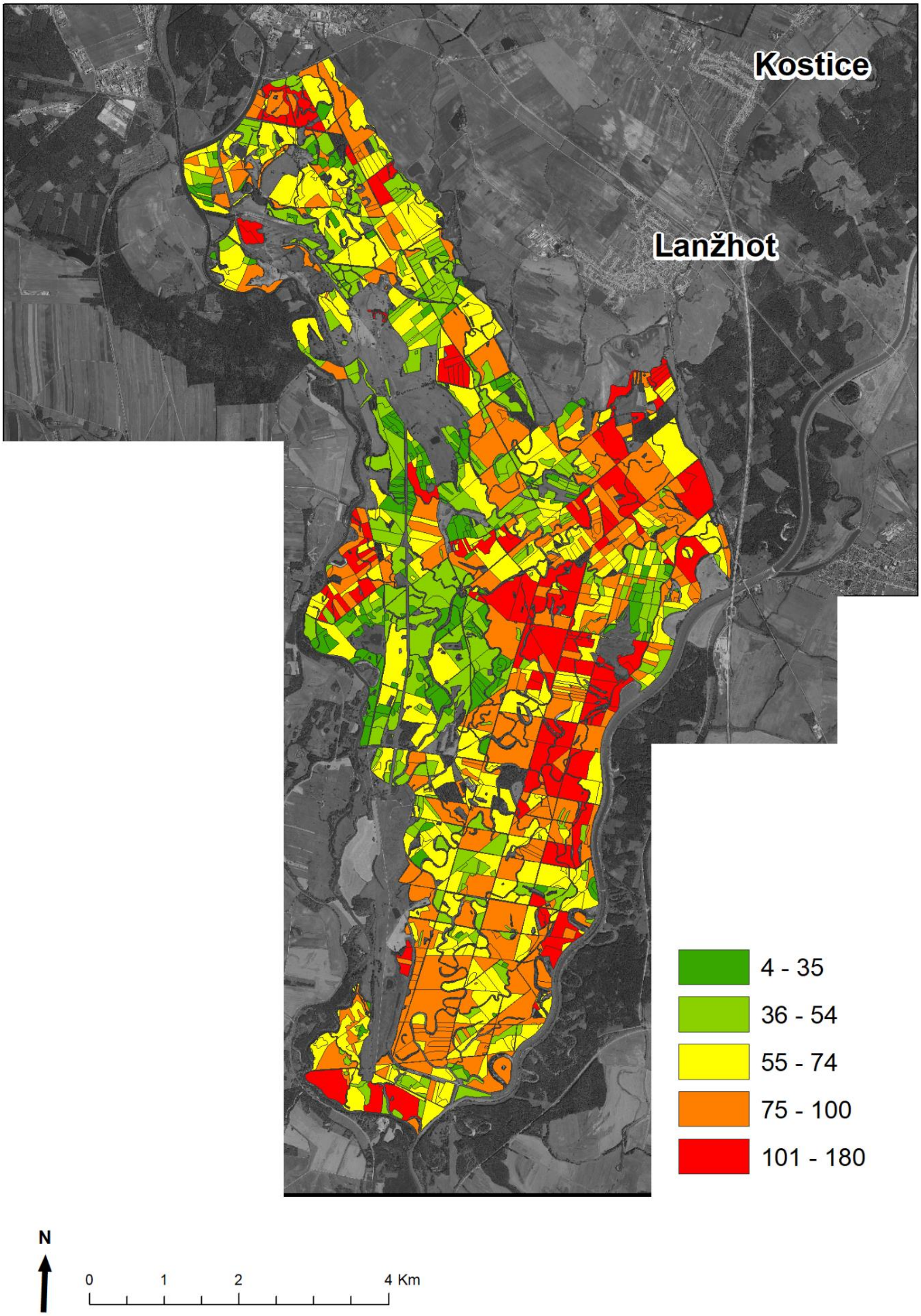


Fig. 3: Map of the number of all vascular plant species per segment in the study area



We also examined the frequency of species occurrence (presence of a taxon in segments) in the study area (Table 1). The analysis shows that 126 species (i.e. nearly 17 %) occurred in one segment only, 343 species (i.e. 45 %) were present in 1–9 segments; it means that the species scarcely occurred in the area and were rare. The table also shows that another 251 species (i.e. 33 %) were present in 10–99 segments. These species can be referred to as scattered. 167 species (i.e. 22 %) were present in over 100 segments – these species were abundant. Only 20 species occurred in over 60 % of segments (Table 2) – the species with high stability and diagnostic species of suballiance *Ulmenion* (Chytrý, 2013) only one adventive species is in this group – invasive neophyte *Aster lanceolatus*.

Table 1: The frequency of species occurrence in the study area

Classes of segments number	Number of species
1000 +	4
900–999	3
800–899	9
700–799	4
600–699	8
500–599	21
400–499	11
300–399	15
200–299	31
100–199	61
1–99	597
90–99	14
80–89	7
70–79	17
60–69	16
50–59	17
40–49	18
30–39	26
20–29	42
10–19	94
1–9	343

Table 2: The species with frequency over 60 % of segments in the study area

Species	No. of segments
Ficaria verna	1080
Rubus caesius	1065
Urtica dioica	1046
Acer campestre	1003
Quercus robur	968
Fraxinus angustifolia	911
Carex riparia	908
Symphytum officinale	890
Geum urbanum	889
Glechoma hederacea	868
Rumex sanguineus	866
Aster lanceolatus	854
Phalaris arundinacea	839
Deschampsia cespitosa	835
Brachypodium sylvaticum	828
Lysimachia nummularia	816
Galium aparine	782
Ranunculus repens	761
Iris pseudacorus	755
Viola reichenbachiana	733

From the perspective of nature conservation, it is interesting to evaluate the proportion of adventive species (based on Pyšek *et al*., 2012a) and endangered species (based on Grulich & Chobot, 2017). Considering merely the number of species (Fig. 4), almost a quarter (23.2 %, i.e. 177 taxa) were various categories of adventive species and 20.8 % (156) taxa were species with various categories of conservation status. However, Fig.5 has a higher information capacity concerning the role of these groups in the study 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 dropped to 14.8 % (10,562 records) and the proportion of endangered species to 11.2 % (7,948 records).

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

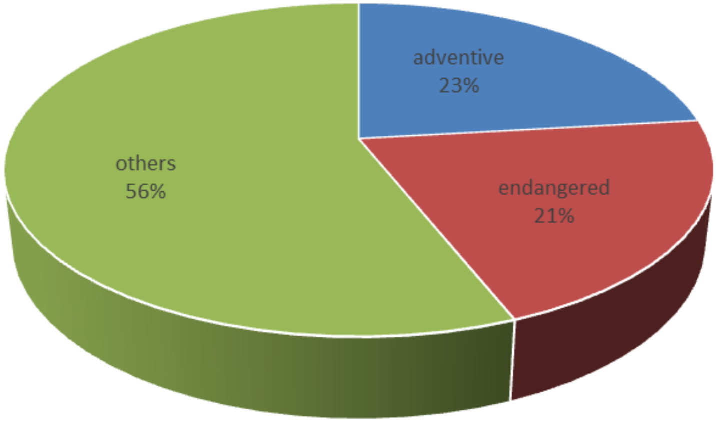
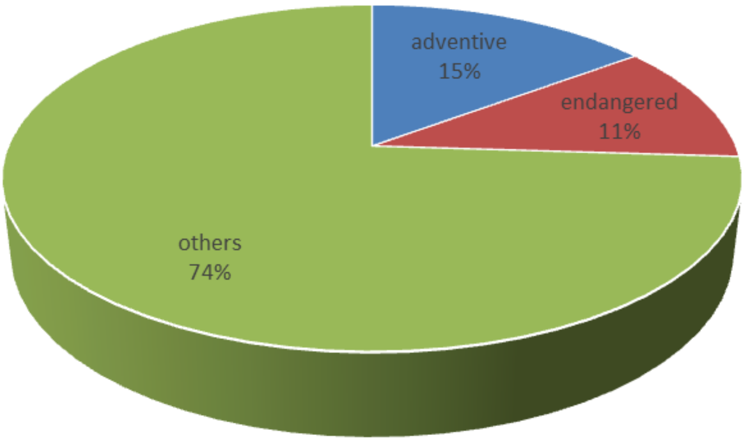


Fig. 5: Proportion of adventive, threatened and others vascular plant species in the study area according to the number of records



Within the set of adventive species, archeophytes (54.8 %) slightly prevailed over neophytes (45.2 %); there were 38, i.e. 21.4 % of invasive species in total (Fig. 6, Table 3). On average, there were 8 adventive species in a segment (range of 0–42). Only 27 segments contained no adventive species. There were up to 10 % of adventive species in 440 segments, 10–20 % in 579 segments, 20–30 % in 126 segments, 31–40 % in 14 segments, and no segment contains over 40 % 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.*,2012a). Arch = archeophytes, neo = neophytes, cas = causal, nat = naturalized, inv = invasive

Adventive species category	all species		herbs		woody plants	
	species number	records number	species number	records number	species number	records number
arch cas	4	13	4	13	0	0
arch nat	85	5235	79	4821	6	414
arch inv	8	792	8	792	0	0
neo cas	22	164	6	23	16	141
neo nat	28	1017	24	931	4	86
neo inv	30	3341	20	2922	10	419

Fig. 6: Proportion of adventive species (classification according to Pyšek *et al.*, 2012a) in the study area

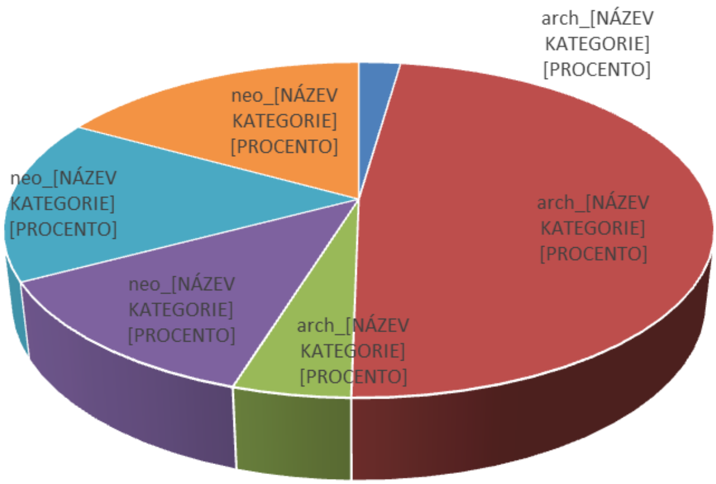


Fig. 7: Map of the number of adventive species per segment in the study area

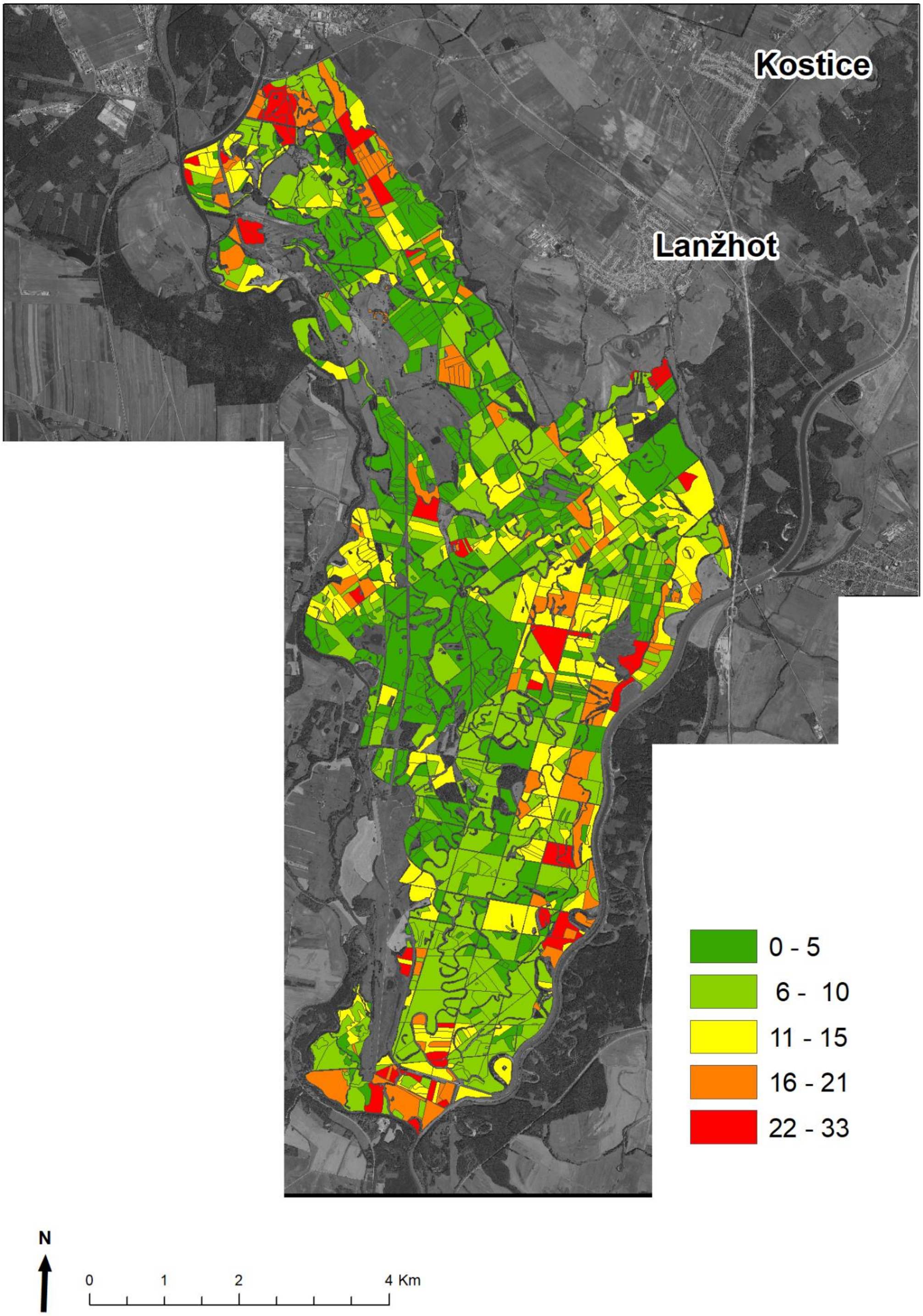
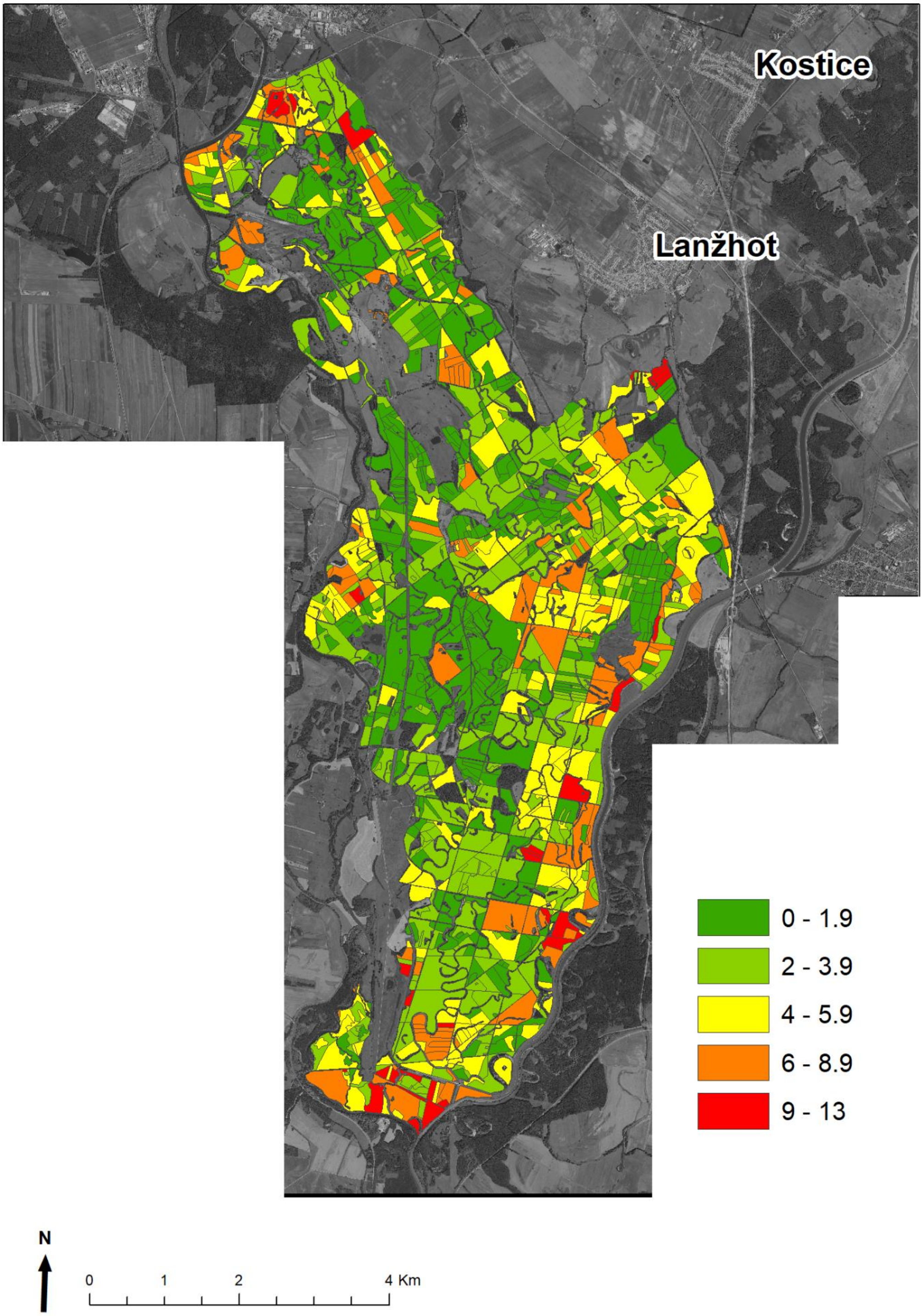


Fig. 8: Map of the number of neophytes per segment in the study area



As concerns endangered species, 20.75 % of them were protected by law, the rest were within various categories of the Red List (Grulich & Chobot, 2017). There were 18 critically endangered species, 34 strongly endangered and 44 endangered, the other 60 species were within C4 category – requiring further attention (Fig. 9, Table 4). The analysis shows that the mean number per segment was 5.4 of endangered species (range of 0–24). Endangered species were not present in 20 segments only; there were at least one endangered species in the other segments. Most segments (383) contain 6–9 % of endangered species; 76 segments even over 15 %. The most of endangered species (62.2 %) were present in 1–10 segments and only 11.3 % of endangered species were present in over 100 segments. The spatial distribution of the numbers of endangered 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 frequency of endangered species (according to Grulich & Chobot, 2017) in the study area

threat and protection category	all species		herbs		woody plants	
	species number	records number	species number	records number	species number	records number
§1	11	237	11	237	0	0
§2	16	240	16	240	0	0
§3	4	30	3	28	1	2
C1	18	283	17	252	1	31
C2	34	1031	32	919	2	112
C3	44	1574	42	1505	2	69
C4	60	5060	51	2875	9	2185

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

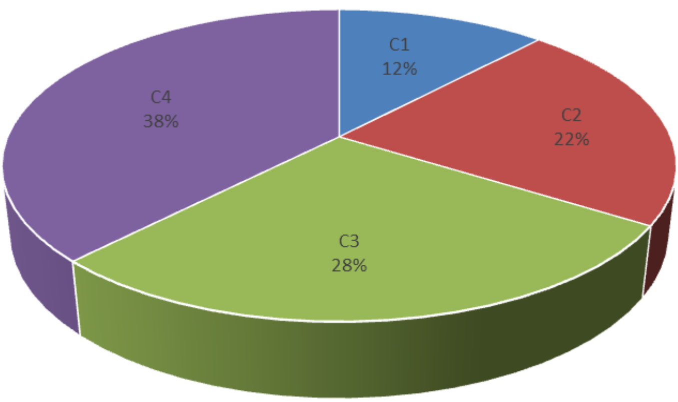


Fig. 10: Map of the number of endangered species per segment according to Grulich & Chobot, (2017) in the study area

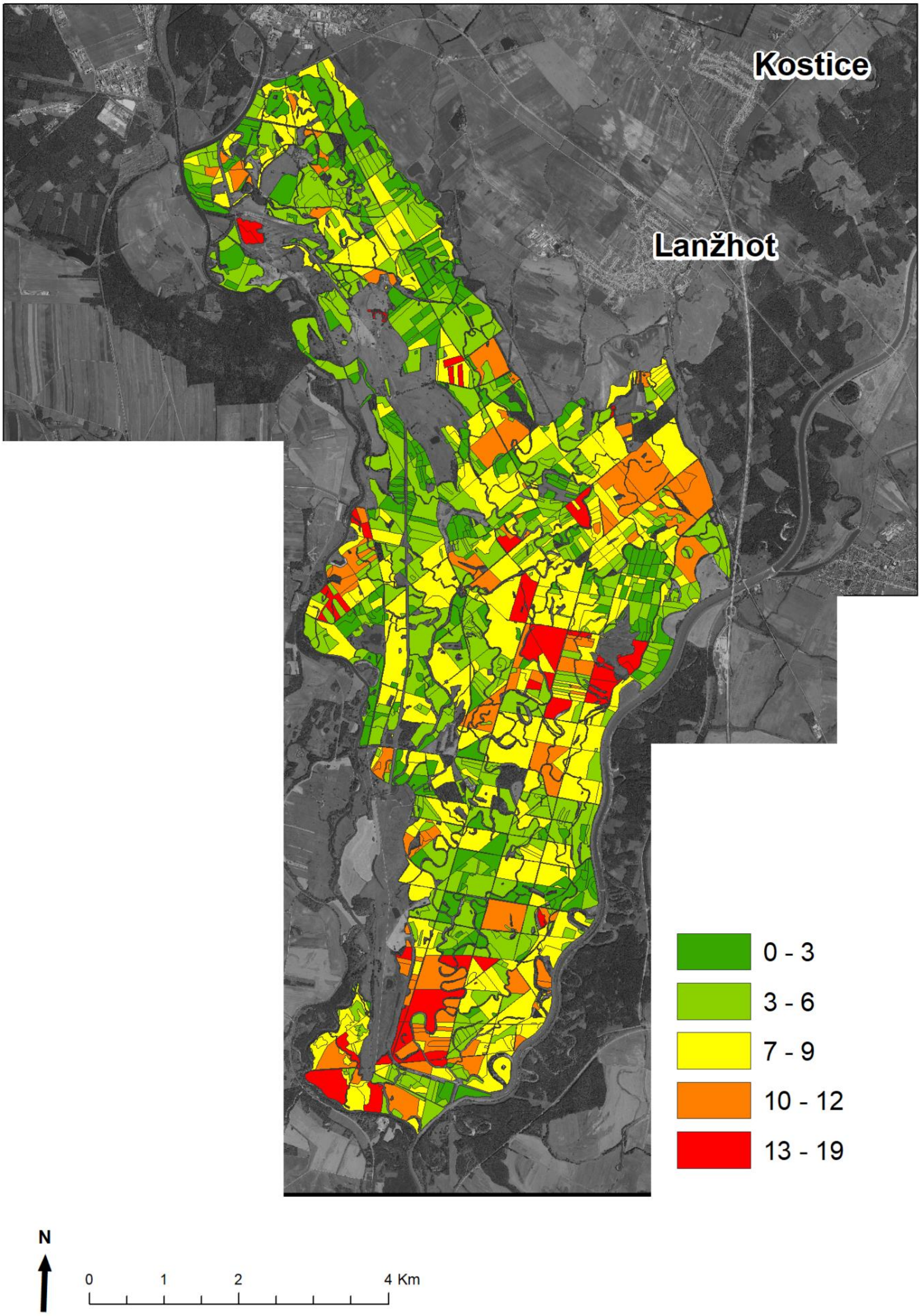
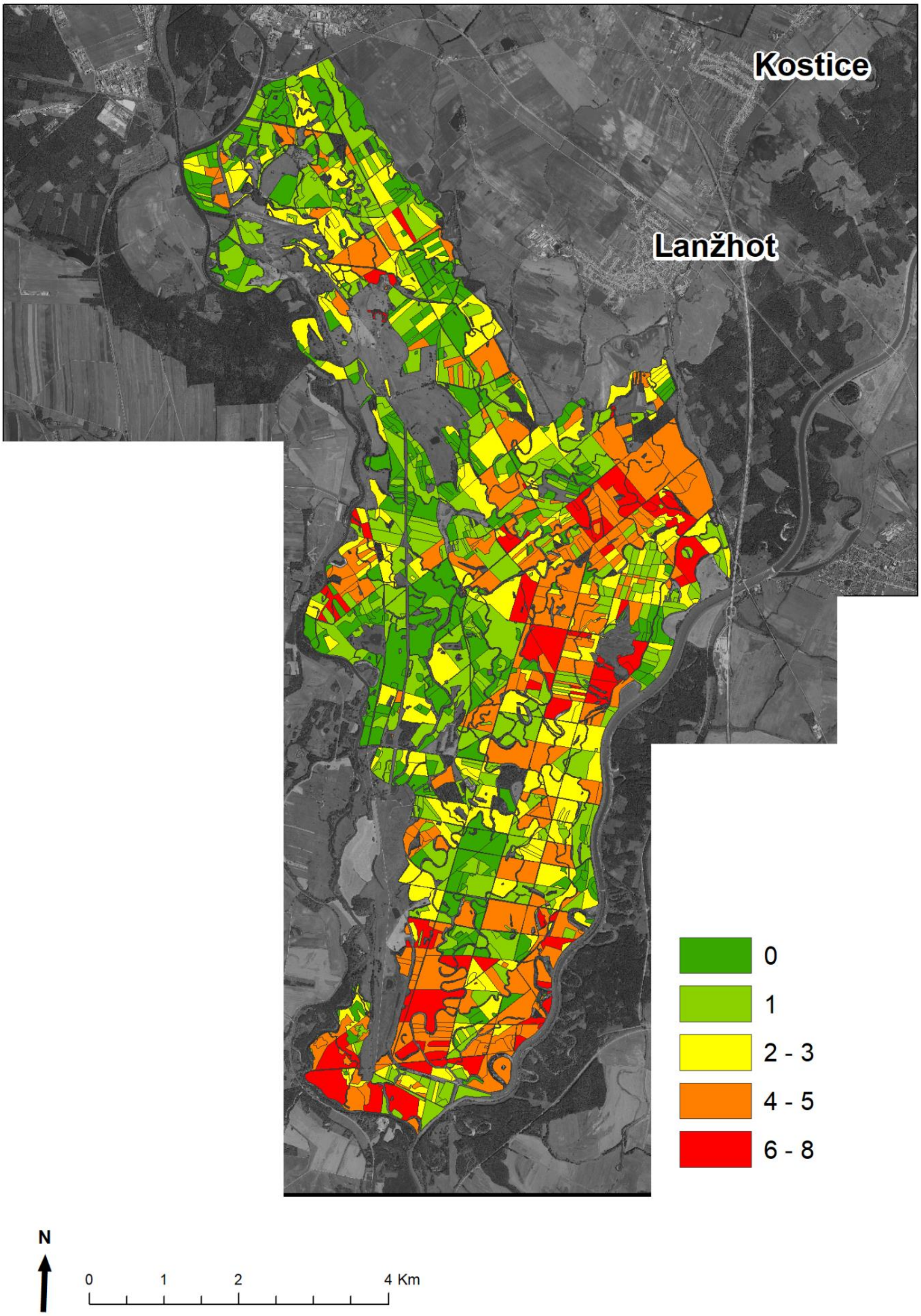


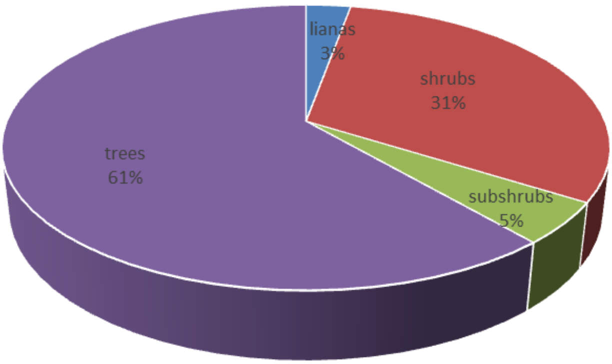
Fig. 11: Map of the number of critical (C1) and strong endangered (C2) species per segment according to Grulich & Chobot, (2017) in the study area.



Diversity of woody plants in the floodplain forests

As has been mentioned above, we found 106 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. *Vinca minor*) or woody lianas (e.g. *Vitis vinifera* subsp. *sylvestris*) and shrublets, whose representative has not been found in the area (Fig.12).

Fig. 12: Proportion of occurrence of life forms of woody plants (according to Úradníček et al., 2010) in the study area.



Out of the total number of woody plants found in the study area, there were 29 abundant species (occurrence in over 100 segments), 32 scattered species (10–99 segments) and 43 rare species (1–9 segments) – 18 species were recorded in one segment only.

From the perspective of autochthonous origin, 36 recorded species were various types of adventive species (Table 5). There are 10 recorded invasive neophytes, a more significant presence being recorded for both *Acer negundo* and *Populus* × *canadensis* – in nearly 13 % of segments, the other species were spread less (under 3% of segments). Pyšek *et al*. (2012a) also categorised the frequently grown *Juglans nigra* as an occasionally wild-growing neophyte; however, in the conditions of a floodplain forests, where is often planted, we can assume at least a very good naturalisation as it often regenerates naturally – it was recorded in 8.7 % of segments.

Table 5: The presence of adventive woody plants species in segments (according to Pyšek *et al*., 2012a).

Species	number of segments	proportion of segments [%]	adventive species category	
Pyrus communis	268	22,6	arch	naturalized
Malus domestica	88	7,4	arch	naturalized
Malus × dasyphylla	48	4,0	arch	naturalized
Juglans regia	4	0,3	arch	naturalized
Prunus insititia	4	0,3	arch	naturalized
Prunus domestica	2	0,2	arch	naturalized
Juglans nigra	103	8,7	neo	casual

Morus alba	11	0,9	neo	casual
Fraxinus ornus	7	0,6	neo	casual
Picea pungens	4	0,3	neo	casual
Castanea sativa	2	0,2	neo	casual
Catalpa bignonioides	2	0,2	neo	casual
Gleditsia triacanthos	2	0,2	neo	casual
Tilia tomentosa	2	0,2	neo	casual
Acer saccharinum	1	0,1	neo	casual
Hibicus syriacus	1	0,1	neo	casual
Phellodendron amurense	1	0,1	neo	casual
Platanus × hispanica	1	0,1	neo	casual
Populus candicans	1	0,1	neo	casual
Rosa multiflora	1	0,1	neo	casual
Thuja plicata	1	0,1	neo	casual
Zelkova serrata	1	0,1	neo	casual
Aesculus hippocastanum	58	4,9	neo	naturalized
Pinus nigra	16	1,3	neo	naturalized
Ribes rubrum	11	0,9	neo	naturalized
Pseudotsuga menziesii	1	0,1	neo	naturalized
Populus × canadensis	153	12,9	neo	invasive
Acer negundo	152	12,8	neo	invasive
Robinia pseudacacia	34	2,9	neo	invasive
Parthenocissus inserta	27	2,3	neo	invasive
Quercus rubra	19	1,6	neo	invasive
Prunus cerasifera	16	1,3	neo	invasive
Fraxinus pennsylvanica	12	1,0	neo	invasive
Ailanthus altissima	4	0,3	neo	invasive
Amorpha fruticosa	1	0,1	neo	invasive
Prunus serotina	1	0,1	neo	invasive

14 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 two segments only. Floodplain forests are indispensable biotopes of critically endangered woody species *Populus nigra* (31 segments), endangered species *Malus sylvestris* (68 segments), vulnerable species *Fraxinus angustifolia* (911 segments) and *Pyrus pyraster* (248). There is also a strong population of elms, both *Ulmus laevis* and *U. minor* (517 and 391 segments, respectively). High presence of *Quercus cerris* is due to its artificial plantation in dryer sandy sites.

Table 6: The presence of threatened woody plant species (according to Grulich & Chobot, 2017).

species	number of segments	threat category
Populus nigra	31	C1t
Sorbus aria	2	C2b
Quercus cerris	110	C2r
Malus sylvestris	68	C3
Rosa tomentosa	1	C3
Cornus mas	2	C4a, §3
Fraxinus angustifolia	911	C4a
Loranthus europaeus	108	C4a
Pyrus pyraster	248	C4a
Thymus pannonicus	3	C4a
Ulmus laevis	517	C4a
Ulmus minor	391	C4a
Viscum album subsp. *austriacum*	4	C4a
Quercus polycarpa	1	C4b

Diversity of herbs in the floodplain forests

We determined 655 species, subspecies and hybrids of herbs in the floodplain forest herb layer. Out of the total number of herbs found, there were 138 abundant species (occurrence in over 100 segments), 218 scattered species (10–99 segments) and 299 rare species within the study area (1–9 segments) – 107 species were found in one segment only.

From the perspective of autochthonous origin, 141 recorded species were various types of adventive species (Table 7), out of which there were 91 archeophytes and 50 neophytes, 28 invasive species. The more significant invasive archeophytes was *Cirsium arvense* in 56.5 % of segments which was dominant in forest edges and clearings. The most significant and highly aggressive invasive neophytes in the area was *Aster lanceolatus*, whose presence 72 % 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 were *Bidens frondosa* (50 % of segments), *Impatiens parviflora* (29 %), *Conyza canadensis* (26 %), *Erigeron annuus* (19.6 %) and *Echinocystis lobata* (16.2 %) usually grew in clearings and newly established cultures and only the first two mentioned ones penetrated into forest communities.

Table 7: The presence of adventive herb species in segments (according to Pyšek *et al.*, 2012a).

Species	number of segments	proportion of segments [%]	adventive species category	
Xanthium strumarium	7	0,6	arc	casual
Panicum miliaceum	3	0,3	arc	casual
Triticum aestivum	2	0,2	arc	casual
Beta vulgaris	1	0,1	arc	casual
Descurainia sophia	835	70,4	arc	naturalized
Lapsana communis	568	47,9	arc	naturalized
Arctium lappa	558	47,0	arc	naturalized
Veronica hederifolia	426	35,9	arc	naturalized
Tanacetum vulgare	266	22,4	arc	naturalized
Tripleurospermum inodorum	205	17,3	arc	naturalized
Setaria pumila	175	14,8	arc	naturalized
Sonchus asper	126	10,6	arc	naturalized
Capsella bursa-pastoris	124	10,5	arc	naturalized
Atriplex patula	123	10,4	arc	naturalized
Lactuca serriola	115	9,7	arc	naturalized
Lamium purpureum	91	7,7	arc	naturalized
Ballota nigra	72	6,1	arc	naturalized
Anchusa officinalis	70	5,9	arc	naturalized
Sonchus arvensis	66	5,6	arc	naturalized
Silene latifolia subsp. *alba*	65	5,5	arc	naturalized
Linaria vulgaris	62	5,2	arc	naturalized
Chelidonium majus	58	4,9	arc	naturalized
Solanum nigrum	58	4,9	arc	naturalized
Carduus acanthoides	56	4,7	arc	naturalized
Fallopia convolvulus	56	4,7	arc	naturalized
Geranium pusillum	51	4,3	arc	naturalized
Convolvulus arvensis	46	3,9	arc	naturalized
Setaria viridis	46	3,9	arc	naturalized
Bromus sterilis	40	3,4	arc	naturalized
Bromus hordeaceus	38	3,2	arc	naturalized
Viola odorata	35	3,0	arc	naturalized
Lamium album	32	2,7	arc	naturalized
Sonchus oleraceus	30	2,5	arc	naturalized

Senecio vulgaris	28	2,4	arc	naturalized
Veronica arvensis	27	2,3	arc	naturalized
Digitaria sanguinalis	20	1,7	arc	naturalized
Saponaria officinalis	17	1,4	arc	naturalized
Bromus japonicus	16	1,3	arc	naturalized
Berteroa incana	15	1,3	arc	naturalized
Arctium tomentosum	14	1,2	arc	naturalized
Myosotis arvensis	13	1,1	arc	naturalized
Vicia villosa	13	1,1	arc	naturalized
Vicia angustifolia	12	1,0	arc	naturalized
Melilotus albus	11	0,9	arc	naturalized
Verbena officinalis	11	0,9	arc	naturalized
Lathyrus tuberosus	9	0,8	arc	naturalized
Tragopogon dubius	9	0,8	arc	naturalized
Bromus commutatus	8	0,7	arc	naturalized
Melilotus officinalis	8	0,7	arc	naturalized
Sisymbrium officinale	8	0,7	arc	naturalized
Thlaspi arvense	7	0,6	arc	naturalized
Leonurus cardiaca s.lat.	6	0,5	arc	naturalized
Bromus tectorum	5	0,4	arc	naturalized
Viola tricolor	5	0,4	arc	naturalized
Anagallis arvensis	4	0,3	arc	naturalized
Artemisia absinthium	4	0,3	arc	naturalized
Chenopodium botrys	4	0,3	arc	naturalized
Erodium cicutarium	4	0,3	arc	naturalized
Papaver rhoeas	4	0,3	arc	naturalized
Vicia sativa	4	0,3	arc	naturalized
Armoracia rusticana	3	0,3	arc	naturalized
Avena sativa	3	0,3	arc	naturalized
Cynodon dactylon	3	0,3	arc	naturalized
Lamium amplexicaule	3	0,3	arc	naturalized
Microrrhinum minus	3	0,3	arc	naturalized
Sambucus ebulus	3	0,3	arc	naturalized
Vicia villosa subsp. *varia*	3	0,3	arc	naturalized
Crepis capillaris	2	0,2	arc	naturalized
Erysimum cheiranthoides	2	0,2	arc	naturalized

Geranium columbinum	2	0,2	arc	naturalized
Lithospermum arvense	2	0,2	arc	naturalized
Mentha × verticillata	2	0,2	arc	naturalized
Atriplex tatarica	1	0,1	arc	naturalized
Cichorium intybus	1	0,1	arc	naturalized
Crepis setosa	1	0,1	arc	naturalized
Euphorbia peplus	1	0,1	arc	naturalized
Geranium dissectum	1	0,1	arc	naturalized
Hyoscyamus niger	1	0,1	arc	naturalized
Lepidium ruderale	1	0,1	arc	naturalized
Malva neglecta	1	0,1	arc	naturalized
Onopordum acanthium	1	0,1	arc	naturalized
Parietaria officinalis	1	0,1	arc	naturalized
Veronica polita	1	0,1	arc	naturalized
Cirsium arvense	670	56,5	arc	invasive
Portulaca oleracea	42	3,5	arc	invasive
Echinochloa crus-galli	29	2,4	arc	invasive
Eragrostis minor	24	2,0	arc	invasive
Atriplex sagittata	11	0,9	arc	invasive
Chenopodium pedunculare	8	0,7	arc	invasive
Digitaria ischaemum	7	0,6	arc	invasive
Conium maculatum	1	0,1	arc	invasive
Xanthium italicum	16	1,3	neo	casual
Hemerocallis fulva	2	0,2	neo	casual
Lycopersicum esculentum	2	0,2	neo	casual
Helianthus annuus	1	0,1	neo	casual
Phacelia tanacetifolia	1	0,1	neo	casual
Phytolacca americana	1	0,1	neo	casual
Oxalis fontana	364	30,7	neo	naturalized
Galega officinalis	178	15,0	neo	naturalized
Trifolium hybridum	125	10,5	neo	naturalized
Juncus tenuis	48	4,0	neo	naturalized
Chenopodium strictum	46	3,9	neo	naturalized
Epilobium ciliatum	41	3,5	neo	naturalized
Datura stramonium	24	2,0	neo	naturalized
Amaranthus albus	15	1,3	neo	naturalized

Sagittaria latifolia	15	1,3	neo	naturalized
Rumex thyrsiflorus	13	1,1	neo	naturalized
Chenopodium pumilio	12	1,0	neo	naturalized
Erechtites hieraciifolia	12	1,0	neo	naturalized
Asclepias syriaca	10	0,8	neo	naturalized
Agrostis gigantea	7	0,6	neo	naturalized
Senecio vernalis	6	0,5	neo	naturalized
Oenothera biennis	4	0,3	neo	naturalized
Geranium pyrenaicum	2	0,2	neo	naturalized
Rubus armeniacus	2	0,2	neo	naturalized
Veronica persica	2	0,2	neo	naturalized
Alcea rosea	1	0,1	neo	naturalized
Medicago sativa	1	0,1	neo	naturalized
Ornithogalum nutans	1	0,1	neo	naturalized
Pleioblastus chino	1	0,1	neo	naturalized
Xanthium albinum	1	0,1	neo	naturalized
Aster lanceolatus	854	72,0	neo	invasive
Bidens frondosa	593	50,0	neo	invasive
Impatiens parviflora	347	29,3	neo	invasive
Conyza canadensis	309	26,1	neo	invasive
Erigeron annuus subsp. *annuus*	233	19,6	neo	invasive
Echinocystis lobata	193	16,3	neo	invasive
Solidago gigantea	96	8,1	neo	invasive
Arrhenatherum elatius	65	5,5	neo	invasive
Amaranthus retroflexus	57	4,8	neo	invasive
Amaranthus powellii	44	3,7	neo	invasive
Impatiens glandulifera	32	2,7	neo	invasive
Galinsoga parviflora	27	2,3	neo	invasive
Helianthus tuberosus	24	2,0	neo	invasive
Solidago canadensis	14	1,2	neo	invasive
Galinsoga quadriradiata	8	0,7	neo	invasive
Sisymbrium loeselii	7	0,6	neo	invasive
Ambrosia artemisiifolia	6	0,5	neo	invasive
Oxalis dillenii	6	0,5	neo	invasive
Reynoutria sachalinensis	5	0,4	neo	invasive
Rudbeckia laciniata	2	0,2	neo	invasive

As regards, specially protected and endangered species, there were 142 of them in the study area (Table 8). 40 species within the total number of 505 records in the segments were protected by law.

Table 8: The presence of endangered herb species (according to Grulich & Chobot, 2017).

species	number of segments	threat and protection category	
Leucojum aestivum	142	C1b	§1
Cardamine parviflora	12	C1b	§1
Pulicaria dysenterica	5	C1b	
Hierochloë repens	2	C1b	§1
Clematis integrifolia	1	C1b	§1
Cyperus michelianus	1	C1b	§1
Juncus atratus	1	C1b	§1
Trapa natans	1	C1b	§1
Viola elatior	56	C1t	§1
Pulegium vulgare	9	C1t	
Pulicaria vulgaris	9	C1t	
Xanthium strumarium	7	C1t	
Lathyrus palustris	2	C1t	§1
Crepis setosa	1	C1t	
Nymphoides peltata	1	C1t	§1
Scorzonera laciniata	1	C1t	
Stratiotes aloides	1	C1t	§2
Leonurus marrubiastrum	238	C2b	
Scutellaria hastifolia	93	C2b	§2
Cicuta virosa	78	C2b	
Verbascum blattaria	67	C2b	
Cnidium dubium	28	C2b	
Sium latifolium	24	C2b	
Euphorbia lucida	18	C2b	§1
Thalictrum flavum	15	C2b	§2
Lycopus exaltatus	10	C2b	
Iris variegata	7	C2b	§2
Teucrium scordium	6	C2b	§2
Hydrocharis morsus-ranae	5	C2b	

Iris graminea	5	C2b	§2
Scirpoides holoschoenus	5	C2b	
Senecio sarracenicus	5	C2b	§2
Epipactis albensis	3	C2b	§2
Lythrum hyssopifolia	2	C2b	
Lythrum virgatum	2	C2b	
Ophioglossum vulgatum	2	C2b	§3
Muscari neglectum	1	C2b	
Ornithogalum boucheanum	1	C2b	
Sonchus palustris	1	C2b	
Stellaria palustris	1	C2b	
Viola tricolor subsp. *curtisii*	1	C2b	
Carex strigosa	235	C2r	
Carex fritschii	2	C2r	
Parietaria officinalis	1	C2r	
Carex melanostachya	38	C2t	§2
Althaea officinalis	11	C2t	
Gratiola officinalis	9	C2t	§2
Viola pumila	3	C2t	§2
Viola stagnina	2	C2t	§2
Senecio erraticus	349	C3	
Carex divulsa	264	C3	
Cardamine dentata	236	C3	
Barbarea stricta	178	C3	
Lotus tenuis	56	C3	
Cucubalus baccifer	45	C3	
Euphorbia palustris	40	C3	§2
Pseudolysimachion maritimum	37	C3	
Corydalis pumila	32	C3	
Carex curvata	30	C3	
Silaum silaus	30	C3	
Dipsacus laciniatus	26	C3	
Erysimum diffusum	21	C3	
Galanthus nivalis	15	C3	§3
Leersia oryzoides	14	C3	
Trifolium fragiferum var. *fragiferum*	13	C3	

Verbena officinalis	11	C3	
Hottonia palustris	11	C3	§3
Carex distans	10	C3	
Gagea minima	10	C3	
Thalictrum lucidum	10	C3	
Bromus commutatus	8	C3	
Achillea pannonica	8	C3	
Myosurus minimus	8	C3	
Centaurium pulchellum	6	C3	
Iris sibirica	6	C3	§2
Linaria genistifolia	5	C3	
Scilla vindobonensis	5	C3	§2
Chondrilla juncea	4	C3	
Cyperus fuscus	3	C3	
Allium angulosum	2	C3	§2
Hesperis sylvestris	2	C3	
Hyoscyamus niger	1	C3	
Carex supina	1	C3	
Ficaria calthifolia	1	C3	
Gagea pusilla	1	C3	
Lactuca quercina	1	C3	
Lathyrus latifolius	1	C3	
Muscari comosum	1	C3	
Najas marina	1	C3	
Silene otites	1	C3	
Veronica catenata	1	C3	
Carex riparia	908	C4a	
Aristolochia clematitis	530	C4a	
Veronica hederifolia	426	C4b	
Galega officinalis	178	C4a	
Veronica montana	123	C4a	
Cerastium lucorum	92	C4a	
Allium ursinum	89	C4a	
Myosotis sparsiflora	71	C4a	
Galium rivale	64	C4a	
Carex buekii	58	C4a	

Cardamine matthioli	55	C4a	
Serratula tinctoria	31	C4a	
Aethusa cynapioides	29	C4a	
Nuphar lutea	20	C4a	
Vicia dumetorum	20	C4a	
Bromus japonicus	16	C4a	
Veronica scutellata	14	C4a	
Dianthus armeria	13	C4a	
Verbascum chaixii subsp. *austriacum*	13	C4a	
Galium mollugo	11	C4b	
Batrachium aquatile	10	C4b	
Carex otrubae	8	C4a	
Centaurium erythraea	8	C4a	
Peucedanum oreoselinum	8	C4a	
Berula erecta	7	C4a	
Petrorhagia prolifera	7	C4a	
Butomus umbellatus	6	C4a	
Inula salicina	6	C4a	
Melica transsilvanica	6	C4a	
Isopyrum thalictroides	4	C4a	
Lavatera thuringiaca	4	C4a	
Cynodon dactylon	3	C4a	
Bolboschoenus sp. indet.	3	C4a	
Galium elongatum	3	C4a	
Geranium sanguineum	3	C4a	
Malva alcea	3	C4a	
Primula veris	3	C4a	
Pseudolysimachion spicatum	3	C4a	
Scrophularia umbrosa	3	C4a	
Corydalis intermedia	2	C4a	
Corynephorus canescens	2	C4a	
Omphalodes scorpioides	2	C4a	
Euphorbia esula subsp. *riparia*	2	C4b	
Cerinthe minor	1	C4a	
Anthericum ramosum	1	C4a	
Dianthus pontederae	1	C4a	

Listera ovata	1	C4a	
Neottia nidus-avis	1	C4a	
Polystichum aculeatum	1	C4a	
Schoenoplectus lacustris	1	C4a	
Viola mirabilis	1	C4a	

DISCUSSION

Floodplain forests often represent a high biodiversity area in the European landscape (Ward *et al*., 2002). The species richness of certain organisms, such as vascular plants, often far exceeds that in adjacent upland habitats (Naiman *et al*., 1993; Tabacchi *et al*., 1996; Stohlgren *et al*. 1998). Concerning to the vascular plants, the study area isn´t exception, we found 761 species (591 excluding adventive species) in area of 51 km^2 what corresponds to about a fifth of the flora of the Czech Republic. Many authors confirm the high importance of floodplain forests for vascular plant species diversity maintenance (Tab. 9). Schnitzler *et al*. (2007) summarised available articles focused on the diversity of riparian forests across the whole of Europe and recorded 1,380 species.

Table 9: Overview of studies focusing on vascular plant diversity of floodplain forests

Locality	Number of species	Size of area	Source
Forest district Valtice, Thaya River, Czech Republic	656	16 km^2	Maděra *et al*. (2011)
Forest district Tvrdonice, Morava River, Czech Republic	612	22 km^2	Maděra *et al*. (2013)
northern Croatia	437		Trinajstič *et al*. (2005)
Current and Jacks Fork Rivers, North America	269		Lyon & Sagers (1998)
Adour River (SW France)	1,396		Tabacchi *et al*. (1996)
Pantanal wetland, Brazil	2000	150,000 km^2	Pott *et al*. (2011)
Seine, France	334	20 plots 1 km^2	Ernoult *et al*. (2006)
NE Wisconsin, USA	162	417 plots 1 m^2	Goebel *et al*. (2006)
Danube River	165		Mölder *et al*. (2011)
Sado and Guadiana, Portugal	45 (only woody plants)	70 river sections of 2 km	Santos (2010)
Estonia	372	1600 plots 1 m^2	Paal *et al*. (2007)
Current River and Jacks Fork River, SW Missouri, USA	339	94 plots	Lyon & Sagers (1998)
Cypress Creek NWR, Illinois, USA	193	80 plots 1 m^2	McLane *et al*. (2012)
Ill, Rhine, Loire and Allier	106-157		Schnitzler (1997)
Rhine	37 (only woody plants)		Trémoliéres *et al*. (1998)

Řepka *at al*. (2015) recorded a total of 732 herb and 121 woody species in whole area (89 km^2) of the floodplain forests of Forest Enterprise Židlochovice (Forest Districts Tvrdonice, Valtice and Soutok) demonstrating their immense importance for biodiversity of vascular plants.

History of forest management in the study area is crucial for understanding of the highly valuable current state. In the Middle Ages, coppice forests with 7 year rotation are described and coppices with standard are documented, too (Nožička, 1956). The forests were used for livestock grazing (especially pigs) due to acorn production. The ”modern forest management” began under the Lichtenstein family ownership in the middle of the 18th century (Hrib, 2004). The conversion of coppice forest to high forest started by using the way of alternate forestry (agroforestry) system. Man-made natural ecosystems sensu van Maarel (1975) were established this way, forests developed under influence of both, human activities and natural processes. Key human interventions supporting the high level of biodiversity are (i) using of habitat-original tree species (mainly oak, ash and elm) for reforestation, especially oak regeneration is problematic without artificial reforestation (Libus *et al*., 2010) (ii) diversification of age structure of forests (Řepka & Maděra, 2009b) document that young developmental stages of forests host high diversity), (iii) creation of forest edges as a habitat with high diversity and many endangered plant species (Maděra *et al*., 2011), (iv) maintenance of water channels bringing water inside the floodplain forests after rivers have been regulated (Vybíral & Hrib, 2000). The most important natural conditions co-creating the floodplain forests are (i) meandering rivers, (ii) high groundwater table and nutrient reach fluvisols and (iii) regular flooding (Klimo *et al*., 2008).

Human modifications of streams and rivers have caused extensive stream channel and riparian degradation (Meixler & Bain, 2010). Since 1973, the south Moravian floodplain forests were affected by Dyje and Morava Rivers regulation within complex hydrotechnical measures (Jakubec, 1981). The most serious problem of the study area is the absence of natural hydrological regime due to the regulation of main water courses since this time. The variety of riparian plant communities found in natural floodplains is mainly controlled by the flow regime (Poff *et al*., 1997), which generates physical disturbance and environmental stress on riparian vegetation, ultimately affecting its temporal and spatial dynamics (Shafroth *et al*., 2002). The dynamic fluvial succession by the absence of natural hydrological regime lead to the increase of occurrence of late-serial stages (the driest types of hard-wood forests) and on the contrary, to the decrease of initial-serial stages. Gonzáles (2010) described progressive area decrease (up to 37 %) of the pioneer forest types (*Populus nigra*, *Salix alba* and *Tamarix* spp.) since the intensification of river regulation in the mediterranean region. In contrast, non-pioneer senescent forests have doubled their surface after river regulation was intensified. The same results were published by Maděra *et al*. (2010) from area under study, 60% of area was occupied by “wet hardwood” floodplain forests communities (*Querci roboris-Fraxineta*) and 30 % of area was occupied by “dry hardwood” floodplain forests communities (*Ulmi-Fraxineta carpini*) before rivers regulations. The rate was opposite after 30 years of development without flooding and decreasing ground water table (Penka *et al*., 1991). Dams, land-use changes throughout the basin, and construction of flood defences that restrict the main channel have changed behaviour of the Ebro river system which urgently needs a management plan combining both, improvement and risk reduction (Ollero, 2010).

Technical regulations of the water regime within floodplains can also impact on the species diversity of floodplain forests. For example, Trémoliéres *et al*. (1998) compared various sections of an alluvial hardwood forest along the Rhine. Using six plots of about 2,000 m^2, 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, Amanda *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; Trémoliéres *et al*., 1998; Janík *et al*., 2008, 2011, 2016) in dependence on drying of floodplain forests, when flood-intolerant and mesic species can arrive.

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 177 adventive species in the study area, it is 23.2 % of all vascular plants creating the floodplain forest communities. Many other authors confirmed the sensitivity of floodplain forests to adventive species invasion (Tab 10).

Table 10 Comparison of adventive vascular plant species occurrence in floodplain forests in various parts of the World

Locality	No of adventive species	Ratio of the total (%)	Source
Allegheny River Islands Wilderness (northwestern Pennsylvania)	40	17.8	Williams (2010)
Mura River (NE Slovenia)		15.0	Košir *et al.* (2013)
Cypress Creek NWR, Illinois, USA		14.4	McLane *et al.* (2012)
Yampa and Green rivers (northwest Colorado, USA)		30.0	Amanda *et al.* (2005)
Upper Danube		7.0	Mölder & Schneider 2011
Middle Danube		14.0	Mölder & Schneider 2011
Lower Danube		10.0	Mölder & Schneider 2011
eastern Oregon, USA	60	14.5	Magee *et al*. (2008)

Schnitzler *et al*. (2007) summarised 1,380 species across European riparian forests, 45 (3.3 %) of these were exotic (adventive) species. Pyšek *et al*. (2012b) found that the proportion of neophytes in floodplain forests of the alliance *Alnion incanae* (incl. *Ulmenion* suballiance) was 2.2 ± 2.8 %, in coverage 4 ± 10 %, which is the highest number within the forest communities of the Czech Republic. Our study shows higher average proportion of neophytes in the study area (10.5 %). A number of large-scale studies have confirmed that floodplain forests are one of the most invaded forest habitats (Chytrý *et al*., 2005; Petrášová *et al*., 2013; Řepka *et al*., 2015).

Many exotics found in Schnitzler´s *et al* (2007) 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*). The most important adventive tree species were *Fraxinus pennsylvanica* (Middle and Lower Danube), *Acer negundo* (Middle Danube) and *Robinia pseudacacia* (Upper Danube), which reached considerable proportions in the tree layer. Frequent adventive 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.

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*., 2009a). Brewer (2010) described a similar example: a significant negative effect of species richness on invasive grass *Microstegium vimineum* abundance. 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*). 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.

CONCLUSIONS

Natural riparian corridors are the most diverse, dynamic and complex biophysical habitats on the terrestrial part of the Earth. Riparian corridors, as interfaces between terrestrial and aquatic systems, encompass sharp environmental gradients, ecological processes and communities. Riparian corridors are an unusually diverse mosaic of landforms, communities and environments within wider landscape. They serve as a framework for understanding of the organisation, diversity and dynamics of communities associated with fluvial ecosystems. Riparian corridors possess an unusually diverse array of species and environmental processes and they should play an essential role in water and landscape planning, in the restoration of aquatic systems, and in catalyzing institutional and societal cooperation for these efforts (Naiman *et al*., 1993).

Unfortunately, floodplains forests belong to the most endangered communities not only in Europe (Wenger *et al*., 1990; Klimo & Hager, 2000) affected by diverse human negative interventions. The most serious are hydrotechnical river regulations (Dynesius & Nilsson, 1994). Meixler & Bain (2010) developed the cost-effective, rapid assessment tools can be used to better manage such areas by identifying the status of habitats for restoration planning and protection. Managers can use these cost-effective strategy development tools to identify candidate reaches for further study and prioritize stream channel and riparian restoration actions over large regions. Our results could serve as an unique basis for such management measures.

Gonzáles (2010) recommended measures principally aimed at recovering some hydrogeomorphic dynamism to guarantee the self-sustainability of the floodplain forest ecosystem. In this sense, according to Comín *et al*. (2005), the most effective restoration approach should focus on the recovery of some hydrogeomorphic dynamism (i.e., channel migration, periodic creation of new barren sites, reactivation of secondary channels, meander cut-offs, renaturalized hydroperiod, etc.) both, at the basin and the reach scale, within the current socioeconomic context. Thus, the ideal hydrogeomorphic regime would not necessarily be the preregulation state but one ‘renaturalized’, which led to a selfsustainable forest structure at patch and landscape scale, guaranteed their ecological functions and provided services to society (Dufour & Piégay, 2009).

ACKNOWLEDGEMENT

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

REFERENCES

Amanda, L., 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.

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.

Chytrý, M. (ed.) (2013). *Vegetace České republiky*. 4. Lesní a křovinná vegetace. Academia, Praha, 552 p.

Chytrý, M., Pyšek, P., Tichý, L., Knollová, I., Danihelka, J. (2005). Invasions by alien plants in the Czech Republic: a quantitative assessment across habitats. *Preslia* 77: 339–354.

Comín, F.A., Menéndez, M., Pedrocchi, C., Moreno, S., Sorando, R., Cabezas, A., García, M., Rosas, V., Moreno, D., González, E., Gallardo, B., Herrera, J.A., Ciancarelli, C. (2005). Wetland restoration: integrating scientific-technical, economic, and social perspectives. *Ecological Restoration* 23(3):182–186.

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,* 21: 117–192, Praha.

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.

Dufour, S., Piégay, H. (2009). From the myth of a lost paradise to targeted river restoration: forget natural references and focus on human benefits. *River Research and Applications* 25 (5): 568–581.

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.

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

González, E., González-Sanchis, M., Cabezas, A., Comín, F.A., Muller, E. (2010). Recent Changes in the Riparian Forest of a Large Regulated Mediterranean River: Implications for Management. *Environmental Management* 45: 669–681.

Grulich, V., Chobot, K. (eds.) (2017). *Červený seznam ohrožených druhů České republiky*. Cévnaté rostliny. Praha, Agentura ochrany přírody a krajiny ČR.

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.

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.

Hrib, M. (2004). Z historie lesního hospodářství. In. Hrib M., Kordiovský E. (eds.): *Lužní les v Dyjsko-moravské nivě* (pp. 209–226). Moraviapress, Břeclav.

Hrib, M., Kordiovský, E. (eds.) (2004). *Lužní les v Dyjsko-moravské nivě*. Moraviapress, Břeclav, 591 p.

Jakubec, B. (1981). Vodohospodářské úpravy na jižní Moravě. *Lesnická práce*, 5: 204–212.

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.

Janík, D., Adam, D., Hort, L., Král, K., Šamonil, P., Unar, P., Vrška, T. (2016). Patterns of Fraxinus angustifolia in an alluvial old-growth forest after declines in flooding events. *European Journal of Forest Research*, 135: 215–228.

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 p.

Laštůvka, Z., Barták, M., Bezděk, J., Bílý, S., Čelechovský, A., Dolný, A., Hula, V., Chládek, F., Ježek, J., Kment, P., Malenovský, I., Řezníčková, P., Říha, M., Skuhravá, M., Stejskal, R., Šefrová, H., Tkoč, M., Trnka, F., Vašátko, J. (2016). *Červená kniha ohrožených druhů bezobratlých lužních lesů Biosférické rezervace Dolní Morava*. Mendel University, Brno, 260 p.

Libus, J., Mauer, O., Vavříček, D. (2010). Soil preparation by ploughing in the floodplain forest and its influence on vegetation and primary soil characteristics. *Journal of Forest Science*, 56 (4): 183–194.

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* (pp. 263–274). The Hague, Dr W. Junk B. V. Publishers.

Machar, I., Čermák, P., Pechanec, V. (2018). Ungulate Browsing Limits Bird Diversity of the Central European Hardwood Floodplain Forests. *Forests,* 9: 373; doi:10.3390/f9070373.

Maděra, P. (2001a). Response of floodplain forest communities herb layer to changes in the water regime. *Biológia*, 56: 63–72, Bratislava.

Maděra, P. (2001b). Effect of water regime changes on the diversity of plant communities in floodplain forests. *Ekológia*, 20 (Supplement 1): 116–129, (Bratislava).

Maděra, P. et al. (2007). *100 nejzajímavějších stromů Biosférické rezervace Dolní Morava*. BR Dolní Morava, 120 p.

Maděra, P., Vahalík, P., Řepka, R., Mikita, T. (2010). *Odraz změn vodního režimu lužních lesů LZ Židlochovice v lesnické typologii (Atlas změn skupin typů geobiocénů v letech 1964 a 2001)*. Lesnická práce, Kostelec nad Černými Lesy, 20 p. + 8 maps 1:20 000.

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.

Maděra, P., Řepka, R., Šebesta, J., Koutecký, T., Klimánek, M. (2013). Vascular plant biodiversity of floodplain forest geobiocoenosis in Lower Morava river basin (forest district Tvrdonice), Czech Republic. *Journal of Landscape Ecology*, 6, 2: 34–64.

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.

Meixler, M.S., Bain, M.B. (2010). Landscape scale assessment of stream channel and riparian habitat restoration needs. *Landscape Ecological Engineering* 6: 235–245.

Miklín, J., Čížek, L. (2014). Erasing a European biodiversity hot-spot: Open woodlands, veteran trees and mature forests succumb to forestry intensification, succession, and logging in a UNESCO Biosphere Reserve. *Journal for Nature Conservation*, 22: 35–41.

Miklín, J, Sebek, P, Hauck, D, Konvicka, O, Cizek, L. (2018). Past levels of canopy closure affect the occurrence of veteran trees and flagship saproxylic beetles. *Diversity and Distributions*, 24: 208–218.

Miklín, J., Hauck, D., Konvička, O., Cizek, L. (2017). Veteran trees and saproxylic insects in the floodplains of lower Morava and Dyje rivers, Czech Republic. *Journal of Maps*, 13, 291–299.

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.

Ollero, A. (2010). Channel changes and floodplain management in the meandering middle Ebro River, Spain. *Geomorphology* 117: 247–260.

Opluštil, L., Čupa, P. (2012). *Owls of the Lower Morava Biosphere Reserve*. Biosférická rezervace Dolní Morava, 26 p.

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. (1991). *Floodplain forest ecosystem 2*. Academia, Praha, 632 p.

Petrášová, M., Jarolímek, I., Medvecká, J. (2013). Neophytes in Pannonian hardwood floodplain forests – History, present situation and trends. *Forest Ecology and Management* 308: 31–39.

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.

Poff, N.L., Allan, J.D., Bain, M.B., Karr, J.R., Prestegaard, K.L., Richter, B.D., Sparks, R.E., Stromberg, J.C. (1997). The natural flow regime. A paradigm for river conservation and restoration. *Bioscience* 47: 769–784.

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 (pp. 19–26). John Wiley & Sons Ltd.

Pyšek, P., Danihelka, J., Sádlo, J., Chrtek, J. Jr., Chytrý, M., Jarošík, V., Kaplan, Z., Krahulec, F., Moravcová, L., Pergl, J., Štajerová, K., Tichý, L. (2012a). Catalogue of alien plants of the Czech Republic (2nd edition): checklist update, taxonomic diversity and invasion patterns. *Preslia* 84: 155–255.

Pyšek, P., Chytrý, M., Pergl, J., Sádlo, J., Wild, J. (2012b). Plant invasions in the Czech Republic: current state, introduction dynamics, invasive species and invaded habitats. *Preslia* 84: 575–629.

Richardson, D., Holmes, P.M., Elser, 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.

Řepka, R., Maděra, P. (2009a). Rozšíření adventivních druhů v nížinných luzích jižní Moravy – případ hvězdnice kopinaté (*Aster lanceolatus*). In. Měkotová, J. (ed.): *Říční krajina 6* (pp. 100–106). Sborník příspěvků z konference 21. října 2009, Olomouc.

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.

Řepka, R., Šebesta, J., Maděra, P., Koutecký, T., Klimánek, M. (2013). *Druhová bohatost cévnatých rostlin lužních lesů dolního Podyjí.* Mendel University, Brno, 124 p.

Řepka, R., Šebesta, J., Maděra, P., Vahalík, P. (2015). Comparison of the floodplain forest floristic composition of two riparian corridors: species richness, alien species and the effect of water regime changes. *Biologia*, 70 (2): 208–217.

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.

Shafroth, P.B, Stromberg, J.C, Patten, D.T (2002). Riparian vegetation response to altered disturbance and stress regimes. *Ecological Applications* 12(1):107–123.

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.

Suchomel, J., Lusk, S., Macháček, P., Šebela, M. (2017). *Červená kniha ohrožených druhů obratlovců lužních lesů Biosférické rezervace Dolní Morava*. Mendel University, Brno, 216 p.

Šebela, M. (2004). Obojživelníci a plazi lužního lesa. In. In. Hrib M., Kordiovský E. (eds.): *Lužní les v Dyjsko-moravské nivě* (pp. 373–394). Moraviapress, Břeclav.

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.

Trinajstič, I., Franjič, J., Škvorc, Ž. (2005). The flora of floodplain and marshy forests. In: Vukelič 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.

Úradníček, L., Maděra, P., Tichá, S., Koblížek, J. (2010). *Woody Plants of the Czech Republic*. Lesnická práce, Kostelec nad Černými lesy, 368 p.

Vašíček, F. (1985). Changes in the herbal vegetation along the topographical moisture gradient. In: Penka M., Vyskyt M, Klimo E., Vašíček F.: *Floodplain Forests Ecosystem 2* (pp. 355–386). Academia, Praha.

Vicherek, J. et al. (2000). *Flóra a vegetace na soutoku Moravy a Dyje*. Masarykova univerzita v Brně, Brno, 368 p.

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.

Vybíral, J., Hrib, M. (2000). *Floodplain forests restoration at the Židlochovice Forest Enterprise*. Lesy České republiky s.p. 10 p.

Ward, J.V., Tockner, K., Arscott, D.B., Claret, C. (2002). Riverine landscape diversity. *Freshwater Biology*, 47: 517–539.

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.