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Distribution of alien species in habitats of the Piešťany spa town surroundings

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Abstract: Occurrence of invasive plant species was analysed in semi-natural and anthropogenic habitats in the surroundings of the spa town Piešťany (Western Slovakia) using the floristic data from 96 sites gathered during the years 2009–2011. Together, 102 alien species (19.6 % of the total flora of area) were recorded, among them 71.6 % archeophytes and 28.4 % neophytes. Non-native plant species were widespread unevenly in the area. The highest number of alien species was found in subxerophilous shrubs and hedges between arable fields (48 taxa), in small enclaves of floodplain forest remnants (36 taxa) and in overgrown alluvial meadows (34 taxa), and the smallest number was found in the areas closer to natural habitats, e.g. lakes, gravel bars, glades, abandoned orchards and in various types of deciduous forests and submontane grasslands (1–9). Concerning total occurrence of alien species in individual habitats as well as their average numbers, more invasive species occurred in the Váh river alluvium than in the Považský Inovec Mts. The habitats in the alluvium of the river Váh were characterized also by higher representation of invasive neophytes, which demonstrates a significant role of water streams

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and disturbed river bank habitats in spreading of these species in landscape.

Keywords: alien species, invasive neophytes, habitats, riparian vegetation, alluvium and hilly area, Piešťany town surroundings, Slovakia.

Introduction

Biological invasions can cause large disturbances and changes of the most of ecosystem functions, e.g. primary and secondary production, decomposition processes, cycling of nutrients, etc. (CROOKS 2002; EHRENFELD 2010). According to STRAYER (2012) their influence can be as large as those of any other similar human activites (fertilization, pollution, changes of hydrologic regimes, etc.).

Concerning impacts of allochtonous species on biodiversity, ecosystem services and local economies, invasive neophytes are the most often studied group. The actual results of the biological invasions studies are summarized by STRAYER (2012), who tries to answer the most important relevant questions: e.g. which invasions significantly affect ecosystems; the circumstances under which ecosystem change is most likely; the functions that are most often affected by invaders; the relationships between changes of ecosystems, communities, and populations; the long-term responses of ecosystems to invasions, etc. According to CHYTRÝ et al. (2005) despite big number of the published reports and scientific studies on alien species there still exist huge gaps in the knowledge of the habitat affinities of individual alien species in particular areas, as well as of the level of invasion in different habitats. In this contribution based on results from the floristic inventory of 96 sites in the surrounding of the spa town Piešťany (southwestern Slovakia) we try to at least partially answer these questions.

Piešťany surroundings is floristically very interesting because to the east of the city runs the phytogeographical boundary between the region of Pannonian flora (*Pannonicum*) and the region of West-Carpathian flora (*Carpaticum occidentale*; cf. FUTÁK 1984). The Pannonian geoelements penetrate into area from the south along the former wide Váh river floodplain area (today mostly transformed into arable land) and the Carpathian geolements descend from the north through the mountain ridges of the Považský Inovec Mts, partially penetrating also to their south-western hills (Inovecké predhorie foothills). To the relatively high diversity of flora contribute also complex geomorphologic conditions and predominantly limestone and dolomite geological substrate in the part of the Považský Inovec Mts (relevant to our study). Vegetation of these sites was investigated especially by MAGLOCKÝ (1979) and MUCINA (1980, 1981a, 1981b, 1982a, 1982b, 1987).

The aim of the paper is to evaluate the extension of non-native flora in the selected natural, seminatural and anthropogenic habitats in the Piešťany town surroundings.

Material and methods

The evaluation of alien species in this paper are based on the results of mapping the flora and vegetation in 2009 – 2011 which was realized according to

methodology by ŠEFFER et al. (2000). Vegetation and flora of two ecologicaly different area was investigated: a) in the alluvium of the river Váh (localities between Váh river and the built Váh channel south of the village Horná Streda, in the Prúdy area on the right bank of the Váh north of Piešťany and in Priesaky and Piesky inundation area south of the Sĺňava water dam) and b) on the slopes of Považský Inovec Mts. The localities along the Váh river belong to cadastres of the Piešťany town and of the Horná Streda and Drahovce villages. Localities in the Považský Inovec Mts. belong to cadastres of the villages Hubina, Banka, Ratnovce and Sokolovce. Investigated area was divided according to presence of different habitat types into 96 polygones (smaller areas) in which detailed inventory of vascular plants and their abundance in the Tansley scale (TANSLEY & CHIP 1926) was elaborated.

Floristic data from individual polygons were uploaded to the TURBOVEG programme (HENNEKENS & SCHAMINÉE 2001) and processed in the JUICE programme (TICHÝ 2002), where the polygons were sorted according to their habitats and alien species of vascular plants were sorted into respective categories according to the study of MEDVECKÁ et al. (2012). With the help of this programme, the occurrence of invasive species was compared in various types of habitats, in the alluvial floodplain areas as well as in the hilly area and their relations to the individual types of habitat and environment were analysed. As individual habitats in the area were represented by non-equal numbers of polygons, to achieve a more objective comparison we calculated also average number of alien species per polygon in each habitat type The resulting tables 1 – 3 and figures 1 – 2 were processed in the Excel programme. The nomenclature of the taxa follows MARHOLD & HINDÁK (1998).

Results and discussion

Non-native flora of the studied area

In total, 519 species of vascular plants were determined in the selected 18 types of habitats. From these, 102 taxa (19.7 %) belong to non-native species of the flora of Slovakia (Tab. 1, Tab. 3). Alochtonous flora of the territory was represented mainly by the archeophytes (73 species – 71.6 %), the proportion of neophytes was lower (29 species – 28.4 %). Higher representation of archeophytes was observed also in other areas with prevailing natural or seminatural vegetation, while neophytes prevail (or proportion of both groups of aliens is balanced) inside and in the vicinity of settlements, in various anthropogenically strongly disturbed or ruderalized habitats (e.g. fields, waste dumps, rubbles, trampled areas, etc.) (KUČERA & PYŠEK 1997; CHYTRÝ et al. 2005; MÁJEKOVÁ & ZALIBEROVÁ 2008).

The most frequent non-native species occurring in the evaluated areas were naturalized archeophytes *Convolvulus arvensis*, *Juglans regia*, *Cichorium intybus* and *Melilotus officinalis*, and invasive neophytes *Stenactis annua, Matricaria discoidea* a *Conyza canadensis* (Tab. 1). *Juglans regia* was planted along the dikes in the past (cf. DOMIN 1931) and is common in the gardens, but today it spreads sub-spontanneously and is widespread both in the bank stands of the

Váh river and in the shrubs on the slopes of Považský Inovec Mts. The non-native species in the investigated area belong to 35 families, but only 9 of them were represented by more than three species (Tab. 2). The most frequently occurring species belong to the families Asteraceae, Poaceae and Fabaceae, with striking dominance of the taxa from the Asteraceae family (Tab. 2). According to PYŠEK (1997), in case of the Asteraceae family fruitfulness of the plants in occupying new habitats is conditioned by their biological properties as is the production of the specialized structures which facilitate spreading, occurrence of the apomixia or presence of the secondary metabolites which favour them in individual phases of the invasive process. Representatives of this family are characterised also by high capability of naturalization, which is indicated by many lists of non-native plant species.

Concerning life strategies majority of non-native species from a given territory belong to therophytes and hemicryptophytes (Fig. 1), which is apparently connected to large arable field macrostructures (many of them of the size of hundreds of hectares), which provide suitable habitats for annual plants survival (MÁJEKOVÁ & ZALIBEROVÁ 2008). The wide proportion of therophytes and hemicryptophytes is conditioned also by the biological properties of the recorded invasive species. These include especially production of the huge numbers of seeds, spreading of diasporas with the help of animals, high initial speed of growth, eventually other properties which enable their quick growth and spreading in landscape and thus successful survival in new habitats (HERBEN 1997). Concerning other life forms also woody species, phanerophytes were quite abundant (18 species – 17.6 %), from which the strongest tendency to spread into abandoned plots of agricultural land has been expressed by the invasive neophyte *Robinia pseudoacacia*.

Representation of non-native species in various types of habitats and environment

The research results have shown unproportional representation of allochtonous flora within framework of the evaluated habitats and landscape types. Comparing the selected areas of the river Váh alluvium and of the slopes of Považský Inovec Mts we have recorded relatively small differences between total numbers of non-native species. However, in the Váh alluvium was recorded almost twice as high number of neophytes and invasive species (Fig. 2, Tab. 3), which occupy mainly more degraded segments of alluvium with higher anthropogenic impacts and induced changes.

Similar results were obtained also during preparatory research of the surroundings of the water dam Sĺňava (north of the locality Priesaky), where specially in late summer the most frequent neophyte species in the riparian vegetation is *Impatiens glandulifera*, which in certain places has rather high cover. Apart from this species, other non-native neophytes bound to the same habitat occur here, e.g. *Amaranthus retroflexus, Ambrosia artemisiifolia, Asclepias syriaca, Helianthus tuberosus, Juncus tenuis,* most of them are invasive. In the case of archeophytes – both along the river and on the slopes of dikes – quite common were esp. *Anchusa officinalis, Melilotus albus, Reseda lutea, Saponaria officinalis* and *Setaria viridis.*

Tab. 1 Survey and categories of the alien species found in the surroundings of the Piešťany spa town (Western Slovakia) during years 2009–2011 and their occurrence in the individual habitat types (AS – alien species)

Locality	Považský Inovec Mts											Alluvium of the river Váh							
No of column	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	
Habitat	glade	oak-sessile oak forest	lime-maple forest	oak-hornbeam forests	young oak-hornbeam forests	shrubs and hedges	abandoned orchard	submontane grasslands	cornfields	lanes and ravines	waste deposits	ash-alder alluvial forest	xerothermophilous scrub	alluvial meadows	grasslands on river dikes	waste deposits	gravel bar of the river	littoral of gravel lakes	**Frequency**
No. of evaluated polygons	1	7	1	8	4	17	1	6	3	3	1	12	3	11	8	2	5	3	
No. of AS in habitat	3	12	6	9	12	48	6	11	19	9	14	36	10	34	26	29	29	1	
Average No. of AS per polygon	3.0	2.4	6.0	1.9	3.0	8.6	6.0	5.3	3.3	7.0	6.4	5.7	7.6	7.5	6.0	27.0	9.0	0.3	
Invasive neophytes																			
Amaranthus retroflexus	.	.	.	.	.	.	.	.	.	.	.	.	.	x	.	x	x	.	5
Ambrosia artemisiifolia	.	.	.	.	.	.	.	.	.	.	.	x	.	.	.	x	.	.	2
Asclepias syriaca	.	.	.	.	.	.	.	.	.	.	.	.	.	x	.	.	.	.	1
Aster lanceolatus	.	.	.	.	.	.	.	x	.	.	.	x	.	x	.	.	.	.	6
Conyza canadensis	.	x	.	.	x	x	x	x	.	.	.	x	x	x	x	x	x	.	17
Fallopia cf. *japonica*	.	.	.	.	.	.	.	.	.	.	x	.	.	.	.	x	.	.	2
Helianthus tuberosus	.	.	.	.	.	.	.	.	.	.	.	x	.	.	.	x	x	.	6
Impatiens glandulifera	.	.	.	.	.	.	.	.	.	.	.	x	.	.	.	.	x	.	2
Impatiens parviflora	x	x	x	x	x	x	.	.	.	.	.	x	.	.	.	.	.	.	12
Juncus tenuis	.	.	.	.	.	.	.	.	.	.	.	x	.	.	.	.	.	x	2
Lycium barbarum	.	.	.	.	.	.	.	.	.	.	.	x	.	.	.	.	.	.	1
Matricaria discoidea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	x	.	1
Negundo aceroides	.	.	.	.	.	x	.	.	.	.	.	x	.	.	x	.	.	.	4
Robinia pseudoacacia	.	x	.	x	x	x	.	.	.	x	x	x	.	x	.	x	.	.	22
Solidago gigantea	.	.	.	.	.	.	.	.	.	.	x	x	.	.	.	.	.	.	2
Stenactis annua	x	.	.	x	.	x	.	x	x	.	.	x	x	x	x	x	x	.	34
Naturalized neophytes																			
Aesculus hippocastanum	.	x	.	x	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Geranium pyrenaicum	.	.	.	.	.	.	.	.	.	.	.	.	.	x	.	.	.	.	1

Tab. 1. – cont.

Locality	Považský Inovec Mts											Alluvium of the river Váh							
No of column	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	
Habitat	glade	oak-sessile oak forest	lime-maple forest	oak-hornbeam forests	young oak-hornbeam forests	shrubs and hedges	abandoned orchard	submontane grasslands	cornfields	lanes and ravines	waste deposits	ash-alder alluvial forest	xerothermophilous scrub	alluvial meadows	grasslands on river dikes	waste deposits	gravel bar of the river	littoral of gravel lakes	**Frequency**
Juglans nigra	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	x	.	.	1
Medicago sativa	.	.	.	.	.	.	.	.	.	.	.	x	.	.	.	x	x	.	3
Morus alba	.	.	.	.	.	.	.	.	.	.	.	x	.	x	.	.	.	.	3
Oenothera biennis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	x	.	1
Pinus nigra	.	.	x	x	x	.	.	.	.	.	.	.	.	.	.	.	.	.	4
Populus ×canadensis	.	.	.	.	.	.	.	.	.	.	.	x	.	x	.	.	.	.	2
Syringa vulgaris	.	.	.	.	.	x	.	x	.	.	.	.	.	.	.	.	.	.	2
Veronica persica	.	.	.	.	.	x	.	.	.	.	x	.	.	.	.	.	.	.	3
Casual neophytes																			
Helianthus annuus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	x	.	16
Trifolium pratense	.	.	.	.	.	x	.	x	.	x	x	x	x	x	x	.	x	.	1
Zea mays	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	x	.	.	1
Invasive archeophytes																			
Cardaria draba	.	.	.	.	.	x	.	.	.	.	.	.	.	.	.	.	.	.	3
Echinochloa crus-galli	.	.	x	.	.	.	.	.	.	x	.	x	.	.	.	x	x	.	5
Naturalized archeophytes																			
Anagallis arvensis	.	.	.	.	.	x	.	.	x	.	.	.	.	x	.	.	.	.	3
Anagallis foemina	.	.	.	.	.	.	.	.	x	.	.	.	.	.	.	.	.	.	1
Anchusa officinalis	.	.	.	.	.	.	.	.	.	.	.	x	.	x	x	x	x	.	12
Arctium lappa	x	x	.	x	.	x	.	.	.	.	x	x	.	.	.	x	x	.	13
Artemisia absinthium	.	.	.	.	.	.	.	.	.	.	.	.	.	x	.	.	.	.	1
Atriplex sagittata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	x	.	.	1
Avena fatua	.	.	.	.	.	x	.	.	.	x	.	.	.	.	.	.	.	.	2
Ballota nigra	.	.	.	.	.	x	.	.	.	.	.	x	x	x	.	x	.	.	15
Berteroa incana	.	.	.	.	.	.	.	.	.	.	.	.	.	x	x	x	.	.	4

Tab. 1. – cont.

Locality	Považský Inovec Mts											Alluvium of the river Váh							
No of column	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	
Habitat	glade	oak-sessile oak forest	lime-maple forest	oak-hornbeam forests	young oak-hornbeam forests	shrubs and hedges	abandoned orchard	submontane grasslands	cornfields	lanes and ravines	waste deposits	ash-alder alluvial forest	xerothermophilous scrub	alluvial meadows	grasslands on river dikes	waste deposits	gravel bar of the river	littoral of gravel lakes	**Frequency**
Bromus arvensis	.	.	.	.	.	x	.	.	.	.	.	.	.	.	.	.	.	.	1
Bromus sterilis	.	.	.	.	x	x	.	.	.	.	x	.	.	.	.	.	.	.	10
Bromus tectorum	.	.	.	x	.	x	.	.	.	.	.	.	.	.	.	.	.	.	2
Bryonia alba	.	.	.	.	.	.	.	.	.	.	.	x	.	.	.	.	.	.	1
Capsella bursa-pastoris	.	.	.	.	.	x	.	.	x	.	x	.	.	.	x	.	.	.	4
Carduus acanthoides	.	x	.	.	.	x	.	x	.	.	.	x	x	x	x	x	x	.	26
Cerasus vulgaris	.	.	.	.	.	x	.	.	.	.	.	.	.	.	.	.	.	.	16
Cichorium intybus	.	.	.	.	.	x	.	.	.	.	.	x	.	x	x	x	x	.	1
Consolida regalis	.	.	.	.	.	x	.	.	x	.	.	.	.	.	.	.	.	.	4
Convolvulus arvensis	.	.	.	.	.	x	.	x	.	.	.	x	.	x	x	x	x	.	29
Descurainia sophia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	x	.	1
Fumaria officinalis	.	.	.	.	.	.	.	.	.	.	x	.	.	.	.	.	.	.	1
Geranium dissectum	.	x	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Chelidonium majus	.	x	.	.	x	x	.	.	.	x	.	.	x	.	.	x	.	.	10
Chenopodium murale	.	.	.	.	.	x	.	.	.	.	.	.	.	.	.	.	.	.	1
Juglans regia	.	x	x	x	x	x	.	.	.	x	.	x	.	x	.	.	.	.	21
Kickxia spuria	.	.	.	.	.	.	.	.	x	.	.	.	.	.	.	.	.	.	1
Lactuca serriola	.	.	.	.	.	x	.	.	.	.	x	x	.	x	.	x	.	.	7
Lamium purpureum	.	.	.	.	.	x	.	x	.	.	.	.	.	.	.	.	x	.	6
Lathyrus tuberosus	.	.	.	.	.	x	.	x	x	.	.	.	.	x	x	x	.	.	12
Lepidium campestre	.	.	.	.	.	.	.	.	.	.	.	.	.	.	x	.	.	.	1
Lycopsis arvensis	.	.	.	.	.	.	.	.	.	.	.	.	.	x	.	.	.	.	2
Marrubium vulgare	.	.	.	.	.	.	.	.	.	.	.	.	.	x	.	.	.	.	1
Melampyrum arvense	.	.	.	.	.	.	.	x	.	.	.	.	.	.	.	.	.	.	1
Melilotus albus	.	.	.	.	.	.	.	.	.	.	.	x	.	x	x	.	x	.	6

Tab. 1. – cont.

Locality	Považský Inovec Mts											Alluvium of the river Váh							
No of column	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	
Habitat	glade	oak-sessile oak forest	lime-maple forest	oak-hornbeam forests	young oak-hornbeam forests	shrubs and hedges	abandoned orchard	submontane grasslands	cornfields	lanes and ravines	waste deposits	ash-alder alluvial forest	xerothermophilous scrub	alluvial meadows	grasslands on river dikes	waste deposits	gravel bar of the river	littoral of gravel lakes	**Frequency**
Melilotus officinalis	.	.	.	.	x	x	.	x	x	.	x	x	.	.	x	x	.	.	16
Mercurialis annua	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	x	.	.	1
Myosotis arvensis	.	.	.	.	.	x	.	.	x	.	.	.	.	.	x	.	.	.	3
Nepeta cataria	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	x	.	1
Nigella arvensis	.	.	.	.	.	.	.	.	x	.	.	.	.	.	.	.	.	.	1
Onopordum acanthium	.	.	.	.	.	.	.	.	.	.	.	.	.	.	x	.	.	.	1
Papaver rhoeas	.	.	.	.	.	.	.	.	x	.	x	.	.	.	x	.	x	.	4
Parietaria officinalis	.	.	.	.	x	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Portulaca oleracea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	x	.	.	1
Pyrus communis	.	x	.	x	x	x	.	.	.	.	.	.	.	.	.	.	x	.	14
Raphanus raphanistrum	.	.	.	.	.	x	.	.	x	.	.	.	.	.	.	.	.	.	2
Reseda lutea	.	.	.	.	.	x	.	.	.	.	.	x	x	x	x	.	x	.	14
Saponaria officinalis	.	.	.	.	.	.	.	.	.	.	.	x	x	x	x	x	x	.	17
Setaria pumila	.	.	.	.	.	.	.	.	.	.	.	x	x	x	.	.	.	.	3
Setaria viridis	.	.	x	.	.	x	x	.	x	x	.	x	.	x	x	x	x	.	15
Silene latifolia subsp. *alba*	.	x	.	.	.	x	.	.	x	.	.	x	.	x	x	.	x	.	16
Sinapis arvensis	.	.	.	.	.	.	.	.	x	.	.	.	.	.	.	.	.	.	1
Solanum nigrum	.	.	.	.	.	x	.	.	.	.	.	.	.	.	.	.	.	.	1
Sonchus asper	.	.	.	.	.	x	.	.	.	.	.	.	.	.	.	.	.	.	1
Sonchus oleraceus	.	.	x	.	.	x	.	.	.	.	.	x	.	x	.	.	x	.	12
Stachys annua	.	.	.	.	.	.	.	.	x	x	.	.	.	.	.	x	.	.	4
Thlaspi arvense	.	.	.	.	.	.	.	.	.	.	.	.	.	x	x	.	x	.	3
Torilis arvensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	x	.	.	.	1
Tripleurospermum perforatum	.	.	.	.	.	x	.	.	x	.	x	x	.	x	.	x	x	.	12
Veronica arvensis	.	.	.	.	.	x	.	.	.	.	.	.	.	.	x	.	.	.	6

Tab. 1. – cont.

Locality	Považský Inovec Mts											Alluvium of the river Váh							
No of column	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	
Habitat	glade	oak-sessile oak forest	lime-maple forest	oak-hornbeam forests	young oak-hornbeam forests	shrubs and hedges	abandoned orchard	submontane grasslands	cornfields	lanes and ravines	waste deposits	ash-alder alluvial forest	xerothermophilous scrub	alluvial meadows	grasslands on river dikes	waste deposits	gravel bar of the river	littoral of gravel lakes	**Frequency**
Vicia angustifolia	.	.	.	.	.	x	.	.	.	.	x	.	.	.	x	.	.	.	4
Vicia hirsuta	.	.	.	.	.	x	.	.	.	.	.	.	.	.	.	.	.	.	2
Vicia tetrasperma	.	.	.	.	.	x	.	.	.	.	.	.	.	.	.	.	.	.	1
Viola arvensis	.	.	.	.	x	x	.	.	x	.	.	.	.	x	x	.	.	.	9
Vitis vinifera	.	.	.	.	.	x	.	.	.	.	.	.	.	.	.	.	.	.	1
Casual archeophytes																			
Armeniaca vulgaris	.	.	.	.	.	.	x	.	.	.	.	.	.	.	.	.	.	.	1
Hordeum vulgare	.	.	.	.	.	x	.	.	.	.	.	.	.	.	.	.	.	.	1
Malus domestica	.	.	.	.	.	x	x	.	.	.	.	x	x	x	.	.	.	.	8
Persica vulgaris	.	.	.	.	.	.	x	.	.	.	.	.	.	.	.	.	.	.	1
Prunus domestica	.	x	.	.	x	x	x	.	.	x	.	.	.	.	.	.	.	.	12
Prunus insititia	.	.	.	.	.	.	.	.	.	.	.	x	.	x	.	.	.	.	5
Triticum aestivum	.	.	.	.	.	.	.	.	x	.	.	.	.	.	.	.	.	.	1

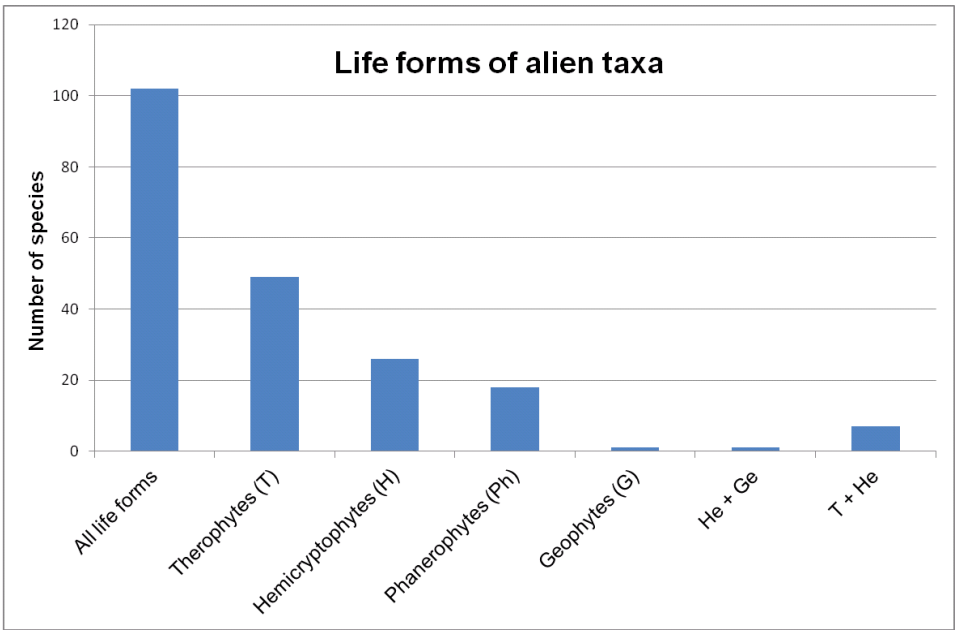

Fig. 1. Spectrum of the Raunkiær life forms of alien species in Piešťany spa town surroundings (Western Slovakia).

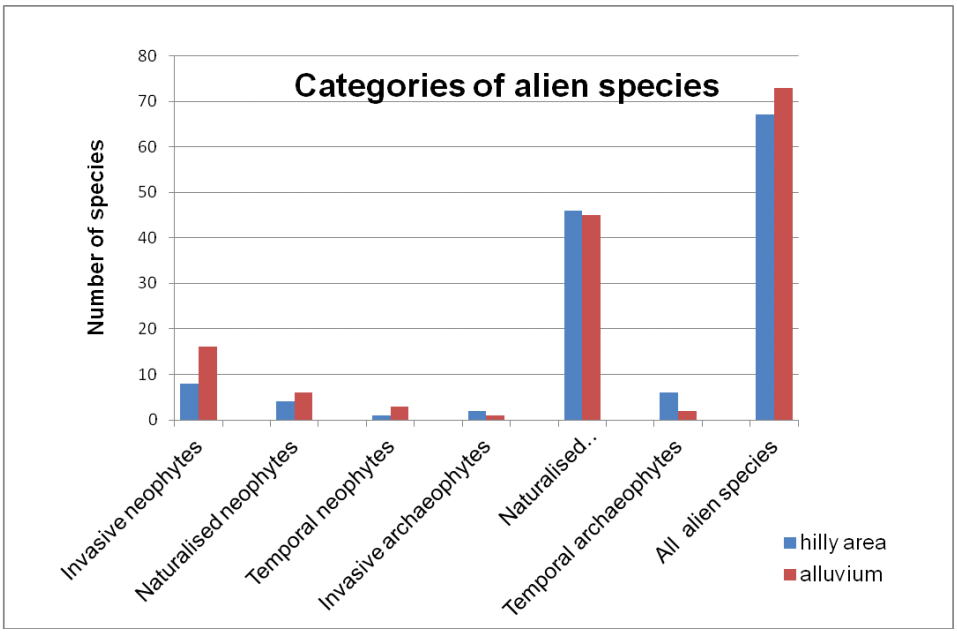

Fig. 2. Comparison of number and percentual proportion of the alien species in individual categories (according to MEDVECKÁ et al. 2012) in alluvium of the river Váh and in Považský Inovec Mts (Piešťany, Western Slovakia).

Tab. 2. Comparison of number of the alien taxa of the most frequent families found in the Piešťany spa town surroundings (Western Slovakia)

Family	Number of alien taxa	Proportion of alien species in %	Number of species records
Asteraceae	17	16.7	158
Poaceae	10	9.8	41
Fabaceae	9	8.8	82
Brassicaceae	8	7.8	19
Rosaceae	7	6.9	37
Lamiaceae	5	4.9	27
Amaranthaceae	3	2.9	7
Boraginaceae	3	2.9	17
Plantaginaceae	3	2.9	10

Families with 2 alien species: Balsaminaceae, Caryophyllaceae, Geraniaceae, Papaveraceae, Primulaceae, Ranunculaceae, Solanaceae;

Families with 1 alien species: Apiaceae, Apocynaceae, Convolvulaceae, Cucurbitaceae, Euphorbiaceae, Fumariaceae, Moraceae, Oleaceae, Onagraceae, Orobanchiaceae, Pinaceae, Polygonaceae, Portulacaceae, Resedaceae, Salicaceae, Sapindaceae, Urticaceae, Violaceae, Vitaceae

Tab. 3 Comparison of number and percentual ratio of the alien species in individual categories (according to MEDVECKÁ et al. 2012) in the alluvium of the river Váh and in Považský Inovec Mts (Piešťany, Western Slovakia)

Category of alien taxa	Považský Inovec Mts		Alluvium of Váh		Together	
	n	%	n	%	n	%
Neophytes	**13**	**12.7**	**25**	**24.5**	**29**	**28.4**
Invasive neophytes	8	7.8	16	15.7	16	15.7
Naturalised neophytes	4	3.9	6	5.9	10	9.8
Temporal neophytes	1	1.0	3	2.9	3	2.9
Archeophytes	**54**	**52.9**	**48**	**47.1**	**73**	**71.6**
Invasive archaeophytes	2	2.0	1	1.0	2	2.0
Naturalised archaeophytes	46	45.1	45	44.1	64	62.7
Temporal archaeophytes	6	5.9	2	2.0	7	6.9
All alien species	**67**	**65.7**	**73**	**71.6**	**102**	**100.0**

Significantly higher representation of neophytes and invasive species in the river Váh alluvium may be explained as a consequence of higher proportion of occurrence of the line landscape elements (e.g. water flows, water ditches, stream-side vegetation), combined with relatively high intensity of their anthopogenic disturbance as well as of higher proportion of the line sources of disturbance (e.g. relatively dense road network, intensively utilised railway), which both facilitate the spreading of neophytes and represent a resource of their diasporas (PYŠEK & PYŠEK 1995, MIHULKA 1997). The spread of invasive species is facilitated here also by denser urbanization and influence of large-block marcostructures of nearby fields.

Differences in representation of non-native species were recorded also in the 18 evaluated habitat types (Tab. 1). Most of the non-native species were found in the line corridors of shrubs and in the small woody patches dissociating the fields on the slopes of Považský Inovec Mts (48 species), in fragmentary

remnants of the floodplain forests (36), in alluvial meadows (34), in gravel bars along the Váh river (29), in illegal waste dumps in the vicinity of the Váh river (29) and in the grassland of the dikes along the Váh river and Váh channel from their both sides.

The smallest number of the non-native species was found in the littoral zone of the former gravel deposits (nowadays filled with water, beaded with relatively dense poplar and willow stands and serving as non-commercial fishponds) and of the small size forest glade, followed by various types of deciduous forests, also by abandoned meadows and by abandoned orchard (1–9 species). Concerning the average number of non-native species in individual habitat types, the biggest resource of their diasporas are illegal waste dumps in the Váh river alluvium, followed by gravel bars, shrubs and small woody patches between fields, as well as abandoned alluvial meadows (Tab. 1). We can summarize that the largest resource of neophytes in the studied area are the Váh river alluvial habitats, mostly with high degree of anthropogenic disturbance: especially fragments of former floodplains forests (touching large plots of fields), abandoned alluvial meadows and illegal waste dumps.

Conclusions

A number of authors have tried to find an answer to the question, which properties of communities and ecosystems are responsible for their affinity and vulnerability to invasions, however, there is a lack of concrete research experiments, especially due to several methodological difficulties. According to PRACH & PYŠEK (1997) quite an important role in biological invasions has spatial scale, position of the communities on the environmental gradient(s) and their biotic characteristics.

On the scale of topical ecosystems the biggest number of invasive species can be found in the vegetation of settlements and in the riverine and littoral communities (cf. MASKELL et al. 2006; CHYTRÝ et al. 2008; LAPOINTE et al. 2012 etc.), which partially confirm also results of our research. According to these authors the reason of this is probably combination of severe and regular anthropogenic disturbance of the respective habitats, rich supply of invasive species diasporas and their further spreading by means of water flows, growing travel, transport of materials, etc. Concerning position in respective environmental gradient, important roles are played by trophia and humidity of the habitat. Better off are mesohabitats and dry habitats, latter successional stages (earlier successional stages are invaded more easily) and changes in disturbance regimes, which are currently considered as one of the main factors of the communities affinity towards invasions.

The results of the floristic inventory of habitats in Piešťany surroundings confirm that spreading of alien invasive species in agricultural landscape is bound mainly to the banks of water streams, to anthropogenic habitats with synanthropic vegetation, to edges of the intensively cultivated arable land and to the narrow ecotones between arable land and remnants of natural and seminatural habitats. Relatively low number of invasive species in less disturbed deciduous forests of Považský Inovec Mts confirm that from the viewpoint of ecosystem structure, more resistant towards biological invasions are those plant

communities which are structurally more complex, higher and richer in biomass. On the other side, it seems that high affinity to biological invasions have habitats with high level of anthropogenic disturbance, especially pollution (the Váh river and its banks), change of the hydrological regime (inundation area between the river and the Vážsky channel), destruction of the bank stands and high nutrition level (river pollution, illegal waste deposits and also excrements from home pests).

This result coincides also with the thermodynamic theory of ecological systems (JØRGENSEN & SVIREZHEV 2004) and with our field studies (SABO et al. 2010), which imply that more complex and more integrated ecosystems are also more resistant towards biological invasions. This hypothesis may be supported by the fact that DOMIN (1931) published 81 years ago lists a number of currently recorded invasive species as quite common and several even abundant (e.g. *Cardaria draba* on the fields – also today widespread in the fields, fallows and on the dikes) already in his time. He had find them especially in the floodplain lowlands around Piešťany, including alluvial meadows, stream-side shrubs, grassland dikes, road edges, fields, etc., but also in grasslands and shrubs of Piešťanské hills in the Považský Inovec Mts. He recorded almost half of the invasive neophytes found during our research: *Amaranthus retroflexus, Conyza canadensis, Juncus tenuis, Lycium barbarum, Matricaria discoidea, Robinia pseuodoacacia* and *Solidago gigantea,* and both invasive archeophytes which we found in the area: *Cardaria draba* and *Echinochloa crus-galii.* We have also confirmed some Domin´s observations concerning high density of local populations, apart from *Cardaria draba* also in case of *Conyza canadensis* (in many habitats), *Solidago gigantea* (along the fishponds and gravel pits) and of *Helianthus tuberosus* (along the Váh river, on waste and gravel deposits).

On he other hand, Domin did not mention e.g. *Impatiens glandulifera* or *Fallopia* spec. div., which are currently in a high speed spreading in landscape and often form rather dense local populations.

The answer to the question why currently highly invasive species did not cause 80 years ago such a big damage to ecosystems as today (and apart from the weed *Cardaria draba* did not raise at all the question of how to cope with them) may be hidden in changes of the area. At those times the floodplain forest along the Váh river was much less fragmented, the grasslands were regularly mowed or grazed (both in floodplain area and in the Piešťany hills or the Piešťanské kopce hills), the hydrological regime was not strongly changed by Vážsky channel, the Váh river was not so heavily pollutied by nutrients and agrochemicals and the studied ecosystems suffered much less from the negative anthropogenic impacts as today. They were in a better „environmental health“ condition, preserving higher ecological complexity and ecological integrity. Therefore, they were probably more resistant to spreading of invasive species than today area´s ecosystems. If this hyppothesis proves true, then one of the measures to mitigate biological invasions should be protection of ecological complexity and biodiversity in natural and seminatural ecosystems also outside protected areas.

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