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ALIEN PLANT SPECIES GROWING NEAR TRAFFIC LINE STRUCTURES IN THE TŘEBOŇSKO PROTECTED LANDSCAPE AREA

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Abstract - The occurrence of non-native species is one of the priorities for nature and landscape protection. Protected areas are among the most valuable parts of the landscape, so nature conservation takes care not only of rare and endangered species, but also of alien species. The aim was to map out the occurrence of invasive and other non-native plant species on model examples of two types of propagation vectors - roads and railways in the Třeboňsko Protected Landscape Area. The total of 75 alien plant species were identified in 68 locations, of which 28 are listed in the Black, Gray and Watch Lists of alien species in the Czech Republic. The most abundant families were Asteraceae, Poaceae and Amaranthaceae. No difference in the occurrence of alien plants between the observed types of propagation vectors was found. The most dangerous invasive species growing along the main roads and railways were: *Reynoutria japonica* Houtt. var. *japonica*, *Impatiens glandulifera* Royle, *Helianthus tuberosus* L., *Solidago* sp., *Conyza canadensis* (L.) Cronq., and *Echinochloa crus-galli* (L.) P.B. Another non-native species that was captured successfully along rail tracks and road sides was *Digitaria sanguinalis* (L.) Scop. subsp. *sanguinalis*. Near roads, a significant spreading of the expansive halophilic species *Puccinellia distans* (Jacq.) Parl. was also found. The rare growings of *Plantago coronopus* L. near a road and *Alopecurus myosuroides* Huds. near a highway were also reported. The occurrence of many aliens and spreading species was discussed.

Keywords: Highway; invasive species; protected area; roads; railways; alien plants spreading.

Introduction

The Třeboňsko Protected Landscape Area (PLA), located in a flat landscape, cultivated by man for centuries, has preserved extremely valuable natural parameters. In many places, we can talk about a harmonious landscape where human activities are in a certain balance with nature. That is why the Třeboň region has been declared one of the six Czech biosphere reserves of the UNESCO Man and the Biosphere Programme. Třeboň ponds and Třeboň peat bogs belong to the list of wetlands protected by the Ramsar Convention. Due to the dense network of large water areas, the area is of international importance also from an ornithological point of view, as it has become the center of occurrence of nesting and migrating waterfowl species (AOPK ČR, 2016).

There is also a number of localities in the Třeboň Basin, in which invasive plant species create extensive involved stands and thus pose a significant danger to the original vegetation. Among the species that were intentionally planted in the Třeboň region in the past, the most problematic are *Robinia pseudoacacia* L., *Quercus rubra* L. and *Populus* x *canadensis* Moench. Extensive floods between 2002 and 2006 were the cause of the intense invasion of *Impatiens glandulifera* Royle as well as *I. parviflora* (DC.) Ser. which spread widely in the forest immediately adjacent to the river floodplains. *Reynoutria japonica* Houtt. and *R. sachalinensis* (F. Schmidt) Nakai spread uncontrollably into the open landscape, *Helianthus tuberosus* L., *Rudbeckia laciniata* L.,

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Solidago canadensis L. and *S. gigantea* Ait. often appear near human settlements and other disturbed habitats. As a result of historical soil deposits from other regions, there are also three small isolated localities with the occurrence of *Heracleum mantegazzianum* Sommier et Levier populations in the Třeboň region (AOPK ČR, 2016; 2017).

Alien plant species are a growing concern in protected areas, yet little information is available on the role of roads as corridors for alien species. Pauchard and Alaback (2004) found that elevation and alien species richness along roadsides were negatively correlated in Villarrica and Huerquehue national parks in the Andean portion of south-central Chile. This trend is well known, for example flora representation by neophytes decreased with altitude in nature reserves located in the Czech Republic (Pyšek et al., 2002). Both the number and proportion of alien plants significantly increased with increasing number of native species in a reserve and the proportion of neophytes increased with increasing density of human population. Therefore early detection and control of invasive species is probably important prevention in the protected areas.

National governments schould to increase the effectiveness of prevention of invasions, detect and respond quickly to new potentially harmful invasions, control and slow the spread of existing invasions, and provide that these efforts are coordinated and cost effective (Lodge et al., 2006). Many projects around the world focus on improving biodiversity as well as research on invasive organisms in natural ecosystems (Van Driesche et al., 2010). Lodge et al. (2006) recommend in their research work to use diagnostic technologies to increase active surveillance and sharing of information about invasive species so that responses to new invasions can be more rapid and effective.

The aim of this study is to confirm that the territory of the Třeboňsko PLA is relatively susceptible to plant invasions. We assumed that the area is characterized by an interconnected network of line corridors, such as rivers, roads, highways and railways. As prevention is the best strategic approach to controlling invasive alien species, acting at a regulatory level is fundamental for the effective management of biological invasions in all stages of the invasion process (Brundu et al., 2020). In our study, we focused on the occurrence of invasive and potentially invasive species along important terrestrial lines. Invasive species mean a possible uncontrolled spread through the landscape and pose a significant threat to both natural and secondary plant communities. This certainly applies to this flat area of the Třeboňsko PLA. Awareness of the found species and their location will be the basis for management measures in this protected area.

Material and methods

Characteristics of the study area

The Třeboňsko PLA, located in the southern part of the Czech Republic, has a total area of 700 km^2 and is comprised of 40 small protected areas. The area occupies a large part of the geomorphological unit of the Třeboň Basin. The eastern part flows smoothly into the ridges of the Kardašořečické Hills, the western part is separated from the Českobudějovická Basin by the Lišovský Threshold. The average altitude of the Třeboň Basin is 457 meters above sea level (Albrecht, 2003). Most of the Třeboňsko PLA lies in moderately warm climatic areas, characterized by long, warm summers and short-mild winters (Quitt, 1971). The average annual air temperature in the town of Třeboň, located in the central part of the territory, is 7.8 °C. The warmest month is July with an average temperature of 18 °C, the coldest is January with -2.8 °C. The growing season lasts from April to September at an average temperature of 14 °C. The average annual total precipitation is around 570 mm, most precipitation is recorded in July (94 mm) and in the long run the lowest precipitation totals are in January (30 mm). Snow cover occurs from November to March, the number of days with snow cover does not exceed 60 days (Quitt, 1971; AOPK ČR, 2016).

Land use consists of forests (45%), agricultural land (30%), water areas of ponds, rivers and lakes (15%) and human settlements with a transport structure (10%) (Albrecht, 2003). A characteristic feature is the dominance of coniferous trees, which make up 91% of the forest stand. The largest area is occupied by Scots pine (*Pinus sylvestris* L.) and Norway spruce (*Picea abies* (L.) H. Karst.), deciduous trees are mainly oaks (*Quercus* L.), birches (*Betula* L.), alders (*Alnus* Mill.), and beeches (*Fagus* L.) (Albrecht, 2003).

Study sites

The field survey took place in the years 2018-2019 at 68 localities and was focused on the occurrence of non-native species of flowering plants. The sites were located either on the České Velenice - Veselí under Lužnice (line no. 226) and Prague - České Budějovice (line no. 220) railway lines, the main roads I/34, I/24 and the D3 motorway, so that they cover the south-north and east-west directions of the targeted area. All railway stations (or stops) and some sections between two stops (tracks and the immediate surroundings) were monitored on the railway lines. On the roads, the localities were located mainly at intersections, car parks, rest areas, bus stops, at gas stations, etc., but also in lanes along the road and motorway. The map of localities was created in the QGIS program. The monitored parts of roads, motorways and railways, including all localities, are shown in Figure 1.

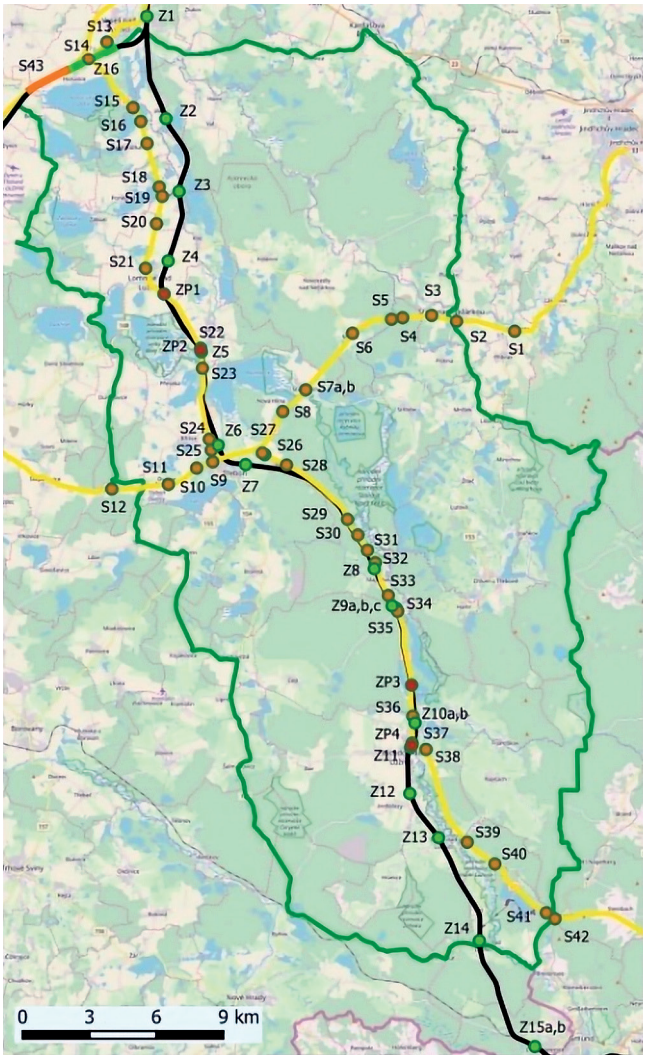

Figure 1. Map of the Třeboňsko PLA with numbered research sites (S – roads, motorway, Z – railway). Lines on the map mean: green - border of the Třeboňsko PLA, yellow - monitored roads, black - monitored railways, red - monitored motorway).

Plant records

Non-native plant species and their cover (especially the dominant position in the community) were registered in individual localities: railway, road (or highway), intersection. A species was considered dominant if its cover at the locality was 50 - 100%. Information on the region of origin was taken from Pyšek et al. (2012). The category of anecophytes was also included Pyšek et al. (2012). Anecophytes are cultigenic taxa and the hybrids between alien taxa as well as between alien and native taxa (Scolz, 2007). All species that are part of the Black, Gray and Watch List of alien species of the Czech Republic were considered invasive and were classified into categories: black lists (BL1, BL2, BL3), gray list (GL), and watch list (WL) (Pergl et al., 2016). In addition to invasive species, other introduced species were monitored as well. They are registered in the list of non-native higher plants of the Czech Republic (Mlíkovský and Stýblo, 2006) and have some invasive potential. Particular attention was paid to monitoring of *Puccinellia distans* (Jacq.) Parl., which spreads intensly along the roads throughout Central Europe. The frequency of occurrence of botanical families at the monitored types of localities was tested using the Friedman ANOVA and Kendell's concordance dialog ($\alpha<0.05$). For statistical data processing we used STATISTICA programme. Taxonomic determination of the species was performed according to the botanical key Kubát (2002) and consulting the specialists from the Třeboňsko PLA Administration.

Results

A total of 75 non-native taxa were recordet: 56 near railways, and 64 along the roads (Table 1). The most frequently observed species only on railways were *Conyza canadensis* (L.) Cronq., *Impatiens parviflora* DC., *Echinochloa crus-galli* (L.) P.B., *Solidago canadensis,* and *Galinsoga parviflora* Cav., and the most common species only along roads were *Arrhenatherum elatius* (L.) J. Presl et C. Presl, *Echinochloa crus-galli,* and *Conyza canadensis*. Non-native taxa that were recorded on both types of lines were *Chenopodium album* agg., *Digitaria sanguinalis* (L.) Scop subsp. *sanguinalis, Lactuca serriola* L., *Sonchus oleraceus* L., *Tanacetum vulgare* L., and *Tripleurospermum inodorum* (L.) Sch. Bip.

Most alien species (36%) came from the Mediterranean, followed by species from Asia (17%), Europe (16%) and North America (16%) (Table 1). Geographical provenience also included North (3%) and Central America (3%) and Australia (1%). A special category was anecophytes, which accounted for 7%.

Among the recorded taxa 28 are reported in the Black, Gray and Watch List of alien species of the Czech Republic (Pergl et al., 2016). Species listed in the category of the most dangerous invasive species (BL1) were not found. The occurrence of 13 species classified in the category BL2, 9 species in BL3 and 6 species which are listed in GL were recorded (Table 2). In addition to these taxa, 33 of the observed taxa have invasive potential for the Třeboňsko PLA (Table 1).

The most frequently recorded species from the BL2 category was *Solidago canadensis*, the most abundant in České Velenice, where it formed a dense continuous stand. The taxa *Impatiens glandulifera* and *Reynoutria japonica* var. *japonica* grew in shady and humid places. Two small outbreaks of *Helianthus tuberosus* were also found.

Table 1. List of the recorded alien taxa in the Třeboňsko PLA. * taxa with some invasive potencial for the Třeboňsko PLA. Origin of the taxa: M - Mediterranean, E – Europe, As – Asia, AmN – North America, AmC – Central America, AmS – South America, Au – Australia, anec – anecophytes, (according to Pyšek et al., 2012).

Taxa	Origin	Number of localities			
		Railway	Road	Intersection	Total
Chenopodium album agg.*	E	15	42	4	**61**
Digitaria sanguinalis subsp. *sanguinalis**	M	15	40	3	**58**
*Lactuca serriola**	M	17	37	2	**56**
*Tanacetum vulgare**	As + AmS + Am	12	35	3	**50**
*Conyza canadensis**	AmN	18	26	3	**47**
*Sonchus oleraceus**	M	8	36	3	**47**
*Echinochloa crus-galli**	anec	11	29	3	**43**
*Tripleurospermum inodorum**	anec	9	31	2	**42**
Arrhenatherum elatius	E	4	32	2	**38**
*Cirsium arvense**	E + As	6	30	2	**38**
Convolvulus arvensis	M	6	17	2	**25**
*Impatiens parviflora**	As	12	11	2	**25**
Oenothera biennis	E + As	13	10	2	**25**
*Amaranthus retroflexus**	AmN + AmC	5	16	1	**22**
Pastinaca sativa	M	8	12	1	**21**
Erigeron annuus subsp. *annuus**	AmN	7	11	1	**19**
*Galinsoga parviflora**	AmS	9	9	0	**18**
Capsella bursa-pastoris	M	2	13	2	**17**
Epilobium ciliatum	AmN + AmC	8	6	2	**16**
Silene latifolia subsp. *alba*	E + M + As	4	11	1	**16**
Atriplex patula	E + M + As	4	10	0	**14**
*Galinsoga quadriradiata**	AmC + Am S	4	8	2	**14**
Chelidonium majus	E + M + As	4	10	0	**14**
*Solidago canadensis**	AmN	10	4	0	**14**
*Parthenocissus quinquefolia**	AmN	5	7	0	**12**
Senecio vulgaris	anec	3	9	0	**12**
*Eragrostis minor**	M	4	7	0	**11**
Melilotus albus	M + As	5	6	0	**11**
Brassica oleracea	M	1	6	1	**8**
Cichorium intybus subsp. *intybus*	M	2	6	0	**8**
Reynoutria japonica var. *japonica**	As	4	4	0	**8**
*Impatiens glandulifera**	As	4	2	0	**6**
Lamium album	E + M	0	6	0	**6**
Syringa vulgaris	E	3	3	0	**6**
Setaria pumila	M	5	0	0	**5**
*Solidago gigantea**	AmN	2	3	0	**5**

Taxa	Origin	Number of localities			
		Railway	Road	Intersection	Total
Arctium tomentosum	E	1	3	0	**4**
*Atriplex sagittata**	E + M + As	1	2	0	**3**
Bromus tectorum	M	2	1	0	**3**
Chenopodium strictum	M	0	3	0	**3**
Oxalis fontana	AmN	2	1	0	**3**
Papaver rhoeas	M	1	2	0	**3**
*Acer negundo**	AmN	1	1	0	**2**
Agrostis gigantea	M	1	1	0	2
Apera spica-venti	E + M	0	2	0	**2**
Avena sativa	anec	0	2	0	**2**
*Bidens frondosus**	AmN	1	1	0	**2**
Centaurea cyanus	anec	0	2	0	**2**
*Helianthus tuberosus**	AnmN	2	0	0	**2**
Juncus tenuis	AmN	0	2	0	**2**
Malva neglecta	M	1	1	0	**2**
Matricaria discoidea	As	0	2	0	**2**
Portulaca oleracea subsp. *oleracea**	M	2	0	0	**2**
Reseda lutea	M	1	1	0	**2**
*Rhus typhina**	AmN	2	0	0	**2**
Sisymbrium officinale	M	1	1	0	**2**
*Ailanthus altissima**	As	1	0	0	1
*Alopecurus myosuroides**	M	0	1	0	**1**
Avena fatua	M	0	1	0	**1**
Calystegia pulchra	As	1	0	0	**1**
*Conium maculatum**	M + as	0	1	0	**1**
Helianthus annuus	AmN	0	1	0	**1**
Chenopodium botrys	M + As	0	1	0	**1**
*Lupinus polyphyllus**	AmN	0	1	0	**1**
*Lycium barbarum**	E + M	1	0	0	**1**
Medicago sativa subsp. *sativa*	anec	1	0	0	**1**
Microrrhinum minus	E + M	0	1	0	**1**
*Robinia pseudoacacia**	AmN	1	0	0	**1**
Rumex thyrsiflorus	E + As	0	1	0	**1**
*Sedum hispanicum**	M	0	1	0	**1**
Sedum spurium	E + M	0	1	0	**1**
Solanum nigrum	M	1	0	0	**1**
Thlaspi arvense	M	0	1	0	**1**
Trifolium hybridum subsp. *hybridum*	anec	1	0	0	**1**
Veronica persica	M	0	1	0	**1**

Table 2. List of the recorded alien plants reported in the Black and Gray List of the Czech Republic. BL2: dangerous black invasive species, BL3: black invasive species, GL: gray invasive species (according to Pergl et al., 2016)

Taxa	Category
Acer negundo	BL2
Ailanthus altissima	
Arrhenatherum elatius	
Helianthus tuberosus	
Impatiens glandulifera	
Lupinus polyphyllus	
Lycium barbarum	
Parthenocissus quinquefolia	
Reynoutria japonica var. *japonica*	
Rhus typhina	
Robinia pseudoacacia	
Solidago canadensis	
Solidago gigantea	
Alopecurus myosuroides	BL3
Amaranthus retroflexus	
Cirsium arvense	
Conium maculatum	
Conyza canadensis	
Echinochloa crus-galli	
Galinsoga parviflora	
Galinsoga quadriradiata	
Portulaca oleracea subsp. *oleracea*	
Atriplex sagittata	GL
Bidens frondosus	
Eragrostis minor	
Erigeron annuus subsp. *annuus*	
Impatiens parviflora	
Sedum hispanicum	

Among the species from the BL3 category, *Conyza canadensis* was the most represented, its largest populations were discovered in Majdalena, Dvory under Lužnice and České Velenice. Other abundant species in this category were *Echinochloa crus-galli* and *Galinsoga parviflora*. Of the species listed in the Gray List, *Impatiens parviflora* was dominant. It was usually found in shady and wet places, but in several localities it also inhabited dry railway embankments. The dangerous invasive species (BL2) were found above all at the railway stations, where the most dominant was *Digitaria sanguinalis* subsp. *sanguinalis*. This taxon was present in the track of almost all mapped railway sites and was very common along roads.

The expansive species with high dominance in all localities was *Calamagrostis epigejos*. The occurrence of the ruderal taxon *Chenopodium album* agg. was common along both types of lines. *Lactuca serriola* was abundant in the vicinity of station buildings and platforms. *Oenothera biennis* L. grew in dry and sunny places, the largest population of which was recorded at the Majdalena station.

The most abundant families were Asteraceae, Poaceae and Amaranthaceae. The families with the largest number of finds in the three types of localities are presented in Figure 2. Non-parametric analysis of the data did not confirm any difference in the occurrence of families among railway, road, and intersection.

Discussion

In the Třeboňsko PLA, 28 taxa (Table 2) listed in the Black, Gray and Watch List of alien species of the Czech Republic were identified along railways and the most important roads (Pergl et al., 2016). Our survey was conducted only in selected localities, so it can be assumed that the total number of invasive species occurring in the area will be higher.

Protected areas include ecosystems that are particularly valuable for the protection of species and habitats and thus serve as a pillar of nature conservation (Chape et al., 2005; Tittensor et al., 2014). Therefore the spread of invasive species in these areas poses a serious danger. Among the species with the largest and most serious impacts on biodiversity and ecosystem functioning in European protected areas there are the herbal taxa *Reynoutria japonica, Heracleum mantegazzianum* Sommier et Levier and *Impatiens glandulifera*, among the trees *Ailanthus altissima* (Mill.) Swingle and *Robinia pseudoacacia* (Pyšek et al., 2013; Braun et al., 2016). Four of these species have been confirmed in our research (Table 1).

Quercus rubra, Populus x *canadensis, Reynoutria sachalinensis, Rudbeckia laciniata,* and *Heracleum mantegazzianum* were found in the territory (AOPK ČR, 2016; 2017), not yet near traffic line structures.

Dangerous species

The taxon *Reynoutria japonica* var. *japonica* successfully spreads in both synanthropic and natural habitats, along watercourses and roads (Mandák et al., 2004). In the Třeboňsko PLA, it was recorded at 4 road and 4 railway localities. It was most abundant at the railway station in Třeboň. The spread of this taxon is largely due to its rapid ability to regenerate from root rhizomes and probably also due to the climate. The ongoing climate change is likely causing a significant spread of this species on the banks of Slovenian and Croatian rivers

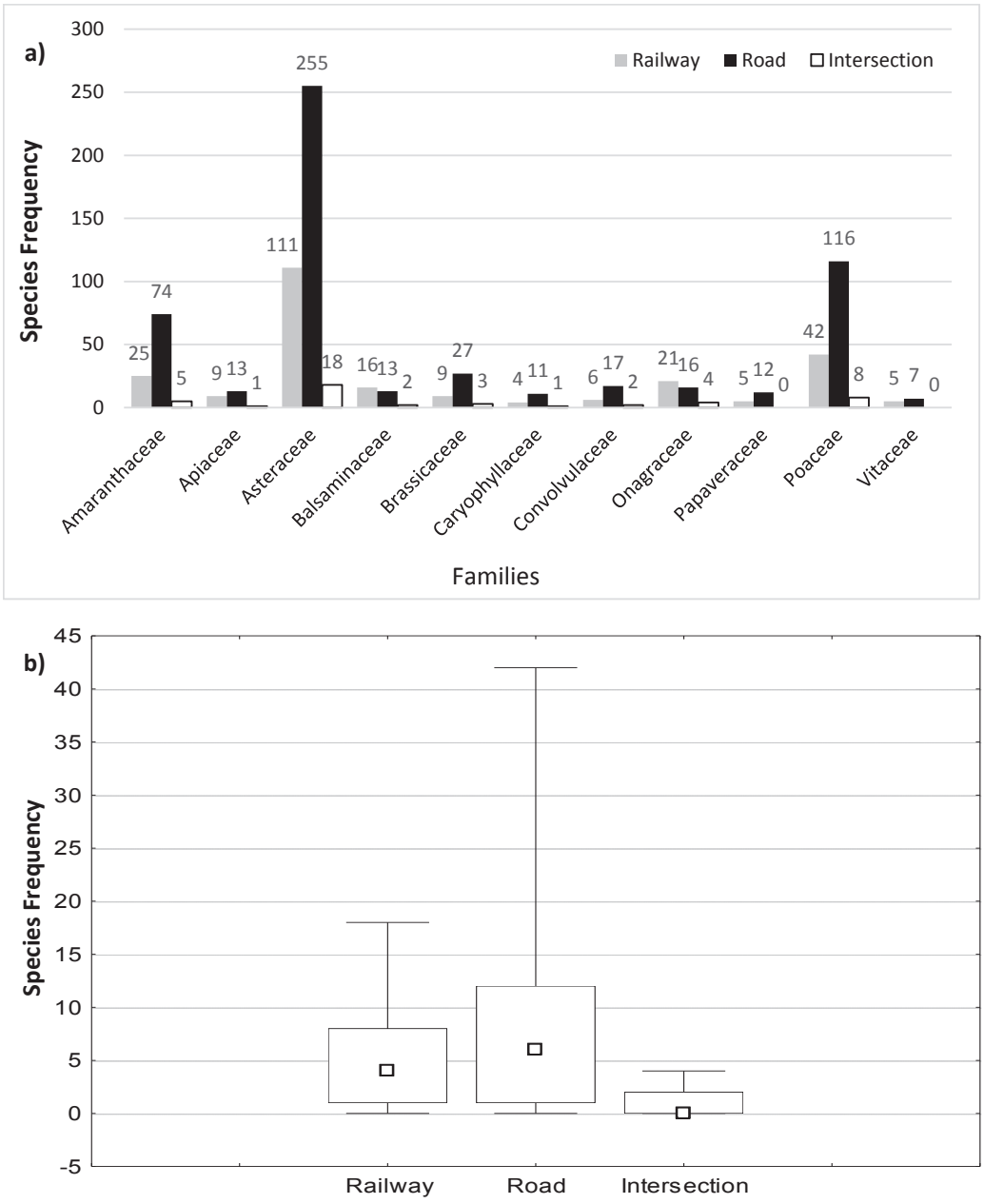

Figure 2. (a) The most abundant families detected along railway, road, and intersection in the Třeboňsko PLA, (b) Boxplot among families (standardized output from the STATISTICA programme). The median, quartiles, and ranges are reported. No difference was found in the abundance of families in the investigated lines (Friedman ANOVA and Kendell's concordance dialog).

(Jovanović et al., 2018). The need and methods of management interventions against this species have been intensly addressed in recent years (Hajzlerová and Reif, 2014; Halas et al., 2018). The species Impatiens glandulifera was found in 2 road and 4 railway localities in the Třeboňsko PLA. The populations were vital and fertile. The low frequency of its occurrence along roads and railways is mainly due to its demands on the environment features, as it requires humid and shady habitats. On the other hand, *Impatiens* grew along roads in higher areas of the Polish part of the Carpathian Mountains (Kostrakiewicz-Gieralt and Zajac, 2014). The invasive success of *I. glandulifera* is due to the extremely long period of seed ripening, significant variability in their weight and the production of large seeds even under adverse habitat conditions (Willis and Hulm 2004). The relatively high number of produced seeds, which are well germinated and stored in a short-term persistent seed bank (Skálová et al., 2019), contributes to the rapid spread (Šerá and Šerý, 2004).

Helianthus tuberosus was found at two railway sites in relatively stable populations. This species has not yet occupied all available habitats in this region. Its high competitive strength and ability to create large-scale stands make it a particularly problematic species, especially in protected areas (Švehláková et al., 2017). The presence of *Reynoutria japonica, Impatiens glandulifera* and *Helianthus tuberosus* is most often linked to the presence of watercourses (Vardarman et al., 2018) and can cause considerable damage to associated agricultural land (Onete et al., 2015). The occurrence of these species along roads and railways in the Třeboňsko PLA opens up great opportunities for these invasive species to spread further into the open countryside.

Solidago canadensis and *S. gigantea* grew in 16 localities. The occurrence of *S. canadensis*, which is less demanding on nutrients and soil moisture, was more frequent; its largest population was found at the railway station in České Velenice. Its occurrence was linked more to the railway embankments than to the surroundings of the roads. *S. canadensis* has a large number of easily spreadable seeds (Šerá and Šerý, 2004) and can also be successfully spread by rhizomes. Species of the genus *Solidago* are also a problem in other protected areas in Central Europe. Specifically *S. gigantea* was one of the main invasive plants threatening natural habitats in the Őrség Protected Landscape Area in western Hungary (Balogh, 2001).

The most common species

The most frequently detected species was the weed *Chenopodium album* agg. (61 localities), but it is not understood as a dangerous invasive species. It is a domesticated weed of the ruderal and segetal communities of Central Europe. On the contrary, a number of invasive weeds has been recorded in the Třeboňsko PLA. Among the most important of them, we observed *Digitaria sanguinalis* subsp. *sanguinalis, Conyza canadensis, Eragrostis minor* Host*, Echinochloa crus-galli, Amaranthus retroflexus* L.*,* and *Galinsoga* sp.

Annual grass *Digitaria sanguinalis* subsp. *sanguinalis* (58 localities) was abundant along railways, roads and in the vicinity of railway crossings. It created particularly large populations in the tracks of the railway stations České Velenice, Lomnice under Lužnice and Suchdol under Lužnice. On the contrary, it is absent in a newer railway corridor between the Veselí under Lužnice station and the Horusice stop. It is the main railway line between Prague and České Budějovice, so the track is very busy there. This railway track is less ruderalized and there is almost no soil substrate on the embankment, which significantly reduces the likelihood of the plant species spreading in the future. On the other hand, *D. sanguinalis* subsp. *sanguinalis* grows very well in the railway line between Veselí under Lužnice and České Velenice stations. The plant stands cannot be permanently destroyed there even by regular spraying with herbicides (anonymous employee: oral communication). This may be due to the fact that *D. sanguinalis* subsp. *sanguinalis* forms resistant plants that have been recorded on some roads (Šerá, 2008).

Another frequently found and highly invasive weed was *Conyza canadensis* (47 localities). It most often grew on gravel or sandy ground near the asphalt edges of roads, on railway embankments, level crossings and platforms. This species is not competitively strong, but it can colonize open or often disturbed habitats very quickly (Mlíkovský and Stýblo, 2006). The study of arbuscular mycorrhizal fungi of *C. canadensis* has not shown any significant effect on its invasiveness (Řezáčová et al., 2020).

Another problematic species is *Echinochloa crus-galli*, which was recorded in 43 localities. It occurred mainly in humid places, such as ditches along embankments and road edges, its occurrence was also numerous on the construction site of the D3 motorway. It often grew near roads at the edges of fields, so crossings of agricultural machinery can contribute to the spread of this species in the region. The species belongs to the C4 plants and is thus ecologically preffered in drier and warmer localities (Jarolímek et al., 1999).

Eragrostis minor has received particular attention because its spread to cities and the wild is a process that has only begun in the recent past. Thanks to its resistance to salinity, it successfully spreads in urban environment, fills cracks in paving, and lines the edges of roads. In the warmer regions of the Czech Republic, it also spreads rapidly along the railways (Mlíkovský and Stýblo, 2006). Together with *D. sanguinalis* and *C. canadensis*, they are among the most common invasive weeds, e.g. along railway lines in Hungary (Dancza et al., 2002). *E. minor* was identified in 11 localities in the Třeboňsko PLA. It was found at railway stations and at petrol stations in most major settlements, such as Veselí under Lužnice, Třeboň, Majdalena and Suchdol under Lužnice.

Narrow lines along roadsides

One of the important species spreading along the roads in the Třeboňsko PLA was *Digitaria sanguinalis* subsp. *sanguinalis* (see above) and the native halophyte *Puccinellia distans*. In the monitored area, *P. distans* spreads along roads (Husák, 2000), but also throughout the country (Šerá, 2008; 2010; Kaplan et al., 2018). The species was present in the vast majority of road localities, in a narrow zone of sparse vegetation along the asphalt roads. This expansive grass was also present to a limited extent on the newly built D3 motorway. These are places with a shallow soil substrate, which are affected by winter salting of roads and mowing of road edges. The success of this less competitive species may be related to its ability to grow on shallow soils and in places around mowing roads (Beyschlag et al., 1996; Ryel et al., 1996). Due to its successful spread

along other roads in the Třeboňsko PLA, it can be assumed that in the coming years it will also spread along this newly emerging corridor.
The consequence of intense salting of roads in the Třeboň region is also the presence of *Plantago coronopus* L., which was recorded at the crossroads near the town of Stráž under Nežárka, where it grew together with *D. sanguinalis* subsp. *sanguinalis* and *P. distans*. The monitored motorway D3 was also the only place where the occurrence of the invasive species *Alopecurus myosuroides* Huds. was recorded.

Invasive woody plants

Invasive woody plants also grow in the Třeboňsko PLA. Specifically *Parthenocissus quinquefolia* (L.) Planch.*, Syringa vulgaris* L.*, Robinia pseudoacacia, Ailanthus altissima, Acer negundo* L. and *Rhus typhina* L. have been recorded. Their occurrence in the monitored localities was rather accidental, with the exception of the liana *P. quinquefolia* (12 localities). Like *Acer negundo* and *Ailanthus altissima* (and many others), *P. quinquefolia* is considered to be the most dangerous species in Ukraine's natural communities. The lower number of records of invasive trees can be explained by the fact that our research was focused on narrower sites along line structures.
R. pseudoacacia is a common tree within the Třeboňsko PLA. However, it successfully invades, for example, dam communities rather than transport corridors (AOPK ČR, 2016). *R. pseudoacacia* can quickly colonize disturbed habitats, threatens species-rich dry and semi-dry grasslands (Vítková et al., 2017; Montecchiari et al., 2020) and, together with *A. altissima*, is the most widespread invasive tree in European oak forests (Campagnaro et al., 2018; Montecchiari et al., 2020). Together with *A. altissima* and *A. negundo*, it also spreads in the floodplain forests of the Donau-Auen National Park (Höfle et al., 2014).
Thanks to the occurrence of invasive tree species along line structures together with the ongoing climate change, the possibility of the penetration of the mentioned tree species into the open landscape and into the protected small-scale areas of the Třeboň region can be expected.

Conclusion

The results of this work show that the occurrence of invasive plants along linear transport corridors is a process that deserves an increasing interest, especially in protected areas. The total of 77 alien plant taxa were identified growing along the transport lines, of which 28 are listed in the Black, Gray and Watch Lists of alien species in the Czech Republic. The most abundant families were Asteraceae, Poaceae and Amaranthaceae. No difference in the occurrence of alien plants between the observed types of line elements was found. Our results can contribute to the protection of the landscape from invasive alien species found in the areas of interest.

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