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Alien and invasive species in plant communities of the Vistula and Brennica rivers gravel bars (Western Carpathians, Poland)

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Abstract: Gravel bars are the initial habitats, inseparably connected to the mountain streams. On the one hand, they are an unstable substrate, influenced by the overflows and high waters; however, they are also exposed to strong sunlight and heat. This situation determines specific vegetation which, due to dynamic changes in the habitat, has a pioneer character. What is more, gravel bars are areas where many river migratory species and many random species appear. Among them, there are also synanthropic species. In years 2011-2012, floristic and phytosociological studies were conducted in the Silesian Beskids. The goal of these studies was to recognize the vegetation of the gravel bars of the Vistula and the Brennica rivers – from their springs in the Silesian Beskids to the point where the Brennica River flows into the Vistula River in the Silesian Foothills. The studied section of the two rivers is regulated. Particular attention was paid to the synanthropic species that pose a threat to the native flora. In 9 recognized types of plant communities, 293 vascular plant species were recognized. More than 15% of the flora were alien species (45) and 22 of them were considered to be invasive. The most common invasive species that were spotted included: *Impatiens glandulifera*, *Heracleum mantegazzianum* and *Reynoutria japonica*. Plant communities with the biggest number and share of alien species were *Plantago major-Barbarea vulgaris* community and *Phalaridetum arundinaceae*.

Key words: synanthropization, vegetation, Silesian Beskids, Silesian Foothills

1. Introduction

Rocky streams are a common element of mountain landscapes. Gravel bars are initial habitats, inseparably connected to them. On the one hand, they are an unstable substrate, frequently flooded by overflows and high waters but on the other hand, they are also exposed to strong sunlight and heat. This situation determines specific vegetation, which – due to the dynamic changes in the habitat – has a pioneer character. What is more, gravel bars are areas where many river migratory species and many random and alien species appear.

The Vistula is the longest river in Poland. Springs of this river are located in the area of the Silesian Beskid Mts. Most gravels are located along the first 30 km of the Vistula and on the riverbed of its biggest tributary in this area – the Brennica River (Fig. 1).

The vegetation and succession of gravel bars in the area of the Carpathian Mountains were object of research carried out by Zarzycki (1956) in the area of two streams – Skawa and Skawica. Another research in this field concerned the Babia Góra massif (Uziębło & Ciapała 2006) and the Silesian Beskid Mountains (Kamycka 2013). Alluvial plant communities of mountain streams were studied also during extensive research of different mountain ranges in the Carpathian Mountains (e.g. Kornaś & Medwecka-Kornaś 1967; Grodzińska 1979; Dubiel *et al.* 1999).

The problem of alien species in riparian habitats was object of many studies (Dajdok *et al.* 1998; Chittka & Schürkens 2001; Hejda & Pyšek 2006; Yoshikawa *et al.* 2013; Chmura *et al.* 2015), but in the Carpathian Mountains the issue was raised only by Uziębło & Skowronek (2008).

The aim of this study was to recognize the share of alien species in plant communities of the discussed area.

ECOLOGY

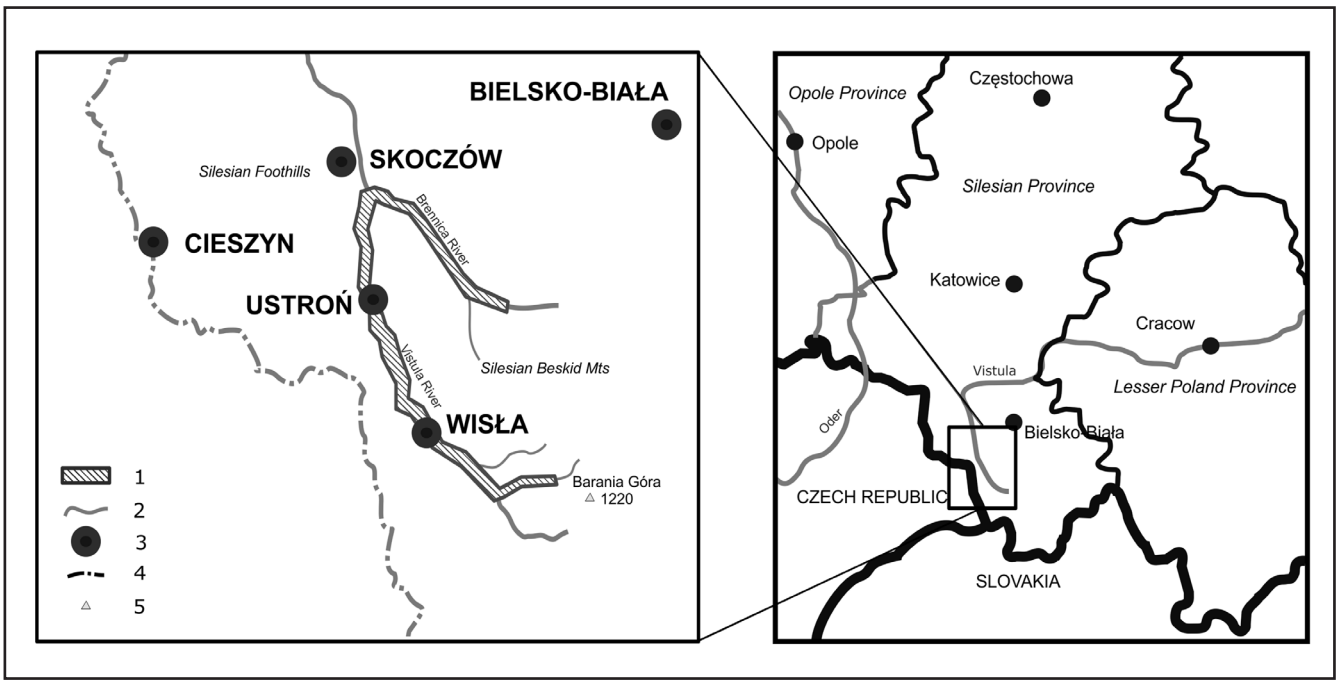

Fig. 1. Location of the studied gravel bars of Vistula and Brennica Rivers (Southern Poland) Explanations: 1 – studied parts of rivers, 2 – rivers, 3 – towns and rivers, 4 – country border, 5 – peaks

2. Material and methods

Field research was carried out in gravel bars of the Vistula and the Brennica rivers – from their springs in the Silesian Beskids to the point where the Brennica River flows into the Vistula River in the Silesian Foothills (Fig. 1). The studied sections of these two rivers are modified by river engineering.

The research was carried out in years 2011-2013. The basis for the investigation included vegetation surveys conducted by Braun-Blanquet (1964) method. The studied material consisted of 143 relevés (5-50 m^2 each) and is available in the Department of Ecology, University of Silesia (Kamycka 2013). The number of relevés depended on each community area. The list of alien and invasive plants was compiled according to Tokarska-Guzik *et al.* (2012). Species nomenclature followed Mirek *et al.* (2002) and association nomenclature – that of Matuszkiewicz (2008). Occurrence of each alien species in plant communities was described using constancy degrees and cover coefficient following Pawłowski (1972).

3. Results

3.1. Plant communities

Agrostis stolonifera-Phalaris arundinacea community – the most common initial type of vegetation on gravel bars in the studied area. It usually has poor coverage (less than 10%) with only a few species (2-12). The following 2 grasses: *Agrostis stolonifera* and *Phalaris arundinacea* are most frequent and they seem to be pioneer species in this habitat.

Polygono-Bidentetum (Koch 1926) Lohm. 1950 – usually occurs on labile substrate with fine-grained gravel, silt and sand in places with southern exposure. It is dominated by therophytes, such as *Polygonum hydropiper* and *Bidens tripartita*. Phytocoenoses of this community usually occur near edges of gravel beds.

Rorippo-Agrostietum (Moor 1958) Oberd. et Th. Müller 1961 – loose floodplain grasslands typical to West-Carpathian rivers on rocky-gravelly substrates. *Agrostis stolonifera*, *Rorippa sylvestris* and *Phalaris arundinacea* are the most frequent species. Phytocoenoses stand out great number of random species. The habitat of this community is usually flooded in spring and over-dried in summer.

Plantago major-Barbarea vulgaris community – the community is rich in species (total number reaches 204) and *Barbarea vulgaris* is the most frequent. The most constant species represent the alliance of floodplain grasslands: *Agropyro-Rumicion crispi* and the class of ruderal vegetation – *Artemisietea vulgaris*.

Phalaridetum arundinaceae (Koch 1926 n.n.) Libb. 1931 – reed beds dominated by *Phalaris arundinacea*. The most common type of phytocoenosis in the studied area. It presents several types of plant composition which differ in the species richness; this seems to be related to stages of succession and type of gravel bar.

Sparganio-Glycerietum fluitantis Br.-Bl. 1925 n.n. – low reed beds in silt substrates. The most frequent species are: *Glyceria fluitans* and *Sparganium erectum*.

Glyceria fluitans community – thick aggregations of *Glyceria fluitans* in places that are under constant influence of river water in all vegetation periods.

Table 1. Share of alien species in plant communities of gravel bars of Vistula and Brennica Rivers

Plant communities	1	2	3	4	5	6	7	8	9
Number of relevés	15	10	15	24	53	8	3	2	13
Average number of species in relevé	7	19	15	44	17	18	10	21	19
Number of all species	36	86	94	208	184	58	19	31	83
Number of non-invasive species	0	4	8	19	8	1	0	1	0
Number of invasive species	3	7	6	15	17	4	2	1	4
Alien non-invasive species									
Anthemis arvensis				I^{2}					
Capsella bursa-pastoris				I^{2}					
Chamomilla suaveolens			I^{3}						
Cichorium intybus				I^{2}					
Cucurbita pepo				I^{2}					
Fallopia convonvulus					I^{1}				
Lamium purpureum				I^{2}					
Lycopersicon esculentum				I^{2}					
Medicago sativa				I^{2}	I^{1}				
Oenothera biennis		I^{10}		II^{91}	I^{3}				
Papaver rhoeas				I^{21}					
Parthenocissus quinquefolia				I^{2}		I^{5}			
Physocarpus opulifolius				I^{6}					
Rudbeckia hirta					I^{1}				
Sarothamnus scoparius				I^{13}					
Scleranthus annuus		I^{10}		I^{2}					
Sedum spurium		I^{5}		I^{10}					
Senecio vulgaris				I^{6}	I^{1}				
Sisymbrium officinale				I^{2}					
Sonchus oleraceus				I^{4}	I^{1}				
Triticum aestivum				I^{2}					
Vicia hirsuta				I^{2}					
Viola arvensis				I^{2}					
Alien invasive species									
Bidens frondosa			I^{3}						
Conyza canadensis		I^{5}		III^{60}	I^{32}				
Echinochloa crus-galli	I^{3}	I^{10}			I^{19}	II^{110}			
Echinocystis lobata		I^{5}			I^{33}				
Eragrostis albensis						I^{50}			
Erigeron annuus				II^{50}	I^{3}				
Galinsoga ciliata				I^{2}					
Galinsoga parviflora				I^{2}					
Heracleum mantegazzianum	I^{3}		I^{116}	II^{85}	II^{237}				III^{319}
Impatiens glandulifera		IV^{1085}	II^{71}	IV^{227}	IV^{588}	I^{5}	II^{3}	III^{25}	II^{12}
Impatiens parviflora		I^{10}	I^{7}	II^{17}	II^{27}	I^{5}			I^{4}
Juncus tenuis				I^{3}	I^{1}				
Lolium multiflorum			I^{3}	II^{67}	I^{5}		II^{170}		
Mimulus guttatus				I^{117}	I^{2}				
Reynoutria japonica	I^{1}	I^{10}		I^{2}	I^{100}				I^{40}
Reynoutria sachalinensis		I^{5}		I^{2}	I^{1}				
Robinia pseudoacacia				I^{2}	I^{1}				
Rudbeckia lacinata				I^{2}					
Solidago canadensis				I^{63}	I^{81}				
Solidago gigantea					I^{2}				
Telekia speciosa					I^{1}				
Veronica persica			I^{6}		I^{1}				

Explanations: 1 – *Agrostis stolonifera-Phalaris arundinacea* community, 2 – *Polygono-Bidentetum*, 3 – *Rorippo-Agrostietum*, 4 – *Plantago major-Barbarea vulgaris*, 5 – *Phalaridetum arundinaceae*, 6 – *Sparganio-Glycerietum fluitantis*, 7 – *Glyceria fluitans* community, 8 – *Mentha longifolia* community, 9 – *Phalarido-Petasitetum hybridi*

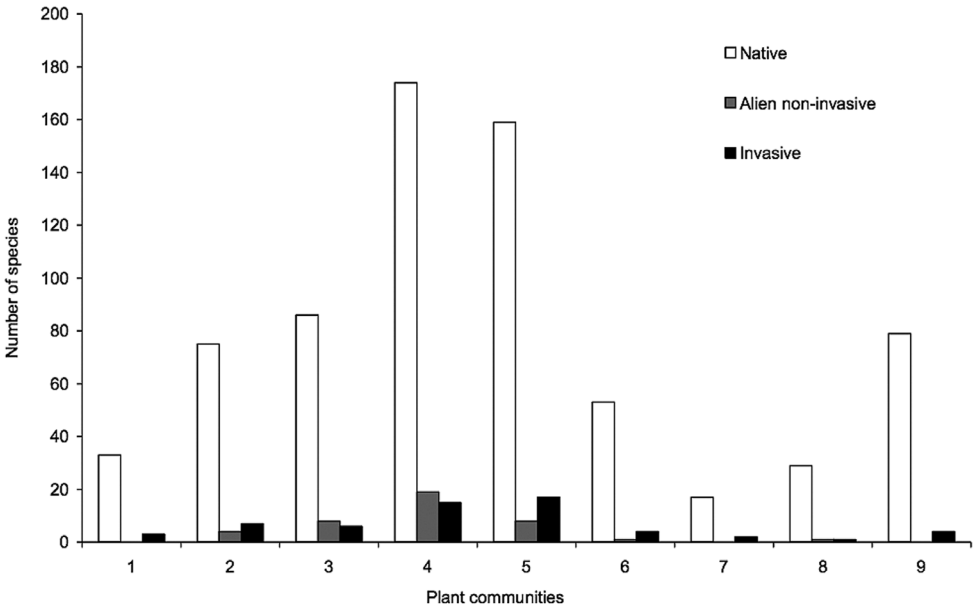

Fig. 2. Share of native, alien non-invasive and invasive species in plant communities of gravel bars of Vistula and Brennica Rivers

Explanations: 1 – *Agrostis stolonifera-Phalaris arundinacea* community, 2 – *Polygono-Bidentetum*, 3 – *Rorippo-Agrostietum*, 4 – *Plantago major-Barbarea vulgaris*, 5 – *Phalaridetum arundinaceae*, 6 – *Sparganio-Glycerietum fluitantis*, 7 – *Glyceria fluitans* community, 8 – *Mentha longifolia* community, 9 – *Phalarido-Petasitetum hybridi*

Mentha longifolia community – infrequent community of fertile substrates dominated by *Mentha longifolia*.

Phalarido-Petasitetum hybridi Schwick. 1933 – dominated by massive herb *Petasites hybridus*. In contrast to previous communities, it can last for many years on stabilized gravel bars.

3.2. Share of alien and invasive species

The total of 293 vascular plant species were recorded in plant communities of the studied area. More than 15% of the flora were alien species (45) and 22 of them were considered to be invasive (Table 1).

In the flora of all studied plant communities, the most common were native species. The greatest numbers of alien species were observed in patches of *Plantago major-Barbarea vulgaris* and *Phalaridetum arundinaceae* communities. These plant communities were also under the highest pressure of invasive species (Fig. 2). The most common and most dangerous alien invasive species comprised: *Impatiens glandulifera*, *Heracleum mantegazzianum* and *Reynoutria japonica*. Initial stages of gravel bar succession were almost free from invasive species (Table 1).

From among alien species, the biggest impact on the structure of plant communities was exerted by species considered to be invasive. Other alien species were sporadic and their cover was insignificant, so they did not pose a significant invasive potential on gravel bars (Table 1).

4. Discussion

The results show that gravel bars provide habitats for many different types of vegetation which are dynamically related. The vegetation of gravels in the Polish Carpathians were objects of some former research but results are often not comprehensive or out of date (Zarzycki 1956; Kornaś & Medwecka-Kornaś 1967; Grodzińska 1979; Dubiel *et al.* 1999) or were published in popular science magazines (Piękoś-Mirkowa & Mirek 1996; Koczur 1999). The vegetation in area of the Vistula and Brennica rivers is similar to the results of the above-mentioned research, but there are some differences between plant communities. For example, such typical gravel phytocoenoses as *Calamagrostis pseudophragmites-Festuca rubra* community and *Myricaria germanica* community were not identified by our research. In general, there is no complex and comprehensive research regarding gravel bars of all Western Carpathians.

Due to initial and open character, specific geomorphology and role in species migration, gravel bars constitute a suitable habitat for a lot of different species (Uziębło & Ciapała 2006). Many of these plants prefer dry and periodically disturbed environment which is typical for gravel bars (Yoshikawa *et al.* 2013). The analysis of the flora of studied communities showed that 15% of all species were alien plants. 22 plants occurring in the studied area were considered to be at least locally invasive (Tokarska-Guzik *et al.* 2012). The most

common invasive species that were identified included: *Impatiens glandulifera*, *Heracleum mantegazzianum* and *Reynoutria japonica* and they were the most dangerous for natural phytocoenoses of gravel bars. Studies concerning anthrophytes in riparian habitats of another part of the Polish Carpathians – the Babia Góra Massif (Uziębło & Skowronek 2008), indicated that *Impatiens glandulifera*, *I. parviflora* and *Reynoutria japonica* were the most common invasive species too, but *Heracleum mantegazzianum* was not reported at all.

Three of the most invasive species of Vistula and Brennica gravel bars – *Impatiens glandulifera*, *Reynoutria japonica*, *Heracleum mantegazzianum* have an advantage in competition with native species because of their ecology. For all of these species, phytotoxicity was confirmed (Moravcová *et al.* 2011; Vrchotová *et al.* 2011; Balezentiene & Renco 2014). The above-mentioned species are also highly competitive because of their large sizes. *Impatiens glandulifera* is considered to be the tallest annual herb in Europe (Hejda & Pyšek 2006) and *Hercleum mantegazzianum* – the tallest European forb (Nehrbass *et al.* 2006). In addition, alien species could also be highly competitive to native plants with respect to pollination services. *Impatiens glandulifera* attracting pollinators by massive nectar production can be given as a good example (Chittka & Schürkens 2001). *Heracleum mantegazzianum*, because of its phototoxic effects, is also dangerous for humans (Balezentiene & Renco 2014) and should be removed (Śliwiński & Anioł-Kwiatkowska 2011). It poses a considerable threat to tourists who are often sunbathing in the Vistula banks.

Gravel bars are unique places for nature. In addition, native species considered to be diagnostic for ruderal vegetation (classes: *Artemisietea* and *Stellarietea*) were naturally occurring on gravel bars, where the level of disturbance could be similar to anthropogenic habitats (Kamycka 2013). Gravel bars are also places with high occurrence of alien and invasive species. It is important, however, that patches with a big share of invasive species are still species-rich. It suggests that the impact of invaders is not as big as in other natural habitats. Similar conclusion was reached in studies of the impact of *Impatiens glandulifera* on riparian habitats (Hejda & Pyšek 2006).

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