THE IMPORTANCE OF LAND USE TYPE IN *FALLOPIA (REYNOUTRIA) JAPONICA* INVASION IN THE SUBURBAN ENVIRONMENT

ABSTRACT: In total 273 stands of the invasive species *Fallopia (Reynoutria) japonica* in Oświęcim valley (southern Poland) were examined, in terms of cover, area, abundance, height and width of shoots, and presence of coexisting species. *F. japonica* occurred more frequently in wastelands and was the rarest in forests. Statistical analyses revealed some significant differences among habitats with particular traits. The most abundant populations, occupying the largest area, were recorded in wetlands and along railway lines. Populations were very diverse in terms of their percentage of flowering shoots within a particular type of habitat, however, the highest percentage was again observed in wetlands and along railways. In forests, gardens and in wastelands the contribution of flowering shoots was lower. The presence of accompanying species in the studied populations was generally low, most frequently stands of *F. japonica* were mono-specific with a slightly higher cover of accompanying species being recorded in *F. japonica* populations in forests. The plant is a rhizomatous dioecious perennial (geophyte) native to Japan, Korea and Taiwan. In its native range it grows in sunny places on hills, high mountains, road verges and ditches, river gravels and managed pastures on a wide range of soils from sea level to 2400 m a.s.l. Reproduction is mainly vegetative from rhizome fragments, but out-crossed wind-borne seed may also be important (Sheppard et al. 2006). The first record for Europe dates from 1823 when *Fallopia japonica* was introduced as an ornamental
plant. Later it was distributed by botanical gardens which offered seedlings of this plant (Tokarska-Guzik 2005). Since the 1820s it has spread exponentially throughout Europe and during the 1900s it started to occur commonly on disturbed areas, roadsides and river banks via accidental transport of rhizome fragments. In Europe Fallopia japonica, of at least var. japonica remains one female clone and produces no viable seed (Sheppard et al. 2006).

It is very hard to eradicate this species because a new plant can originate from a rhizome segment as small as 0.7 g (Brock and Wade 1992). Fallopia japonica is one of the tallest polycarpic perennial species. The stand-forming habit of this species produces a dense summer canopy beneath which few other species can survive. In addition, its rhizome system grows rampantly producing stem litter and the plants intensively remove the nutrients from the soil, thus taking over the ground from their competitors. All these together, result in an almost 100% inhibition of germination and growth in co-occurring species (Balogh 2008). In its secondary range this species grows in almost all man-made habitats, commonly along riverbanks and occasionally on the margins of, or in, open woodlands. It occurs also on waste ground, road verges and railways embankments, colliery waste tips (Woźniak 2010), quarries and more scarcely in agriculture habitats (Beerling et al. 1994). Invasion by F. japonica is likely to seriously affect the diversity of animals and reduce the quality of riparian ecosystems for amphibians, reptiles, birds and mammals whose diets are largely composed of arthropods (Koutika et al. 2011). These risks are perceived not just by environmentalists, but also form priorities in strategic projects and activities undertaken at national and international scales (Tokarska-Guzik 2005, Hulme et al. 2009). At the same time, biological invasions can be considered to be a 'natural experiment' that allow the study of populations and evolutionary processes (Gammon et al. 2007). Invasive species can undergo evolution after colonisation and, moreover, hybridization (cross-breeding between species populations) can be a catalyst for the evolution of enhanced invasiveness (Ellstrand and Schierenbeck 2000).

Invasion success in this species is dependent on a set of plant traits which make it more invasive. However, little is known about the invasibility of the habitats which it occupies.

Apart from natural habitats and rural landscapes this species also invades urban and suburban areas. The main aim of this study was to find any patterns of habitat preferences and abundance of F. japonica and relate them to types of habitats which are to be found in the suburban environment.

Fig. 1. Comparison of number of Fallopia japonica stands between land use type in Oświęcim valley. Total number of stands – 273 per 279.4 km².
The study was carried out between late August and the beginning of September in 2009 and was repeated in 2010 and 2011 in the Oświęcim Valley and environs (Southern Poland) in the following towns: Andrychów 49°51’23”N, 19°20’33”E; Bielsko-Biała 49°49’19”N, 19°3’23”E; Oświęcim 50°2’2”N, 19°13’12”E; Pszczyna 49°59’19”N, 18°56’48”E; Skoczów 49°48’20”N, 18°47’33”E; Tychy 50°7’46”N, 19°1’12”E. The area covered by each of the towns studied varied between 9.9 km$^2$ to 125 km$^2$. The human population of each ranged from 14,700 to 175,000 inhabitants per town. The field survey aimed to collect data randomly in all types of habitats encountered and not to examine the distribution of the species within the borders of each town. The modified method of fieldwork followed a methodology for the monitoring of this species applied in the United Kingdom (Child and de Waal 1997). Due to the similarity of the hybrids between two taxa $F \times$ bohemica ($F.$ japonica $\times$ F. sachalensis) doubtful stands were omitted (Balogh 2008). In each stand of the species the following characteristics were recorded: area occupied by the plants; abundance of each population; mean height of plants in the patch; mean thickness of stems; percentage of flowering shoots; percentage cover of accompanying species within the stand. In the Table 1, scales for each variable are presented. Habitats were divided into 5 main types: forests (forest interiors, forest margins, felled areas), gardens (home gardens, allotments, parks), railways (railway track sides, railways embankments), wastelands (roadsides, dumps and deposits), wetlands (ponds, water courses). Such division of habitats is rather vague, however, from a floristic and a monitoring point of view it is very convenient. The habitat categories could be also defined as a result of land use type.

For a comparison of population characteristics between distinguished types statistical analyses were carried out using free software R (www.r-project.org). In order to test the significant differences of categorical (nominal) variables contingency tables (G test) with Bonferroni correction for multiple comparisons were used. Differences in ordinal scale and interval scale were analyzed by the Kruskal-Wallis test and when it gave a significant result then multiple comparisons were performed by post hoc Conover test.

In total 273 stands of Fallopia japonica were monitored and subjected to further analyses. The studied species stands were the most frequently recorded in wasteland and rarest in forest areas (Fig. 1). In the Table 1 results of statistical analyses are shown. Only in the case of percentage cover of accompanying species non-significant differences were revealed between land use type. Stands found in gardens were the least abundant and smallest in size of the Fallopia japonica patch, followed by forests. The most abundant populations which occupied the largest area were those recorded in wetlands and along railways (Figs 2 A, B). Populations were very varied in their abundance in terms of the percentage of flowering shoots present within stands of particular types of habitat, however, the highest percentage was observed in wetlands and along railways. In forests, gardens and in wastelands the contribution of flowering shoots was lower (Fig. 2 C). The percentage cover of accompanying species generally was low, most frequently patches of F. japonica were mono-specific stands, however, a slightly higher cover abundance of accompanying species was observed within forests (Fig. 2 D). The highest proportion of the tallest shoots
within a patch of *F. japonica* was identified in wetlands, the lowest in wastelands and along railways (Fig. 3 A). The thickest shoots were measured in forests as well as in wetlands and the thinnest in wastelands (Fig. 3 B).

The present study confirms that *F. japonica* occurs most frequently in habitats associated with transport routes. Observations published by Mandáč et al. (2004) at a country-wide scale in the Czech Republic revealed that this species was primarily encountered along roadsides (ca 40%), water courses and ponds (ca 25%). Forest (and forest margins) contributed about 10% of all localities. Other authors (Child and de Waal 1997) state that *F. japonica* occurs more frequently on land which has little or no management. The results presented in our paper are similar; however, habitats associated with railways are more often represented. The dense network of railways is specific for the studied region and it may influence the invasibility of this type of habitats. *F. japonica* occurs more frequently in southern Poland than in the northern part of the country (Tokarska-Guzik 2005). In this region there are more river valleys and montane landscapes. This species spreads in these habitats probably because they function as migration corridors. Any transformations of the environment caused by both natural factors (floods) and human-made factors (earthworks, river regulations) facilitate the spread of rhizomes (Pyšek and Prach 1993). This study also demonstrated differences in the chosen traits of the population characteristics between main groups of habitats. Some studies were devoted to seasonal dynamics of the growth of this species especially in terms of biomass, height and leaf area ratio (Horn 1997, Tokarska-Guzik et al. 2006, Beerling et al. 1994). It is known that above-ground biomass of knotweed is higher at open sites than shaded ones. Thus it can be assumed that biomass is correlated with some biometrical properties such as height and thickness of
plants as well as with number of shoots and area of dense stands of this species (*Fallopia japonica*). The only shaded habitats in this study were forests. In forests the area occupied by populations of this species are smaller and their abundance is lower. In gardens, parks and allotments *Fallopia japonica* was the least abundant, but these habitats are the only one where this species is usually under control (Fig. 2). The tallest plants were found in wetlands, forests and the shortest in wastelands and railways. This is a surprising result because these latter are open habitats, where usually the biomass of knotweed is higher (Beerling *et al.* 1994). The highest values for the thickness of shoots were recorded in forests. This result is indirectly congruent with studies where under shaded conditions *Fallopia japonica* had a higher leaf area ratio than in open sites (Beerling *et al.* 1994). It may be expected that other traits such as thickness of shoots, which are also photosynthetically active, could be higher. The highest proportion of flowering shoots in wetlands proves that the reproductive potential in this type of habitat is the largest, however, in its secondary range, *Fallopia japonica* sets seeds only where *F. sachalinensis* or the hybrid *F. × bohemica* are present in the vicinity. The median of percent cover of accompanying species was zero in all habitats except for forests. This is a consequence of Japanese knotweed forming mono-specific stands and excluding the native flora. In forests *F. japonica* probably is a weaker competitor due to unfavourable conditions and it is unable to exclude species with a higher competitive capacity. The question of which species are outcompeted is worthy of attention. Conflicting results can be found in the literature on invasion ecology concerning species richness and their role in the invasibility of habitats. On the one hand, high species richness in plant communities reduces the possibility of an invasion by alien species (biocoenotic resistance hypothesis – McGrady-Steed *et al.* 1997), on the other hand, these results confirm that communities poor in species are more resistant to invasion (Stohlgren *et al.* 1999). This has led researchers to formulate a concept that combines the success of the invasion not with the number of species but rather with the diversity of functional groups of plants. Further studies should focus on this problem.

Despite the simplistic monitoring nature of this study the data presented demonstrated that *Fallopia japonica* is more confined to some types of habitats and at these sites the species is more vigorous and forms larger stands occupying larger areas. This should be of concern to conservationists and land managers because the study showed that in man-made habitats this species finds favourable conditions for development and further spread. This is especially important since *Fallopia japonica* is known for its ability to reduce native biodiversity.

**ACKNOWLEDGMENTS:** Authors thank two anonymous reviewers for their valuable comments. Dr. Lynn Besenyei kindly improved language of our manuscript. This project no. NN 305384738 was financially supported by the Polish Ministry of Science and Higher Education.
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Received after revision February 2013