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INVASION PATHWAYS ALONG THE RIVERS IN SERBIA – THE EASTERN CORRIDOR OF *REYNOUTRIA* SPP.

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SUMMARY

Increasing levels of invasion worldwide have been the source of concern for scientists, due to significant costs and efforts required for managing them. The knowledge of invasion pathways, both those of initial introduction and subsequent spread, is of key importance, since further increase in the number of pathways and vectors of invasion is predicted for the 21st century. At regional scales habitat type has proven to be a reliable predictor of the level of invasion, as certain habitat types (i.e. frequently disturbed, under strong anthropogenic influence) is characterized by high invasion levels. Riparian habitats, as hotspots of alien species diversity and primary sources of their spread, represent some of the most important invasion corridors, where water acts as an effective dispersal mechanism. Some invasive plant species, like *Reynoutria* spp. show a strong tendency to invade riparian habitats. Preliminary findings of field surveys aimed to assess the level of riparian invasion by *Reynoutria* spp. in Serbia suggest that some river basins are significantly affected by the presence of these invasive species. Bearing in mind the principal means of their propagation, further spread of *Reynoutria* spp. along the rivers in Serbia is to be expected over the following years.

Key words: Invasion, invasion pathways, rivers, riparian habitats, *Reynoutria* spp.

INTRODUCTION

Concepts and definitions of invasion

Over the course of the last two centuries the level of anthropogenic introduction of alien species has increased, raising significant concerns worldwide (Pienimäki and Leppäkoski, 2004). Invasions as phenomena are often seen as a cause of great distress for agriculturists, conservation biologists and natural resource managers (Brown and Sax, 2004), as significant amounts of money and effort are needed to manage them (Vilà et al., 2010). Therefore, the issue of invasive species compiles biological, as well as social and ethical problems (Larson, 2007). When potential implications of biological invasions are observed, the importance of providing clear and objective definitions and models for managers and people in charge of native biodiversity protection becomes paramount (Colautti and MacIsaac, 2004).

The criteria defining the concept of invasive species are very disparate in available scientific literature, as many terms relevant to the field of invasion ecology (e.g. invasive, weed, noxious) represent qualities which are subjective and open to interpretation (see Richardson et al., 2000 and Colautti and MacIsaac, 2004 for examples). Due to subjectivity some species may be considered invasive in areas where they exhibit minimum impact, simply because they have been defined as such elsewhere.

The different terms used in invasion ecology are a result of human perception solely, rather than some real inherent ecological characteristics, thus confounding and complicating research of processes and patterns of invasion. Another problem with definitions is that many terms commonly used in invasion literature (e.g. adventive, alien, exotic) are used interchangeably, in defining the same concept, or inconsistently, in describing dissimilar phenomena. The variability of definitions has the potential to cloud theoretical issues (Colautti and MacIsaac, 2004) and impede further spread of scientific ideas and research efficiency (Colautti and Richardson, 2009). As a result of this, many authors demand greater objectivity in invasion biology (Brown and Sax, 2004, 2005; Colautti and MacIsaac, 2004; Colautti and Richardson, 2009).

The greatest level of ambiguity surrounds the term 'invasive', with a vast array of definitions existing in the literature (Richardson et al., 2000; Colautti and MacIsaac, 2004; Hulme et al., 2013). While Richardson et al. (2000) promote the biogeographical approach in defining terms like 'invasive', 'naturalized' and 'established' to reduce the existing confusion, Colautti and MacIsaac (2004) postulate that any proposal for a unified set of definitions is unlikely to succeed, unless the authors are willing to "forego their individual preferences", thus concluding that a successful invasion framework needs to be process-based and incorporate operational terms without any *a priori* meaning.

Richardson et al. (2000) in their paper propose a comprehensive model which describes invasion as a process in which nonindigenous species (NIS) pass through a series of invasion barriers. It is a model designed specifically for plant invasions. Building upon their model Colautti and MacIsaac (2004) have developed a framework, focusing on the stages of invasion, which further highlights the fact that invasions are in fact biogeographical, and not taxonomical, phenomena (Colautti and MacIsaac, 2004), which overlaps with Richardson et al. (2000) approach.

The problem with the overlapping and often interchangeable use of the terms 'invasive' and 'weed' has been a subject of many debates, and a number of authors have tried to make a clear distinction between these two terms (Ghersa, 2007). Rejmánek (2000) has made a distinction between weeds and invasive plants, by viewing weeds from an anthropomorphic perspective where weeds are "plants growing where they are not desired", and invasive plants from a biogeographical standpoint as "plants that have become locally established and spread to areas where they are not native". Ghersa (2009) points out that the main problem is that the term 'weed' has often been used with an anthropogenic connotation, providing very little insight into their biology, distribution and management practices.

In order to avoid ambiguity in scientific papers dealing with the term 'invasive species', Richardson et al. (2000) recommend the use of this term when describing "naturalized plants that produce reproducitve offspring, often in very large numbers, at considerable distances from parent plants, and thus have the potential to spread over a considerable area", and define weeds as "plants (not necessarily alien) that grow in sites where they are not wanted and which usually have detectable economic and environmental effects". For further definitions on terms 'alien', 'casual aliens', 'naturalized' and 'transformers' refer to Richardson et al. (2000).

Hulme et al. (2013) also include the connotations of impact in their definition of invasive species, saying that the term 'invasive' refers to "established alien organisms that are rapidly extending their range in the new region, usually causing significant harm to biological diversity, ecosystem functioning, socio-economic values, and/or human health in invaded regions".

INVASION PATHWAYS

Ricciardi and MacIsaac (2000) define invasion pathways as transportation pathways which enable long-distance dispersal of species towards specific regions. Terrestrial invasion corridors include important traffic routes (Ricciardi and MacIsaac, 2000), road verges, railway networks, rivers and ditches, where human factor is the main dispersal mechanism (Pyšek and Prach, 1994), while ballast waters are the most important dispersal mechanism of aquatic invasions.

Invasion corridors are affected by the intensity of vector traffic, and environmental conditions of both donor and recipient regions. It is necessary to identify corridors of invasion, linking donor and recipient regions, so that they can be incorporated into predictive models, as mass invasions may be a result of an intense propagule pressure of one or more invasion corridors into recipient systems (Ricciardi and MacIsaac, 2000).

The species' capacity for invasion is a result of a match between the species' ecophysiology and the environmental conditions of the area of its introduction, therefore enabling any given species to become invasive, at the right time and place, often with irreversible consequences (Pienimäki and Leppäkoski, 2004).

Studies mostly focus on recording pathways of initial introductions of NIS into a specific region, and rarely deal with their subsequent spread (Hulme et al., 2008). In order to develop preventive measures (e.g. screening and early warning systems, interception programmes and import regulations), the initial introduction is of key importance (Hulme, 2006). The spread of organisms through waterways can be a result of passive drifting, active dispersal or transport in ballast waters and on the hulls of ships (Galil et al., 2007), making it often difficult to distinguish the pathways of their initial introduction (Hulme et al., 2008).

Hulme et al. (2008) list three mechanisms as a result of which nonindigenous organisms may arrive into a new region: i) import of commodities, ii) arrival of transport vectors and iii) natural spread from neighbouring regions, where the species is also alien. Once introduced, alien species may spread further across the region as a result of natural dispersal. The rate of spread for terrestrial ecosystems is estimated to be 89 km/year (Pyšek and Hulme, 2005).

A dramatic increase in the number of vectors and pathways of invasion has been documented since the 19th century, from one (shipping) to five nowadays (shipping, fishing, aquaculture, accidental introduction and secondary spread, Karatayev et al., 2008). These authors predict a further increase in the number of vectors, during the 21st century, due to recreational activity, ornamental species and live food trade. Also, some of the potential vectors of NIS introductions are birds and semi-aquatic mammals, aquaculture, aquarium trade, fishing gear and unintentional release or escape of these species (Minchin and Gollasch, 2002). Estimating the risk of the introduction of NIS to aquatic environments is very difficult due to many factors which are uncertain and unknown. Nevertheless, the prospects are similar for most of the world's aquatic ecosystems – increase in the introduction of NIS, along with the intensification of their impact on native biodiversity (Pienimäki and Leppäkoski, 2004).

Transoceanic invasions

Plants, along with marine animals and other organisms have been transferred across the world's seas ever since the humans have started crossing them for exploration, colonization and trade. In contrast with the older transport vessels, which carried significant numbers of species on their hulls, nowadays most of the species are transported inside the vessels, in ballast waters (Carlton, 1999).

Ballast waters are waters taken intentionally by ships for greater stability, which are then carried in specifically dedicated ballast water tanks and empty cargo holds. Upon reaching their final destination the ships empty up to tens of thousands of tons of water to take up cargo (Carlton, 1999), leaving behind a number of various life stages of hundreds of plant and animal taxa (Carlton and Geller, 1993). In terms of transfer efficiency ballast waters have few, if any, parallels among transport mechanisms on land or at sea (Carlton, 1999), and represent major vectors of aquatic invasions worldwide (Carlton and Geller, 1993).

To predict potential invaders and in mapping hotspot areas for alien introductions, the origin of the ballast water and the route of the ship are crucial (Pienimäki and Leppäkoski, 2004). There is one rather astonishing estimate which says that modern vessels may carry from 3000 up to 10.000 species in their ballast waters, globally, per day (Carlton, 1999).

Rivers and canals as invasion corridors

Chytrý et al. (2009) stated that habitat type is the most effective predictor of the level of invasion at the regional scale, as same habitats are generally either strongly and frequently or weakly and rarely invaded by alien plants (Chytrý et al., 2008). Research of Chytrý et al. (2008) showed that frequently disturbed, human-influenced habitats, such as arable land, trampled and ruderal areas, as well as coastal, litoral and riverine habitats record typically high invasion levels. The European map on the level of invasion by neophytes anticipates highest levels of invasion in agricultural regions of central and eastern Europe, including the lower Danube valley, and along rivers and irrigated agricultural regions of the sub-Mediterranean zone (Chytrý et al., 2009).

It is to be expected that river catchments represent diversity hotspots and some of the most important natural corridors (Figure 1), especially in temperate areas (Naiman et al., 1993; Naiman and Décamps, 1997; Burkart, 2001). Many invasive plant species also show a preference for riparian zones, primarily in the early stages of invasion (Pyšek and Prach, 1994).

The spread of invasive species usually starts along watercourses, and inland areas are subsequently invaded (Burkart, 2001). The vegetative propagule pressure in riparian corridors is especially high, as water flow and floodwaters transport both buoyant and non-buoyant propagules from a variety of habitats located within the watershed downstream (Barrat-Segretain, 1996; Johansson et al., 1996), thus representing an important introduction vector. Therefore riparian zones, along with urban areas, represent significant hotspots for alien species and potential sources of their further spread (Pyšek et al., 1998).

Central European riparian zones have been subjected to human impact since the Neolithic age (Burkart, 2001). Some riparian forests have been almost completely cleared, and flooding dynamics have been dramatically altered by the construction of dams, dikes and locks, causing these habitats to become highly endangered ecosystems (Burkart, 2001 and references therein). Forest industry emissions, agricultural runoff, as well as the discharge of nutrients and other chemical pollutants into inland waters threaten the biological integrity of these systems (Pienimäki and Leppäkoski, 2004), thereby increasing the chances of invasion. Also, flooding is an important factor in the invasion of riparian habitats, since long periods of high waters have the potential to reduce the rate of survival and establishment of perennial terrestrial plant species, leaving the affected sites open for colonization (Burkart, 2001).

Complex network of inland waters of Europe comprises more than 28.000 km and connects 37 countries in Europe and beyond. Construction of canals has brought about the transfer of species between regions, and this impact was most evident with canals which connected two or more previously isolated biogeographical areas. Rivers connected through canals across narrow strips of land practically eliminate naturally existing barriers for the dispersal of organisms, thereby enabling them to spread both naturally and as a result of human transport, thus making all navigable waterways important invasion corridors (Galil et al., 2007).

There are four important invasion corridors which can be highlighted across Europe: i) "northern corridor", the largest, linking Black, Azov and Caspian Seas with the Baltic and White Seas; ii) "central corridor" connecting the regions of Black and Baltic Sea, via Dnieper river; iii) "southern corridor" connecting rivers Danube and Rhine, through the Main river; iv) "western corridor" linking the Mediterranean Sea with the North Sea, via the river Rhone and the Rhine-Rhone Canal (Galil et al., 2007).

Studies have shown that vectors of invasion are usually directed from a more diverse region, to a poorer one (Karatayev et al., 2008), in this sense, the Suez Canal represents a nearly unidirectional route for the biota of the Red Sea and the Indo-Pacific region to cross into the Mediterranean. As a result of this more than 500 species originating from the Red Sea basin have become established as far westward as the Adriatic Sea (Galil, 2000).

Further interconnection of European rivers and canals has enabled the invasion of native species from the basins of the Caspian and Black Seas into the Baltic and North Sea (Galil et al., 2007). The importance of canal construction in the transfer of NIS of Ponto-Caspian origin is clear from the fact that first exotic aquatic invertebrates in Belarus appeared after first interbasin canals have been constructed (Karatayev et al., 2008). Also, invasions of the Rhine River followed the opening of the Rhine-Danube-Main Canal in 1992, as a result of linking of the River Rhine, and its tributaries in western Europe, to the Black Sea (Ricciardi and MacIsaac, 2000). As a result of rising global temperatures, the number of introduced Ponto-Caspian, sub-tropical and tropical species of vascular plants has increased lately in the areas of the northern hemisphere, arriving via the Black Sea-Baltic Sea corridor (e.g. *Lemna gibba* L., *Vallisneria spiralis* (Tiger), *Phragmites altissimus* (Benth.) and *Typha laxmannii* (Lepech.)) (Pienimäki and Leppäkoski, 2004).

REYNOUTRIA SPP. AS RIPARIAN INVADERS

Certain invasive species have been proven to show a strong affinity towards riparian zones, and their spread is aided by rivers in a considerable measure, as water flow is their main mechanism of dispersal (Pyšek and Prach, 1994).

Among the most problematic invasive species, infamous for their tendency to invade riparian habitats, are Japanese Knotweed *s.l.* species: *Reynoutria japonica* Houtt. (syn. *Fallopia japonica* (Houtt.) Ronse Decr.), *Reynoutria sachalinensis* (F. Schmidt) Nakai (syn. *Fallopia sachalinensis* (F. Schmidt) Ronse Decr.), and their hybrid *Reynoutria* x *bohemica* Chrtek & Chrtková (syn. *Fallopia* x *bohemica* (Chrtek & Chrtková) J.P. Bailey). *Reynoutria japonica* has been categorized as one of the worlds 100 worst invasive alien species by the Global Invasive Species Programme (Lowe et al., 2000), and a highly invasive species in Serbia (Lazarević et al., 2012). The issue of the invasion of *Reynoutria* species has been extensively researched over the past two decades in Europe (Pyšek and Prach, 1994; Bailey et al., 1996; Bailey and Conolly, 2000; Bímová et al., 2003; Bímová et al., 2004; Mandák et al., 2004; Mandák et al., 2005; Bailey et al., 2009), and in Serbia (Glavendekić, 2008; Širka et al., 2013).

The species of *Reynoutria* have been introduced to Europe from the Far East (Japan, Korea, Taiwan, northern China) for ornamental purposes (Figure 5), in the 19th century, and have since escaped cultivation and become highly problematic across the continent. They show a distinctive competitive superiority over other ecologically similar native species, through a reduction in light availability and changes in soil environment (Pyšek and Prach, 1994; Barney et al., 2006) and can have detrimental effects on native riparian communities (Barney et al., 2006), (Figure 2).

Over the course of the summer/autumn period of 2013 an extensive field survey was conducted along the watercourses of Serbia. The survey was conducted to assess the level of plant invasion of these riparian areas and to determine the most important riparian invasion corridors, with *Reynoutria* species in focus. The field survey was carried out along the 500 m stretches of riverbanks, at regular intervals, according to RHS (Raven et al., 1997) river stretches. A signifficant number of tributaries in the water basins of Zapadna Morava, Drina, Danube, Velika and Južna Morava rivers was included in the survey. The mapping was done using the method of GPS positioning with a GPS Garmin eTrex 10 handheld GPS navigator. The data gathered was then included in an Excel database, and subsequently georeferenced using DIVA-GIS software.

The areas studied was scattered along the watercourses of Serbia, making it difficult to give an universal description of the study area. The rivers of Serbia belong to the drainage basins of the Black, Adriatic and Aegean Sea, where the Black Sea drainage basin is the largest one, and covers an area of 92% of the territory of Serbia. Of the rivers whose tributaries are most affected by the presence of *Reynoutria* spp. stands, Zapadna Morava and Drina rivers stand out.

Zapadna Morava is a river in Central Serbia which stretches far westward into the Dinaric mountains, originating east of Požega, from the Golijska Moravica and Đetinja headstreams. Along its course it passes through a number of valleys and gorges (Ovčar-Kablar gorge). Its river valley is of great economical importance, having a significant hydroelectric and irrigation potential and due to the developed industry of the cities it flows through (Užice, Požega, Čačak, Kraljevo, Kruševac). This river also stands out by the number of tributaries it receives along its course (85), the most imortant being Čemernica, Kamenica, Dičina, Ribnica, Rasina and Ibar, which is the largest one.

Drina is an international river, forming in part the border between Serbia and Bosnia and Herzegovina. It is the longest tributary of Sava, and the richest one in terms of its average water discharge. It is a fast river, which has carved several gorges along its length, but becomes a meandering river in its lower course, spilling into many arms and flows and creating a large floodplain in the Mačva region.

Preliminary findings (Figure 3) show that the rivers from the basins of Zapadna Morava and Drina stand out by the level of *Reynoutria* spp. invasion. Zapadna Morava river in itself shows a very high level of invasion, especially in the territory of the city Čačak, while its tributaries show signs of further spread of invasive *Reynoutria* spp. upstream. On the other hand, in the Drina river basin, the invasion seems to be spreading downstream towards the confluence of the Štira river into Drina. Other findings mostly show signs of initial stages of *Reynoutria* spp. propagule pressure, with a high potential for its further spread in the upcoming years, portraying Serbian watercourses as a potential eastern corridor of *Reynoutria* spp. invasion.

Dense stands (Figure 4) of *Reynoutria japonica* generally occupy large areas in habitats strongly influenced by man (Beerling et al., 1994), mainly in riparian and ruderal habitats (Bailey et al., 2009). It is a fast growing, strongly competitive species, often found in nutrient rich habitats, forming stands with a very dense canopy, beneath which not many species can survive (Beerling et al., 1994). When compared with *Reynoutria japonica*, *R. sachalinensis* is a less successful invader, however an increase in the spread of vegetative fragments by water has also been recorded for this species in the last several decades (Pyšek and Prach, 1994).

As asexual reproduction is the primary means of reproduction and colonization for invasive *Reynoutria* species in their introduced range, through the dispersal of rhizome and stem fragments (Barney et al., 2006), riparian habitats are primarilly affected due to the fact that their rhizome and stem fragments are transported mainly by water flow (Beerling et al., 1994).

Figure 1. River Čemernica as a potential invasion corridor (orig.).
Slika 1. Reka Čemernica kao potencijalni koridor invazije.

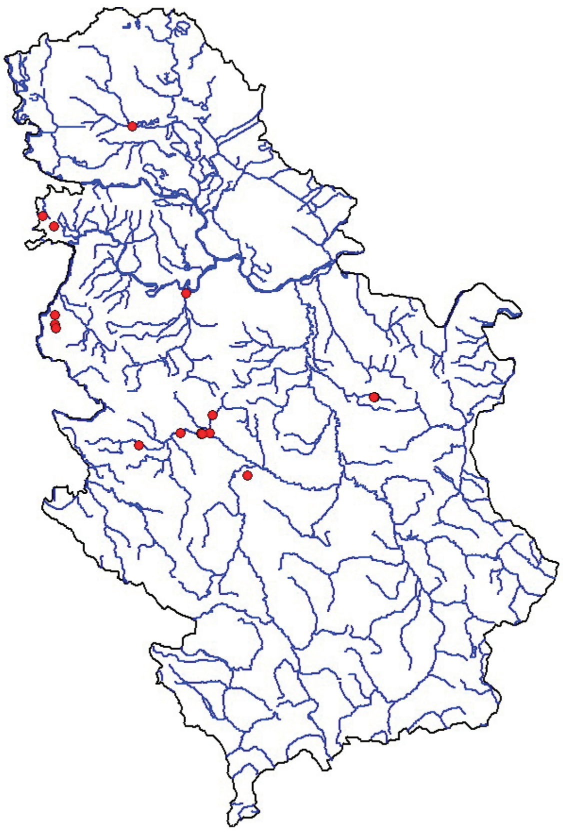

Figure 3. Potential corridors of *Reynoutria* spp. invasion in Serbia.
Slika 3. Potencijalni koridori invazije *Reynoutria* spp. u Srbiji.

Figure 2. *Reynoutria* spp. encroaching on river-bank's native vegetation (orig.).
Slika 2. *Reynoutria* spp. potiskuje nativnu vegetaciju rečne obale.

Figure 4. Large stand of *Reynoutria* spp. on the banks of Zapadna Morava (orig.).
Slika 4. Velika sastojina *Reynoutria* spp. na obali Zapadne Morave.

Figure 5. *Reynoutria* spp. inflorescence (orig.).
Slika 5. Cvast *Reynoutria* spp.

CONCLUSION

To successfully manage the invasive alien species problem, there is a need for preventive measures and the development of mechanisms which would minimise the risk of future introductions and attempt to reduce the uncertainty of existing risk assessments (Pienimäki and Leppäkoski, 2004).

A dramatically significant reduction of native species densities, and in certain cases almost complete removal of native species are two direct negative effects which invasive species may have on biodiversity. Even though their ecological role is often overlooked, their effects on ecosystems can be devastating (Karatayev et al., 2008). Even though Simberloff (2011) postulates that only a fraction of 10% of the total number of NIS have a noticeable effect on natural ecosystems, knowing that there are around 5789 naturalized alien plant species in Europe (Lambdon et al., 2008), the number of species potentially affecting natural ecosystems is still very significant (Hulme et al., 2013).

Since invasive species of the genus *Reynoutria* are known as some of the most troublesome alien invasive species in the world, and due to their well documented tendency to pose a serious threat to native biodiversity, especially in the riparian areas, *Reynoutria* spp. invasion should be a focal point of future invasive species research in Serbia. Up to this point, it has been documented that certain watercourses in our country show a significant level of Japanese Knotweed *s.l.* invasion, however only future results, along with the results of other researchers who have also been mapping the distribution of these species in Serbia will show us the magnitude of the *Reynoutria* spp. invasion. Since its dispersal is primarily linked with water flow, and its presence has already been confirmed in a number of river basins, further spread and intensification of its invasion are to be expected over the course of the years to come.

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REFERENCES

Bailey, J.P., Bímová, K., Mandák, B. (2009): Asexual spread versus sexual reproduction and evolution in Japanese Knotweed *s.l.* sets the stage for the “Battle of the Clones”. Biological Invasions, 11: 1189-1203.

Bailey, J.P., Child, L.E., Conolly, A.P. (1996): A survey of the distribution of *Fallopia x bohemica* (Chrtek et Chrtkova) J. Bailey (Polygonaceae) in the British Isles. Watsonia, 21: 187-198.

Bailey, J.P., Conolly, A.P. (2000): Prize winners to pariahs – a history of Japanese Knotweed s.l. (Polygonaceae) in the British Isles. Watsonia, 23: 93-110.

Barney, J.N., Tharayil, N., DiTommaso, A., Bhowmik, P.C. (2006): The Biology of invasive alien plants in Canada. 5. *Polygonum cuspidatum* Sieb. & Zucc. Š=*Fallopia japonica* (Houtt.) Ronse Decr.Ć. Canadian Journal of Plant Science, 86: 887-905.

Barrat-Segretain, M.H. (1996): Strategies of reproduction, dispersion, and competition in river plants: a review. Vegetatio, 123: 13–37.

Beerling, D.J., Bailey, J.P., Conolly, A.P. (1994): *Fallopia japonica* (Houtt.) Ronse Decraene. Journal of Ecology, 82: 959-979.

Bímová, K., Mandák, B., Pyšek, P. (2003): Experimental study of vegetative regeneration in four invasive *Reynoutria* taxa (Polygonaceae). Plant Ecology, 166: 1-11.

Bímová, K., Mandák, B., Kašparova, I. (2004): How does *Reynoutria* invasion fit the various theories of invasibility? Journal of Vegetation Science, 15: 495-504.

Brown, J. H., Sax, D. F. (2004): An Essay on Some Topics Concerning Invasive Species. Austral Ecology, 29: 530–536.

Brown, J. H., Sax, D. F. (2005): Biological invasions and scientific objectivity: Reply to Cassey et al. (2005). Austral Ecology, 30: 481–483.

Burkart, M. (2001): River corridor plants (Stromtalpflanzen) in Central European lowland: a review of a poorly understood plant distribution pattern. Global Ecology & Biogeography, 10: 449-468.

Carlton, J.T. (1999): The scale and ecological consequences of biological invasions in the world's oceans. In: Sandlund, O.T., Schei, P.J., Viken, Å. (eds) Invasive Species and Biodiversity Management. Kluwer Academic Publishers, Dordrecht, the Netherlands, pp 195–212.

Carlton, J.T., Geller, J.B. (1993): Ecological roulette: the global transport of nonindigenous marine organisms. Science, 261: 78–82.

Chytrý, M., Maskell, L. C., Pino, J., Pyšek, P., Vilà, M., Font, X., Smart, S. M. (2008): Habitat invasions by alien plants: a quantitative comparison among Mediterranean, subcontinental and oceanic regions of Europe. Journal of Applied Ecology, 45: 448–458.

Chytrý, M., Pyšek, P., Wild, J., Pino, J., Maskell, L. C., Vilà, M. (2009): European map of alien plant invasions based on the quantitative assessment across habitats. Diversity and Distributions, 15: 98–107.

Colautti, R. I., MacIsaac, H. J. (2004): A neutral terminology to define 'invasive' species. Diversity and Distributions, 10: 135–141.

Colautti, R.I., Rihardson, D.M. (2009): Subjectivity and flexibility in invasion terminology: too much of a good thing? Biological Invasions, 11: 1225-1229.

Galil, B.S. (2000): A sea under siege – alien species in the Mediterranean. Biological Invasions, 2:177–186.

Galil, B.S., Nehring, S., Panov, V.E. (2007): Waterways as invasion highways: impact of climate change and globalization. Biological Invasions (ed. W. Nentwig). Ecological Studies No. 193. Springer, Berlin, Germany. pp. 59–74

Ghersa, C. M. (2007): Weeds and Invasive Plants. Ecology of weeds and invasive plants: relationship to agriculture and natural resource management (ed. Radosevich, S. R., Holt, J. S., Ghersa, C. M.), John Wiley & Sons, Inc., Hoboken, New Jersey, pp. 3-33.

Glavendekić, M. (2008): *Reynoutria japonica* Houtt. i *Reynoutria* x *bohemica* u Srbiji. Šumarstvo, 1-2: 67-72.

Hulme, P.E. (2006): Beyond control: wider implications for the management of biological invasions. Journal of Applied Ecology, 43: 835–847.

Hulme, P. E. (2012): Weed risk assessment: a way forward or a waste of time? Journal of Applied Ecology, 49: 10–19.

Hulme, P. E., Bacher, S., Kenis, M., Klotz, S., Kühn, I., Minchin, D., Nentwig, W., Olenin, S., Panov, V., Pergl, J., Pyšek, P., Roques, A., Sol, D., Solarz, W. and Vilà, M. (2008): Grasping at the routes of biological invasions: a framework for integrating pathways into policy. Journal of Applied Ecology, 45: 403–414.

Hulme, P.E. Pyšek, P., Jarošík, V., Pergl, J., Schaffner, U., Vilà, M. (2013): Bias and error in understanding plant invasion impacts. Trends in Ecology & Evolution, 28: 212-218.

Johansson, M. E., Nilsson, C. and Nilsson, E. (1996): Do rivers function as corridors for plant dispersal? Journal of Vegetation Science, 7: 593–598.

Karatayev, A.Y., Mastitsky, S.E., Burlakova, L.E., Olenin, S. (2008): Past, current, and future of the central European corridor for aquatic invasions in Belarus. Biological Invasions, 10: 215-232.

Lambdon P.W., Pyšek P., Basnou C., Hejda M., Arianoutsou M., Essl F., Jarošík V., Pergl J., Winter M., Anastasiu P., Andriopoulos P., Bazos I., Brundu G., Celesti-Grapow L., Chassot P., Delipetrou P., Josefsson M., Kark S., Klotz S., KokkorisY., Kühn I., Marchante H., Perglová I., Pino J., Vilà M., Zikos A., Roy D., Hulme P. E. (2008): Alien flora of Europe: species diversity, temporal trends, geographical patterns and research needs. Preslia, 80: 101–149.

Larson, B.M.H. (2007): An alien approach to invasive species: objectivity and society in invasion biology. Biological Invasions, 9: 947-956.

Lazarević, P., Stojanović, V., Jelić, I., Perić, R., Krsteski, B., Ajtić, R., Sekulić, N., Branović, S., Sekulić, G., Bjedov, V. (2012): Preliminarni spisak invazivnih vrsta u Srbiji, sa opštim merama kontrole i suzbijanja kao potpora budućim zakonskim aktima. Zaštita prirode, 62: 5-31.

Lowe, S., Browne, M., Boudjelas, S., De Poorter, M. (2000): 100 of the World's Worst Invasive Alien Species A selection from the Global Invasive Species Database. Published by The Invasive Species Specialist Group (ISSG) a specialist group of the Species Survival Commission (SSC) of the World Conservation Union (IUCN), 12pp., available online at: www.issg.org/booklet.pdf

Mandák, B., Pyšek, P., Bímová, K. (2004): History of the invasion and distribution of *Reynoutria* taxa in the Czech Republic: a hybrid spreading faster than its parents. Preslia, 76: 15-64.

Mandák, B., Bímová, K., Pyšek, P., Štepanek, J., Plačkova, I. (2005): Isoenzime diversity in *Reynoutria* taxa: escape from sterility by hybridization. Plant Systematics and Evolution, 253: 219-230.

Minchin, D., Gollasch, S. (2002): Vectors – how exotics get around. In: Leppakoski, E., Gollasch, S. Olenin, S. (eds) Invasive Aquatic Species of Europe. Distribution, Impacts and Management, Kluwer Academic Publishers, Dordrecht, The Netherlands. pp 183–192.

Pienimäki, M., Leppäkoski, E. (2004): Invasion pressure on the Finnish Lake District: invasion corridors and barriers. Biological Invasions, 6: 331-346.

Pyšek, P., Hulme, P.E. (2005): Spatio-temporal dynamics of plant invasions: linking pattern to process. Ecoscience, 12: 302-315.

Pyšek, P., Prach, K. (1994): How important are rivers for supporting plant invasions? Ecology and management of invasive riverside plants (ed. de Waal, L.C. et al.), Wiley, Chichester, pp. 19–26.

Pyšek, P., Prach, K., Mandák, B. (1998): Invasions of alien plants into habitats of central European landscape: an historical pattern. Plant invasions. Ecological mechanisms and human responses (eds. Starfinger, U., Edwards, K., Kowarik, I., Williamson, M.), Backhuys, Leiden, pp. 23–32.

Raven, P.J., Fox, P., Everard, M., Holmes, N.T.H., Dawson, F.H. (1997): River habitat survey: a new system for classifying rivers according to their habitat quality. Freshwater Quality: Defining the Indefinable? (eds. Boon, P.J. and Howell, D.L.) The Stationery Office, Edinburgh. pp. 215–234.

Rejmánek, M. (2000): Invasive plants: approaches and predictions. Austral Ecology, 25: 497-506.

Ricciardi, A., MacIsaac, H.J. (2000): Recent mass invasion of the North American Great Lakes by Ponto-Caspian species. Trends in Ecology & Evolution, 15: 62-65.

Richardson, D. M., Pyšek, P., Rejmánek, M., Barbour, M. G., Panetta, F. D., West, C. J. (2000): Naturalization and invasion of alien plants: concepts and definitions. Diversity and Distributions, 6: 93–107.

Simberloff, D. (2011): How common are invasion-induced ecosystem impacts? Biological Invasions, 13: 1255-1268.

Širka, V.H., Lakušić, D., Šinžar-Sekulić, J., Nikolić, T., Jovanović, S. (2013): *Reynoutria sachalinensis*: a new invasive species to the flora of Serbia and its distribution in SE Europe. Botanica Serbica, 37: 105-112.

Vilà, M., Basnou, C., Pyšek, P., Josefsson, M., Genovesi, P., Gollasch, S., Nentwig, W., Olenin, S., Roques, A., Roy, D., Hulme, P.E., DAISIE partners (2010): How well do we understand the impacts of alien species on ecosystem services? A pan-European, cross-taxa assessment. Frontiers in Ecology and the Environment, 8: 135-144.

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REKE SRBIJE KAO PUTEVI INVAZIJE – ISTOČNI KORIDOR INVAZIJE *REYNOUTRIA* SPP.

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REZIME

Stepen invazija koji je u porastu širom sveta zabrinjava naučnike, zbog značajnih troškova i napora koji su neophodni u njihovom kontrolisanju. Poznavanje puteva invazije, kako početnog unosa tako i naknadnog širenja vrsta, od ključnog je značaja, jer je u 21. veku prognoziran dalji porast broja puteva i vektora invazije. Na regionalnom nivou tip staništa se pokazao kao pouzdani pokazatelj nivoa invazije, jer određene tipove staništa (često remećena, pod snažnim antropogenim uticajem) karakteriše visok nivo invazije. Riparijalna staništa, kao centri diverziteta alohtonih vrsta i primarni izvor njihovog širenja, predstavlja-ju neke od najznačajnijih koridora invazije, u kojima voda deluje kao uspešan mehanizam disperzije. Neke invazivne vrste biljaka, poput *Reynoutria* spp. pokazuju snažnu tendenciju ka invaziji riparijalnih staništa. Preliminarni rezultati terenskih istraživanja koji su za cilj imali procenu nivoa invazije riparijalnih staništa vrstama roda *Reynoutria* u Srbiji ukazuju na to da su slivovi nekih reka pod značajnim uticajem prisustva ovih invazivnih vrsta. Imajući u vidu osnovni vid njihove propagacije, dalje širenje *Reynoutria* spp. duž reka u Srbiji može se očekivati tokom narednih godina.

Ključne reči: Invazija, putevi invazije, reke, riparijalna staništa, *Reynoutria* spp.

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