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Riparian areas as invasion corridors of *Xanthium strumarium* in Serbia

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SUMMARY

Xanthium strumarium L., also known as common cocklebur, is a potentially invasive weed species in Serbia. It is one of the most competitive weeds, strongly affecting the yield of some crops, such as maize, soybean, sunflower, sugar beet, etc. Since watercourses act as important transportation routes for the long-distance dispersal of weeds and the fruit of *X. strumarium* is easily dispersed by water, our aim was to analyse the degree of *X. strumarium* invasion in riparian areas of Serbia and examine the role of rivers and canals as its potential invasion corridors. The field research was carried out during the summer months of 2013, 2014, and 2015, along the course of 35 rivers and five major canals of the Danube-Tisa-Danube Hydrosystem (HSDTD) in Serbia. Fieldwork was conducted along 100 m long transects of 500 m long river stretches (chosen following the RHS methodology), where the invasive alien weed species presence and abundance were recorded. Over the period of three years, the presence of *X. strumarium* was recorded along the course of 33 rivers (94.25%), while it was documented along 66.85% of the total number of river stretches. However, along the canals, it was recorded in only 12% of the localities. The data on the distribution of *X. strumarium* expand the existing knowledge on the distribution of this economically harmful weed species in our country, while at the same time highlighting riparian areas of rivers as potentially important corridors of its spread.

Key words: *Xanthium strumarium* L., invasion corridors, rivers, canals, Serbia

INTRODUCTION

Xanthium strumarium L. (syn. *Xanthium italicum Moretti, Xanthium strumarium ssp. italicum* (Moretti) D. Löve), also known as common cocklebur, a member of the Asteraceae family, is a 20-120 (150) cm tall annual herb. It falls into the therophyte (T) life form, with a tap root, and stems which are often covered with purple or light-brown stripes and spots, erect, ridged and of a rough-hairy texture. Its cotyledons are long and narrow, 6.0-7.5 mm in length, the leaves simple, opposite, ovate in shape and with lobed margins, pubescent on both surfaces. The flowers of *X. strumarium* are small, green and unisexual, organized in heads positioned at the ends of the branches and the main stem. It is a wind pollinated plant, which flowers from July to August. The fruit is a bur (Figure 1), 10-15 mm x 5-10 mm in size, ellipsoid in shape, green to grey-green in colour, containing two achenes, covered with spines, pubescent, with two stout, incurved thorns at the apex ("beaks"), often of a different length. This type of fruit is adapted to epizoochory, but its buoyancy makes it also well-adapted to hydrochory (Weaver and Lechowicz, 1982; Nikolić et al., 2014; Mueller-Bieniek et al., 2015; Vrbničanin, 2015).

X. strumarium is considered to be one of the most economically important weeds of soybean (*Glycine max* (L.) Merr.), cotton (*Gossypium hirsutum* L.) and peanut (*Arachis hypogaea L.*) worldwide (Haroun, 2015), but it is also highly problematic in maize *(Zea mays* L., Karimmojeni et al., 2010) and other crop fields at the stages of crop emergence and early growth (Vrbničanin, 2015). Its infestations in soybean have been shown to cause major yield reductions, of up to 80% (Bloomberg et al., 1982). Moreover, it is considered to be the most competitive annual weed in soybean in North America (Klingaman and Oliver, 1994), which is extremely difficult to control, due to its emergence and seedling characteristics (Buhler et al., 1993).

Figure 1: Fruit (bur) of *Xanthium strumarium* (orig.)

Species of the genus *Xanthium* are cosmopolitan, generally found on disturbed sites and along the waterways (Mueller-Bieniek et al., 2015), with both X. strumarium and *Xanthium spinosum* L. listed as invasive in Serbia (Lazarević et al., 2012). *X. strumarium* is a highly variable species, both within and between different populations (DiTomaso and Healy, 2007), with its phenotypic plasticity being caused by varying environmental factors (Baldoni et al., 2000). Consequently, numerous biotypes were named as separate species, subspecies and varieties in the past, leading to a long-standing taxonomic confusion (DiTomaso and Healy, 2007). In Serbia, *X. strumarim* is considered to be an invasive alien plant species included in the Preliminary list of invasive species in Serbia (Lazarević et al., 2012), the Invasive alien species of Vojvodina database - IASV (IASV, 2011) and the most recent monograph on invasive weeds of Serbia (Vrbničanin, 2015).

Aquatic freshwater habitats are generally considered to be particularly susceptible to biological invasions (Coetzee et al., 2009), while riverine riparian habitats have been shown to record high levels of invasion, due to frequent disturbances and human impacts (Chytrý et al., 2008). Furthemore, as the invasion of alien species generally begins along the watercourses, spreading into inland zones (Burkart, 2001), while rivers and canals provide important pathways for the rapid dispersal of their propagules (Lodge et al., 1998; Rahel and Olden, 2008). The aim of our research was to analyse the degree of *X. strumarium* invasion in riparian areas of Serbia and inspect the role of rivers and canals as its potential invasion corridors.

MATERIAL AND METHODS

Field research was carried out during the summer months of three consecutive years (2013, 2014, and 2015), along the course of 35 rivers and five major canals of the Danube-Tisa-Danube hydrosystem in Serbia. Fieldwork was performed along 100 m long transects of 500 m long river stretches, where the presence and abundance of invasive alien weed species were recorded.

The total number of 179 localities along the rivers (i.e. river stretches) and 28 along the canals were included in the analysis. The number and position of the river stretches on which the field studies were carried out was determined following the RHS (River Habitats Survey) methodology (Raven et al., 1997), with distances between the river stretches being between 2 and 10 km, depending on the total length of the watercourse. The aim of the field surveys was to ascertain the level of plant invasions within the riparian areas of these watercourses and to determine which riparian areas are the most important invasion corridors of alien plant invaders, in this instance *X. strumarium.*

Mapping of the *X. strumarium* presence was done by the GPS positioning method, using a handheld GPS navigator Garmin eTrex 10. Distribution data was subsequently incorporated in an Excel database, and distribution maps based on the recorded geographic data were produced in the UTM (Universal Transverse Mercator) projection, using free DIVA-GIS 5.2 software (Hijmans et al., 2004).

RESULTS AND DISCUSSION

On the European scale, *X. strumarium* has been included in the list of 150 most widespread European alien plant species (Lambdon et al., 2008). Its presence was recorded in the total of 43 European regions (Lambdon et al., 2008) and it has also been listed among the 20 most common neophytes in Catalonia (Chytrý et al., 2008). The species has also been recorded as invasive in the territory of the neighbouring countries of Croatia (Boršić et al., 2008; Nikolić et al., 2014), Montenegro (Stešević and Petrović, 2010; Stešević and Caković, 2013), Bulgaria (Petrova et al., 2013) and Romania, where it is considered to be one of the most agressive invasive aliens in wetland areas and also one of the invaders with a detrimental effect on natural ecosystems in the protected wetland area of the Danube Delta (Anastasiu et al., 2007).

Previous research (Vrbničanin et al., 2009) dealing with the distribution of *X. strumarium* in Serbia has reported that this weed species is present more or less across the entire territory of our country. Furthermore, this invasive species was not documented exclusively in agricultural areas, but also on ruderal habitats (Vrbničanin et al., 2009). The results of our extensive field surveys in riparian zones have shown a similar pattern of distribution (Figure 2) to that recorded by Vrbničanin et al. (2009). The results show that the presence of *X. strumarium* was recorded along the course of 33 rivers, i.e. 94.25% of the total number of rivers studied, with rivers Krivaja (Vojvodina Province, Bačka region) and Štira (Western Serbia, Mačva region) being the only ones where this invasive species was not documented (Figure 3). Such a high presence along the rivers in Republic of Serbia, concurs with the findings of Anastasiu et al. (2007) in neighboring Romania, which shows that, even though *X. strumarium* is distributed across the entire country, it most frequently forms monodominant stands along the riparian habitats and alluvial zones of rivers.

When analysing its presence along the rivers in different regions of our country (Figure 4), it is evident that *X. strumarium* was most often documented along the rivers in the wider area of the capital – recorded along the course of all three rivers (Sava, Danube and Kolubara) and in all of the field sites (total 10). This finding was not unexpected, given that Jovanović et al. (2014) have previously proven, while analysing the changes in the flora of Belgrade over the last 150 years, that *X. strumarium*

is one of the neophytes which had inhabited the modified wetlands along the regulated banks of the rivers Sava and Danube over the last 60 years, during the period of intensive urbanisation processes.

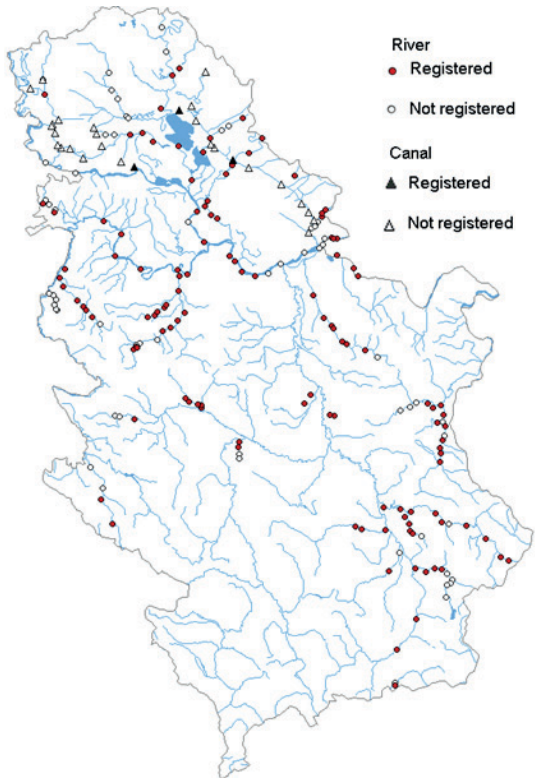

Figure 2: Distribution map of *Xanthium strumarium* in riparian areas of Serbia (orig.)

Similar results have been documented for the rivers in the region of Southeastern Serbia, where the presence of *X. strumarium* was recorded along the course of all of the rivers included in the field surveys (12 in total, Figures 3 and 4), i.e. at 71.4% of field sites (45 out of the total number of 63 river stretches, Figure 4). This coincides with the results of Vrbničanin et al. (2009) which have shown that in the territory of Southern Serbia *X. strumarium* was mostly present along the larger river valleys. The regions of Vojvodina and Šumadija and Western Serbia portray a similar situation (Figure 4), with *X. strumarium* being present in 93% and 91.67% of rivers, respectively, with 67.35% of field sites being invaded in Šumadija and Western Serbia and 52.63% in Vojvodina Province.

Figure 3. Percentage of river stretches where *Xanthium strumarium* was recorded (expressed per each river)

The analysis of all of the river stretches has shown that *X. strumarium* is present in all of the localities along certain rivers in Vojvodina and Šumadija (e.g. rivers: Tamiš, Čemernica, Ub, Sava; Figure 3), concurring with previous results regarding its distribution (Vrbničanin et al., 2009), which have revealed that its abundance is the greatest in these two regions. This is also in line with the results regarding the riparian invasion corridors of *Fallopia sp.* (Anđelković et al., 2013), where river Čemernica was portrayed as a potentially important invasion corridor of alien plant species. However, along other watercourses, the degree of its presence has displayed strong variations, ranging between 25% and 90% of the localities along certain rivers (Figure 3). Similarly to the results of Oprea and Sârbu (2006), which have marked *X. strumarium* as one of the most frequent alien taxa on the banks of the Tisa river in Romania, recorded with a frequency of over 75% along the entire riverbed of the Romanian section of the river, in Serbia it was documented along 66.67% of its watercourse, with Kanjiža and Senta being the only two field sites with no records of its presence (Figures 2 and 3).

Of the total number of river stretches included in the field analysis (179), *X. strumarium* was recorded in 66.85%. Contrary to this, *X. strumarium* was recorded only along 12% of the analysed localities along the canals of the Danuba-Tisa-Danube hydrosystem in Vojvodina (along the course of the Novi Sad – Savino Selo and Banatska Palanka – Novi Bečej canals; results not shown). Such a situation is unexpected, as previous research (Vrbničanin et al., 2009) has revealed that its abundance is the greatest in the territory of Vojvodina province, and mostly in the intensively farmed agricultural areas, which are closely connected with the canal network of the Danube-Tisa-Danube hydrosystem. This is also in strong contrast with the results of Anđelković et al. (2016) which have highlighted the elaborate canal network of Vojvodina as one of the most important invasion corridors of aquatic alien plant species in Serbia.

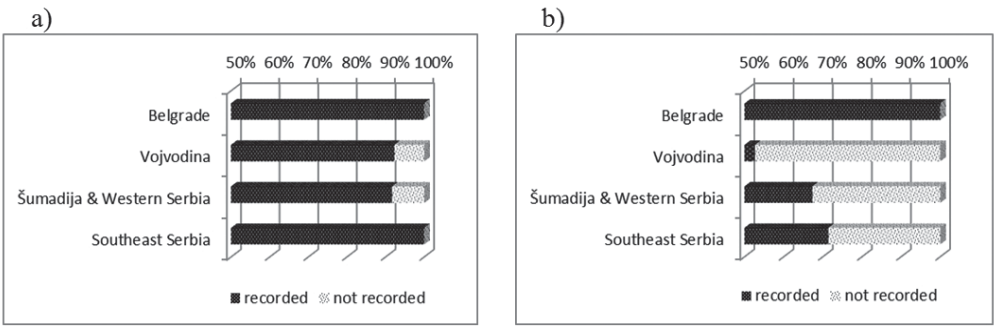

Figure 4. Regional overview of *Xanthium strumarium* invasion, expressed by the percent of a) rivers and b) river stretches where *X. strumarium* was recorded.

CONCLUSION

The results obtained through extensive three-year long period of field research has expanded the existing knowledge on the distribution of *X. strumarium* in Serbia. Its very high incidence which was documented along rivers has highlighted the riverine riparian zones as potentially important invasion corridors for this economically important weed species, concurring with the results from some of the neighbouring countries. However, the surprisingly low number of records of *X. strumarium* reported along the canal network of the Danube-Tisa-Danube hydrosystem, contrasting with some previous findings regarding their importance as corridors of invasion, presents a potentially interesting avenue for future research.

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Riparijalne oblasti kao koridori invazije *Xanthium strumarium* u Srbiji

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REZIME

Xanthium strumarium L., u narodu poznat kao obična ili zelena boca, je potencijalno invazivna korovska vrsta na području Srbije. Jedna je od najkompetitivnijih korovskih vrsta, koja jako utiče na prinos nekih kultura, kao što su kukuruz, soja, suncokret, repa, itd. Imajući u vidu činjenicu da vodotokovi predstavljaju značajne transportne puteve za disperziju korovskih vrsta na veće razdaljine, naš cilj je bio da analiziramo stepen invazije *X. strumarium* u riparijalnim područjima Srbije i ispitamo kakva je uloga reka i kanala kao njegovih potencijalnih koridora invazije. Terenska istraživanja obavljena su u periodu letnjih meseci 2013, 2014. i 2015. godine, duž toka 35 reka i pet glavnih kanala hidrosistema Dunav-Tisa-Dunav u Srbiji. Istraživanja su vršena na 100m dugim transektima u okviru 500 m dugih deonica rečnog toka (odabranih u skladu sa RHS metodologijom), gde su beleženi prisustvo i pokrovnost stranih invazivnih biljnih vrsta. Tokom trogodišnjeg perioda istraživanja, prisustvo *X. strumarium* zabeleženo je duž toka 33 reke (94,25%), a duž 66,85% od ukupnog broja rečnih deonica. Međutim, duž toka kanala, ova potencijalno invazivna vrsta registrovana je na samo 12% lokaliteta. Podaci o rasprostranjenju vrste *X. strumarium* proširuju postojeće znanje o rasprostranjenju ove ekonomski značajne korovske vrste u našoj zemlji, dok u isto vreme ističu riparijalne oblasti reka kao potencijalno značajne koridore njenog širenja.

Ključne reči: *Xanthium strumarium* L., koridori invazije, reke, kanali, Srbija