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Established stands of the highly invasive *Echinocystis lobata* on the Ramsar sites of the southern part of the Pannonian Plain

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ABSTRACT:
Monitoring the presence of invasive species in natural wetlands is crucial for numerous reasons, including their negative impact on biodiversity, conservation and the ecosystem services provided by these important fragile areas. The aim of this paper was to investigate the presence and distribution of the highly invasive liana *Echinocystis lobata* (wild cucumber), and to determine its coenological relations with the native plant species in the Ramsar sites of the southern part of the Pannonian Plain (the southeastern part of Central Europe, northern Serbia). We conducted the phytocenological research of the selected protected riparian areas in detail over a six-year period (2011–2015 and 2020). This study revealed the significant presence of the highly invasive species *E. lobata* in the studied sites. Wild cucumbers were found in 146 plots in four out of the seven investigated areas. Cluster analyses distinguished four groups of relevés dominated by *E. lobata*, which were described, and their dominant and constant species were identified. Habitat type identification was done, and the habitat preferences of *E. lobata* were determined. The spatial distribution of the four groups is such that they occur in a number of different habitat types or local communities. The species pool which makes up each of these four groups is thus geographically larger than the local community under study, so we can treat them as independently established and well-defined new community assemblages. Plant communities dominated by the invasive species *E. lobata* have not been described previously. Therefore, this work provides new data, and contributes to the further research and comparative analyses needed to describe invasive plant communities dominated by wild cucumber. In addition, the identification of habitat types which are most occupied by *E. lobata* is very important for managers of protected areas, as it allows them to better control and remove this highly invasive species, but also to prevent its further spread.

Keywords:
allochthonous climber, assembly, habitat type, Pannonian ecoregion, wetlands, wild cucumber

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INTRODUCTION

Regardless of the different approaches to defining the concept of biological invasions, the common denominator is the successful adaptation to the new environment and unhindered realization of the potential for spreading propagules over a large area (Richardson *et al.* 2000; Hejda *et al.* 2009; Hobbs *et al.* 2009; Pyšek & Richardson 2010; Vilá *et al.* 2011). This, in turn, can lead to the formation of so-called novel ecosystems (Hobbs *et al.* 2006, 2009).

As a result, invasive species are now ranked as the second greatest threat to autochthonous biodiversity

worldwide, just after the degradation of natural habitats (Wilson 1992; Brennan & Withgott 2005). The potential harm is even greater when natural habitats are rare, fragile and protected on a global scale, such as wetlands. Wetlands are fragile, and among the most endangered and valuable habitats in the world (Hu *et al.* 2017; Ramsar Convention on Wetlands 2018; Davidson *et al.* 2019).

Echinocystis lobata (Michx.) Torr. et Gray, commonly called the wild cucumber, is one of the 20 most dangerous weeds in Europe (Sheppard *et al.* 2006). It is an annual herbaceous climber plant from the family Cucurbitaceae. It spreads rapidly, by water, and its native range is the eastern part of North America (Nesom 1840; Silvertown 1985).

It is not known exactly how *E. lobata* arrived in Europe, but two pathways are suspected: either by accident (through the transport of cotton or wool) or intentionally (introduced as an ornamental plant) (Tokarska-Guzik 2005; Bagi & Böszörményi 2008; Nikolić *et al.* 2014). The first finding of *E. lobata* in Europe was recorded in 1904 in the Carpathian Basin (Romania), south of Braşov (Bagi & Böszörményi 2008). It was then recorded in Croatia in the middle of the 20th century (Devide 1956). In Serbia, the wild cucumber was first recorded in the north (Vojvodina) by Šajinović (1976), and in the vicinity of Belgrade (Gajić 1977). As a weed in crops, *E. lobata* was present only in a few places in Vojvodina in the 1970s (Ivković & Čapaković 1980), but now many populations have been established in Serbia and the species is thus defined as highly invasive (Vasić 2005; Čavlović *et al.* 2011; Rućando 2011; Lazarević *et al.* 2012; Stojanović *et al.* 2021). The wild cucumber is also classified as invasive in the neighbouring countries: Croatia (Boršić *et al.* 2008; Nikolić *et al.* 2014), Hungary (Botta-Dukát & Balogh 2008) and Bosnia and Herzegovina (Maslo 2016). It is naturalized in Central and Southeastern Europe (Tutin *et al.* 2001; Nikolić *et al.* 2014).

In areas where it is non-native, *E. lobata* behaves similarly as in its native range. It inhabits riparian habitats and floodplains. This liana is common in willow forests and shrubs, complex undisturbed riparian zones, in gardens and abandoned places (Gajić 1977; Rućando 2011; Zelnik *et al.* 2020) and is also found on roadsides and in crops. The species is treated as an agricultural weed in maize and soybean crops in its country of origin (Murphy *et al.* 2006; CABI 2019). It prefers nutrient-rich, moist, humus, alluvial or loam soils (Silvertown 1985; Bagi & Böszörményi 2008; Dylewski *et al.* 2018). Like other climbing plants, this species invests most of its energy in the production of additional leaves and reproduction. Its resistance to seed predators is high on the shores of inland surface waters (Kostrakiewicz-Gierałt *et al.* 2022), such as the investigated areas of this study site. Due to its adaptability and intense growth, it can suffocate other species, even trees up to the canopy (Silvertown 1985; Bagi & Böszörményi 2008; Dylewski *et al.* 2018). The wild cucumber is a strong competitor for light in *Salicion albae* R.Tx. and other plant communities (Kostrakiewicz-Gierałt *et al.* 2022). In habitats where it is invasive and forms large populations, *E. lobata* affects the structure of native vegetation, reducing the habitat biodiversity, and is therefore called a structural parasite (Bagi & Böszörményi 2008; Zelnik *et al.* 2020).

Considering that there are still no accurate data on the presence of the invasive *E. lobata* in the protected areas of the southern part of the Pannonian Plain, we aimed to investigate the occurrence and distribution of this invasive species, as well as its phytosociological relationships with the native plant species in the Ramsar sites of northern Serbia.

MATERIAL AND METHODS

Research area. We conducted the surveys on the territory of seven Special Nature Reserves (PZZP 2020): Ludaško Lake, Slano Kopovo, Stari Begej – Carska Bara, Koviljsko–Petrovaradinski Rit, Zasavica, Obedska Bara and Labudovo Okno, which are listed as Ramsar sites at the international level (Ramsar Convention Secretariat 2021) (Fig. 1). The reserves are located in the northern part of the Republic of Serbia, belonging administratively to the Autonomous Province of Vojvodina and geographically to the southern part of the Pannonian Plain.

The vegetation of Vojvodina is greatly changed nowadays. The anthropogenic influence, intensified in the late 19th and early 20th centuries, especially by the draining of wetlands, deforestation and the conversion of large areas into arable land, has led to the disappearance of primary vegetation. The primary, potential and preserved natural vegetation of Vojvodina is steppe and forest-steppe (Jovanović *et al.* 1986), with characteristic alliances *Festucion rupicolae* Soó 1940 and *Aceri tatarici-Quercion* Zólyomi et Jakucs 1957 (Stevanović *et al.* 1999). Nowadays, this vegetation is present only in fragments, mostly in protected natural areas (Jovanović *et al.* 1986; Stojanović *et al.* 1987). Within the researched areas, there is relatively preserved zonal, as well as typical azonal vegetation, presented by alliances *Populion albae* Br.-Bl. ex Tchou 1949, *Fraxino-Quercion roboris* Passarge 1968, *Salicion albae* Soó 1951 and *Rubo caesii-Amorphion fruticosae* Shevchyk et V. Solomakha in Shevchyk et al. 1996 (Mucina *et al.* 2016).

The studied Ramsar sites represent the remaining natural wetlands in Serbia, made up of complex habitats, wet-marsh landforms and the best-preserved remnants of floodplains (Seleši 2006; Puzović *et al.* 2014; Puzović & Panjković 2015).

Vegetation sampling and data analyses. We conducted the phytocenological survey of the selected protected riparian areas over a six-year period (2011–2015 and 2020).

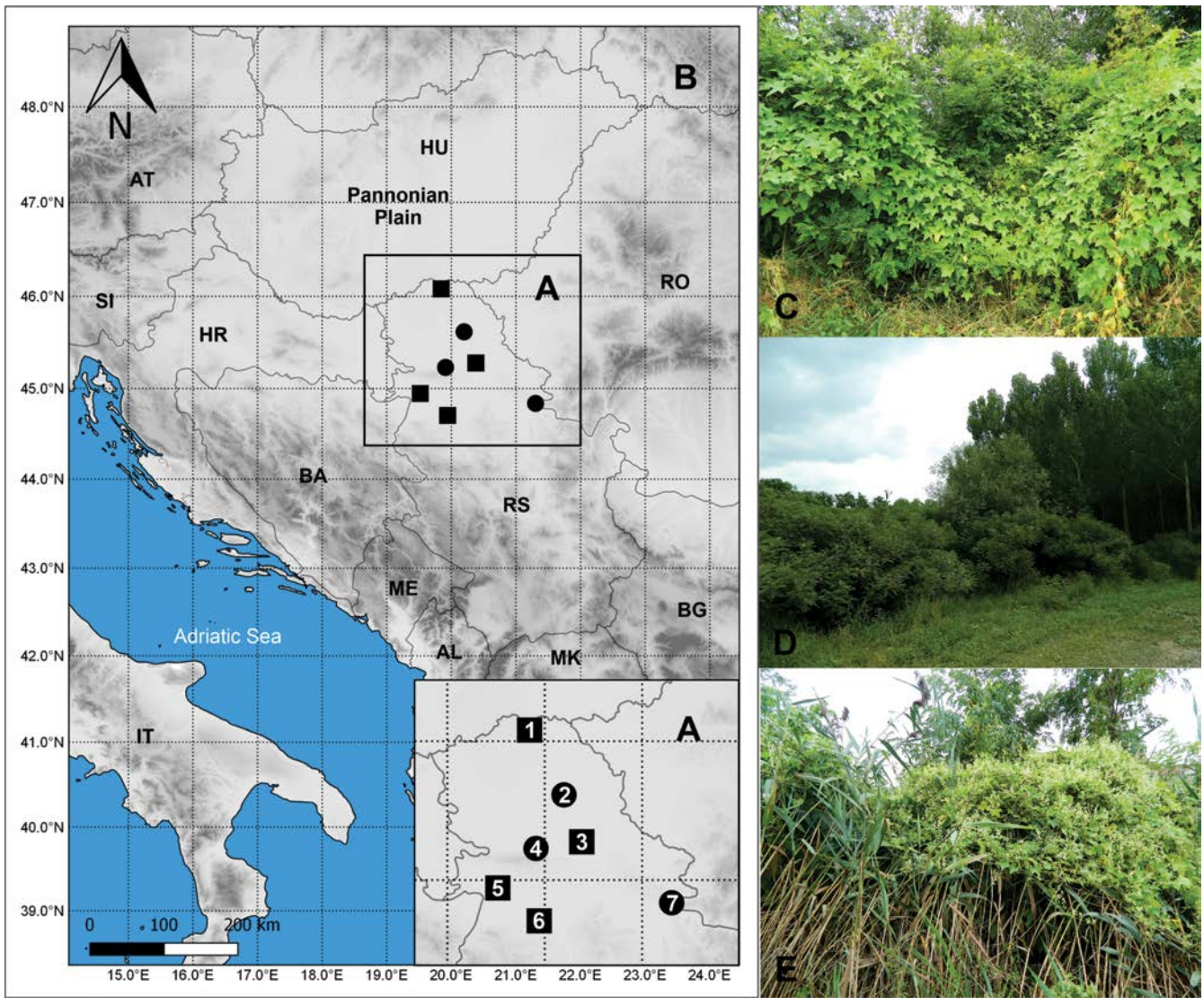

Fig. 1. A – Investigated Ramsar sites in northern Serbia and **B**: Pannonian Plain. Legend: 1. Ludaško Lake, 2. Slano Kopovo, 3. Stari Begej – Carska Bara, 4. Koviljsko–Petrovaradinski Rit, 5. Zasavica, 6. Obedska Bara and 7. Labudovo Okno. Map **B** – AL – Albania, AT – Austria, BA – Bosnia and Hercegovina, BG – Bulgaria, HR – Croatia, HU – Hungary, IT – Italy, ME – Montenegro, MK – North Macedonia, RO – Romania, SI – Slovenia, RS – Serbia, ■ – areas in which the presence of *E. lobata* is registered, ● – areas in which the presence of *E. lobata* is not registered; **C** – Zasavica – locality: Prekopac (photo: V. Stanković 2013); **D** – Obedska Bara – locality: Dužine (photo: V. Stanković 2015); and **E** – Ludaško Lake – locality: Kivago (photo: V. Stanković 2013)

The field sites were selected according to their natural values and level of protection (national and international), and with the aim of achieving uniform geographic coverage of the region. We determined the basic physical characteristics of the habitats (altitude, slope, exposition, soil types) using a GPS device and geological maps, and took digital photographs of the stands. The entire territory of each protected area was searched in detail for the presence of *E. lobata* in the field, and the relevés were made in each stand where its occurrence was observed. Such an approach gave us the opportunity to describe the habitat preference, identify the habitat types and study the differences between the habitats invaded by *E. lobata*.

We conducted the sampling of vegetation data according to the methodology of Braun–Blanquet (1964), using the cover-abundance scale and made a total of 146 phytocenological relevés. The size of the relevés corresponds to the minimum area recommended by Mueller–Dombois & Ellenberg (1974) and Chytrý & Otýpková (2003). We carried out field research during the flowering period of *E. lobata* from July to October. The plant nomenclature and taxonomy, with a few exceptions, followed the Flora Europaea Database (Tutin *et al.* 2001). The collected plant material was deposited in the Herbarium of the University of Belgrade – BEOU (Thiers 2021). All chorological data were georeferenced using the

GPS device (eTrexVistaC – Garmin). We prepared distribution maps using ArcGIS 10.8 software (ESRI 2020). The list of the georeferenced records of the phytocenological relevés and the identified habitat types using the EUNIS habitat classification (EUNIS 2017) are given in Supplementary Table 1. The names of the soil types are aligned with the official international list - the World Reference Base for Soil Resources (WRB) (Knežević 2011).

Following the transformation of Braun–Blanquet combined abundance and coverage values into numerical scores as proposed by Westhoff & van der Maarel (1973), cluster analysis was performed using Ward's method (Ward 1963). Multivariate analyses were done using PAST 2.17 (Hammer *et al.* 2001) and JUICE 7.0 (Tichý 2002) programme packages. Taxa identified at the genus level were excluded from the analyses.

We tested compact groups with representative relevés derived from the analyses for observed differences using SIMPER (Similarity Percentage) and ANOSIM (Analysis of Similarities) tests (Clarke 1993). Both analyses were performed in PAST 2.17 (Hammer *et al.* 2001).

The compact groups with the dominance of *E. lobata* revealed by the cluster analyses were given informal names after the dominant species for each group. We presented the dominant species with a coverage index (D%) (Surina 2004) greater than 5 to describe the phytocenological characteristics of the four cluster groups. Species with a frequency greater than 40% were considered constant. Species with a Φ (Phi) coefficient (fidelity index) (Chytrý *et al.* 2002) higher than 20 were also indicated. The number of all invasive neophytes (according to Pyšek *et al.* 2002 and Anačkov *et al.* 2013) per group, their percentage and the coverage index (D%) were calculated. We created the synoptic table using the following data: frequency (Fr) expressed as a percentage (%), fidelity index Φ (Phi) and constancy class based on the frequency of records (Cc).

RESULTS AND DISCUSSION

We found *E. lobata* in 146 plots in four of the seven Ramsar sites. The largest number of records were found in the Ramsar site of Zasavica (124), mainly alongside the watercourses. A total of 13 records were found in Obedska Bara, on the forest edges, followed by Ludaško Lake with eight records along the roadsides. Finally, there was one record in the Ramsar site of Stari Begej – Carska Bara, next to the footpath. Considering that the natural vegetation along the trail in Stari Begej – Carska Bara is largely destroyed, it is surprising that there is only one record of *E. lobata* (Supplementary Table 2). This confirms wild cucumber as a common invasive species, albeit with an uneven representation in the surveyed Ramsar sites.

A total of 239 taxa were recorded, of which 27 (11.30%) were invasive neophytes. The total coverage index of all the invasive taxa was D% = 28.54. This is a high percentage of invasive plant species considering that the studied areas are highly valuable and internationally protected. The cluster analyses showed that the relevés with the presence of *E. lobata* were divided into four coenological groups, recognized as established and well-defined community assemblages, labelled G1, G2, G3 and G4 (Fig. 2).

The overall average dissimilarity between the four groups obtained by SIMPER analysis was 81.73%, with high values of dissimilarity between pairs of groups (80.25–89.43%). The ANOSIM test based on the obtained p-values after Bonferroni correction showed statistically significant differences between the four groups of relevés, indicating that these coenological groups represent established and well-defined community assemblages (Table 1).

Table 1. Dissimilarities between the groups (G1–G4) obtained in the cluster analysis. SIMPER dissimilarity percentages are in the upper right hand corners, ANOSIM Bonferroni-corrected p values are in the lower left hand corners.

ANOSIM \ SIMPER	G1	G2	G3	G4
G1 *Echinocystis lobata-Amorpha fruticosa*	x	89.43%	80.25%	83.84%
G2 *Phragmites australis-Elymus repens*	0.0006	x	82.9%	85.55%
G3 *Echinocystis lobata-Humulus lupulus*	0.0006	0.0006	x	81.39%
G4 *Echinocystis lobata-Bidens frondosa*	0.0006	0.0006	0.0006	x

Table 2. The distribution of the community assemblages (G1–G4) within different habitat types (according to the EUNIS habitat classification)

Groups	G1	G2	G3	G4
C3.5 (Periodically inundated shores with pioneer and ephemeral vegetation)				+
S3-5 (Temperate and submediterranean thorn scrub)	+			
S9-2 (Temperate riparian scrub)	+	+	+	+
T1-1 (Temperate and boreal *Salix* and *Populus* riparian forest)	+			+
T1-2 (Riparian *Alnus* forest)	+		+	+
T1-3 (Temperate and boreal hardwood riparian forest)	+			
T1-9 (Temperate and submediterranean thermophilous deciduous forest)	+		+	
T1-E (*Carpinus* and *Quercus* mesic deciduous forest)	+		+	
T1-H (Broadleaved deciduous planted forests of non site-native trees)	+	+	+	
I1.5 (Bare tilled, fallow or recently abandoned arable land)	+		+	

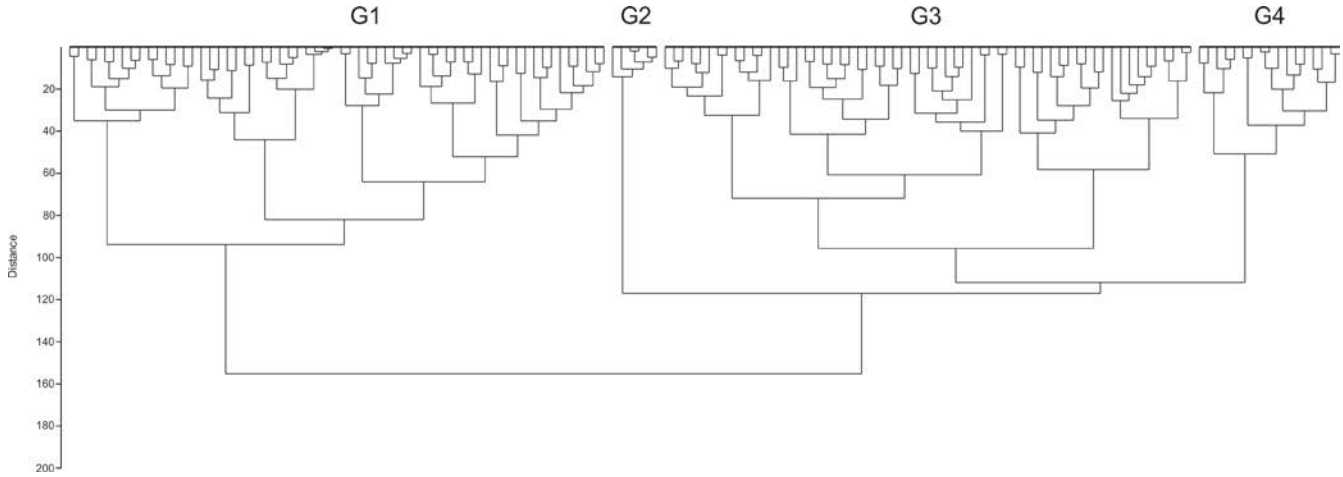

Fig. 2. The results of the cluster analysis (Ward's method, Euclidean distances), with identified four groups of relevés (groups G1-G4)

Cluster G1 (the *Echinocystis lobata-Amorpha fruticosa* group) consisted of 62 relevés in which 180 species were recorded. The dominant species (D% >5) were: *Amorpha fruticosa* (D% = 10.84), *Rubus caesius* (D% = 5.92) and *Echinocystis lobata* (D% = 5.76). The constant species (Fr% > 50) were: *Echinocystits lobata* (Fr% = 100), *Amorpha fruticosa* (Fr% = 84), *Rubus caesius* (Fr% = 81) and *Urtica dioica* (Fr% = 50). Species with a high fidelity index (Phi > 20) in this group were: *Amorpha fruticosa* (Phi = 62.9), *Aster lanceolatus* (Phi = 33.5) and *Populus euramericana* (Phi = 24.6) (Supplementary Table 2). Of the total number of recorded species, 22 were invasive neophytes (12.22%, D% = 30.89), while native and other non-indigenous species were more abundant (158 taxa - 87.78%, D% = 69.11).

Description: Stands of this coenological group developed at the sites of Zasavica and Obedska Bara, on flat terrain, with an altitude ranging from 73 m to 87 m a.s.l. (above sea level). Relevés were recorded in both natural and disturbed habitat types (according to the EUNIS habitat classification, Table 2): S3-5, S9-2, T1-1, T1-2, T1-3, T1-9, T1-E, T1-H and I1.5. The relevés had an average total cover of 94.84%. Stands were found in different soil types: Haplic Gleysol, Cuntanic Cambisol (Eutric) and Chernozem (Gleyic). The dominant invasive liana *E. lobata* mostly overgrows individuals of the species *A. fruticosa* in open places and on forest edges, but also inside forest habitats, where it climbs trees. This community assembly is well established and has already altered the autochthonous phytocoenosis. Despite being floristically rich, the stands of the G1 group appear to be dominated by two highly invasive species - *E. lobata* and *A. fruticosa*. This situation is known from previous research where both wild cucumber and false indigo, also known as transformer species (Török *et al.* 2003), occurred together and reached a high degree of naturalisation (Hulina 2010; Pedashenko *et al.* 2012; Kozuharova *et al.* 2017; Radovanović *et al.* 2017; Kostrakiewicz-Gierałt *et al.* 2022).

Cluster G2 (*Phragmites australis-Elymus repens* group) consisted of six relevés with 19 recorded species. The dominant species were: *Phragmites australis* (D% = 17.10), *Echinocystis lobata* (D% = 16.36), *Elymus repens* (D% = 14.87), *Sambucus nigra* (D% = 9.29), *Dactylis glomerata* (D% = 7.06), *Calystegia sepium* (D% = 6.69), and *Parthenocissus quinquefolia* (D% = 5.20). The constant species with a frequency higher than 50% were: *Calystegia sepium* (Fr% = 100), *Elymus repens* (Fr% = 100), *Echinocystis lobata* (Fr% = 100), *Phragmites australis* (Fr% = 100), *Dactylis glomerata* (Fr% = 83), *Sambucus nigra* (Fr% = 83), *Solanum dulcamara* (Fr% = 83), *Equisetum ramosissimum* (Fr% = 67), *Parthenocissus quinquefolia* (Fr% = 67), *Artemisia vulgaris* (Fr% = 50), *Lactuca serriola* (Fr% = 50), and *Tragopogon pratensis* (Fr% = 50). The following species had an index Fr >20: *Phragmites australis* (Phi = 86.2), *Elymus repens* (Phi = 66.2), *Sambucus nigra* (Phi = 48), *Dactylis glomerata* subsp. *glomerata* (Phi = 43.6), *Parthenocissus quinquefolia* (Phi = 41), *Equisetum ramosissimum* (Phi = 35.1), *Juglans regia* (Phi = 33.4), *Echinocystis lobata* (Phi = 33.2), *Calystegia sepium* (Phi = 25.2), and *Solanum dulcamara* (Phi = 22.5) (Supplementary Table 2). From the total number of recorded species, four were invasive neophytes (21.05%, D% = 24.16) and there were more native and other non-indigenous species (15 taxa - 78.95%, D% = 75.84).

Description: The stands of this community assembly were established on the site of Ludaško Lake. The elevations of all six relevés were 100 m a.s.l., with the exception of one (at 99 m a.s.l.) on flat terrain. The following habitat types were identified (Table 2): T1-H and S9-2. The total cover of all six phytocenological relevés was 100%. The pedological substrates consisted of Chernozem (Arenic) and Endosalic Mollic Gleysol (Calcaric, Arenic). The relevés from this group developed on the edges of forests,

in open areas. Wild cucumber overgrows *P. australis*, but the herb layer seems to be monodominant in *E. repens*. Since only six relevés formed the G2 group, a stable coenosis could not be discussed. This suggests that the natural habitats are threatened. Maćkowiak & Dylewski (2014) came to the same conclusion, where wild cucumber has the highest fidelity to *P. australis* (among other species) in the Grabarski Canal valley (Poland).

Cluster G3 (*Echinocystis lobata-Humulus lupulus* group) contained 61 phytocenological relevés with 170 recorded species. The dominant species (D% >5) were: *Echinocystis lobata* (D% = 9.49) and *Rubus caesius* (D% = 6.89). The constant species with Fr% >50 were: *Echinocystis lobata* (Fr% = 100), *Rubus caesius* (Fr% = 80), *Urtica dioica* (Fr% = 70), and *Humulus lupulus* (Fr% = 57). The species with a fidelity index higher than 20 were: *Urtica dioica* (Phi = 29.1), *Humulus lupulus* (Phi = 28.9), *Cruciata laevipes* (Phi = 23.7), *Solidago gigantea* subsp. *serotina* (Phi = 22.8), and *Rubus caesius* (Phi = 20.5) (Supplementary Table 2). There were 19 invasive neophytes recorded in this group (11.18%, D% = 26.36), while native and other non-indigenous species prevailed (151 taxa - 88.82%, D% = 73.64).

Description: The stands developed at the sites of Ludaško Lake, Stari Begej – Carska Bara and Zasavica were on flat terrain with an elevation ranging from 75 m to 100 m, within the following habitat types: S9-2, T1-1, T1-2, T1-9, T1-E and T1-H (Table 2). Only two relevés were made in disturbed habitat type I1.5. A total of 61 relevés had a cover ratio in the range of 80 to 100%. The stands in this group developed on Haplic Gleysol (Endosalic), Calcic Chernozem (Glossic), Chernozem (Arenic), Haplic Gleysol, Chernozem (Gleyic) and Cuntanic Cambisol (Eutric). This all indicates the great adaptability of the community assembly to different conditions. The dominant invasive climber *E. lobata* grows together with other highly invasive species *Robinia pseudoacacia* and *Ailanthus altissima*, but *Rubus caesius* stands out as the dominant species, particularly in the herbaceous layer. Wild cucumber usually overgrows other shrubs in open areas or climbs trees at the edges of forests. Although *E. lobata* coexists with *H. lupulus*, it is more dominant and the stands of this group appear to be monodominant, as they are overgrown and covered by the dominant invasive wild cucumber.

Cluster G4 (*Echinocystis lobata-Bidens frondosa* group) contained 17 relevés in which 93 species were recorded. Species with D% >5, defined as dominant, were: *Echinocystis lobata* (D% = 9.25) and *Bidens frondosa* (D% = 8.52). Species with Fr% >50, defined as constant, were: *Echinocystis lobata* (Fr% = 100), *Bidens frondosa* (Fr% = 88), *Lythrum salicaria* (Fr% = 59), and *Iris pseudacorus* (Fr% = 53). Species with Phi >20 were: *Bidens frondosa* (Phi = 52.8), *Lolium perenne* (Phi = 35.9), *Mentha aquatica* (Phi = 35), *Lythrum salicaria* (Phi = 31), *Echinochloa crus-galli* (Phi = 29.8), *Iris pseudacorus* (Phi = 26.8), *Melilotus officinalis* (Phi = 26.7), *Poa pratensis* (Phi = 26.1), *Setaria pumila* (Phi = 23.9), *Cyperus fuscus* (Phi = 22), and *Plantago major* (Phi = 20.1) (Supplementary Table 2). Of the total number of species recorded, 15 were invasive neophytes (16.13%, D% = 29.23), while the native and other non-native species consisted of 79 taxa (83.87%, D% = 70.77).

Description: The relevés of this group were recorded at the sites of Zasavica and Obedska Bara. All the sites were flat, with an average elevation of 76.76 m a.s.l. The stands of this group occupied different habitat types (Table 2), on the wettest areas: C3.5, S9-2, T1-1 and T1-2. The average total cover for all 17 relevés was 94.71%. The relevés in this group develop on Haplic Gleysol, Cuntanic Cambisol (Rutric) and Stagnic Fluvisol. Although the habitat types varied, this community assembly occupied the wettest open places when compared to the previous three, where wild cucumber and *B. frondosa* (devil's beggarticks) were equally represented. Previous studies have confirmed the coexistence of these two invasive species, particularly along riverbanks (Tokarska-Guzik 2005; Protopopova *et al.* 2006; Borisova 2011). This situation, where a large number of invasive species are present, especially aggressive ones such as wild cucumber and devil's beggarticks (Borisova 2011; Abramova 2012) is highly risky for native species, as these community assemblies develop in highly invasibile habitats, such as riparian zones (Stohlgren *et al.* 1998; Essl & Rabitsch 2002; Zelnik 2012; Aguiar & Ferreira 2013; Stanković *et al.* 2020). Previous research has confirmed that wild cucumber often occurs in the communities of *Bidentetea* Tx. et al. ex von Rochow 1951 class, in the flood zones of the Polish wetland ecosystems (Dajdok & Kącki 2009).

In addition to the *Bidentetea* class, Hulina (1998) reported *E. lobata* in the bank vegetation of association *Cuscuto europaeae-Convolvuletum sepium* Tüxen 1947 *emend.* Kopecký 1969 (class *Filipendulo ulmariae-Convolvuletea sepium* Géhu and Géhu-Franck 1987), in lowland areas of Croatia. Jarolímek *et al.* (2008) listed *Echinocystis lobata* comm. as a synanthropic vegetation unit, in the syntaxonomic class *Galio-Urticetea* Passarge ex Kopecky 1969. Wild cucumber is also registered in marginal communities from the *Artemisetea vulgaris* Lohmeyer et al. ex von Rochow 1951 class; in the willow river stands of the association *Salicetum triandro-viminalis* (Malcuit 1929) Tüxen 1950 (class *Salicetea purpureae* Moor 1958), and in rich associations *Phalaridetum arundinaceae* Libbert 1931 and *Glycerietum maximae* Nowiński 1930 corr. Šumberová *et al.* in Chytrý 2011 (class *Phragmitetea* Tüxen et Preising 1942) in Poland (CABI 2019). In the study carried out by Stanković *et al.* (2018), the group *Humulus lupulus-Echinocystis lobata* was classified in the alliance *Chelidonio-Acerion negundo* L. Ishbirdin et A. Ishbirdin 1989 (class *Robinietea* Jurko ex Hadač et Sofron 1980), based on the presence of other

species which makes this coenosis the closest to forest invasive communities.

The spatial distribution of the four separate groups is such that they occur in a number of different habitat types or local communities (Table 2). The species pool that makes up each of these four groups is thus geographically larger than the local community under study, so we can treat them as independently established and well-defined community assemblages (Cornell & Harrison 2014; Pearson *et al*. 2018).

The dominance of more than one invasive plant is a common situation at sites where allochthonous species have not been removed for a long time (for example: Tokarska-Guzik 2005; Botta-Dukát & Balogh 2008; Batanjski *et al*. 2015; Radovanović *et al*. 2017; Stanković *et al*. 2020). Their coexistence is possible due to the fact that invasive species usually have a broad ecological valence (Borisova 2011; Krstivojević *et al*. 2012), which is shown in the wide range of occupied habitat types of all community assemblages analysed in this study (Supplementary Table 1). Such a situation indicates that natural habitats have been destroyed in some sites. Of the natural habitats invaded, Broadleaved deciduous forest habitat types (T1) were the most numerous, followed by Riverine and fen scrubs (S9), which was also observed by Anastasiu *et al.* (2007) and Klotz (2009).

Although invasive plant species have been studied worldwide from various aspects for decades, there are not many scientific papers dealing with vegetation studies of plant communities dominated by invasive species (Jurko 1963; Hadač & Sofron 1980; Zerbe 2003; Exner & Willner 2004; Sîrbu & Oprea 2011; Batanjski *et al*. 2015; Stanković 2017). We argue that non-native species can also form communities which can be as stable and rich in characteristic species as native communities. Classifying invasive plant communities into higher syntaxonomic categories poses a particular challenge. Considering that many ruderal or segetal associations with the dominance of allochthonous species have been described so far, the same should be expected and applied to communities where invasive neophytes dominate. More recent research highlights the need for a more detailed study of the issue of establishing invasive plant communities, and a different approach to classifying them into higher syntaxonomic categories (Chytrý & Tichý 2003; Batanjski *et al*. 2015).

CONCLUSION

The highly invasive species *Echinocystis lobata* was found in four of the seven studied Ramsar sites in the northern part of the Republic of Serbia. In addition to wild cucumber, the presence of other invasive species was also noted, above all *Amorpha fruticosa* and *Bidens frondosa*. The analyses showed that the relevés with the presence of *E. lobata* were divided into four coenological groups, recognized as established and stable community assemblages.

A total of 10 different habitat types (according to the EUNIS habitat classification - EUNIS 2017) were occupied by wild cucumber-dominated stands. Although various habitat types are invaded by the highly invasive species *E. lobata*, special attention should be paid to temperate riparian scrubs and forests. This could serve in the future management of protected areas, and the prevention and removal of this highly invasive climber.

A high risk of habitat degradation is present because wild cucumber has already established stable community assemblages. Indeed, it is known that frequent anthropogenic interventions within protected natural habitats result in the competitive advantage of invasive species, which explains the establishment of invasive communities, ultimately leading to the formation of so-called novel ecosystems (Hobbs *et al*. 2006, 2009). These ecosystems reduce the potential for the restoration of natural vegetation.

The study we conducted confirmed the importance and necessity of an urgent and rigorous approach to solving the problem of the presence of wild cucumber and its strong coenotic relationships with autochthonous species. The impact of this invasive climber could result in numerous negative consequences for native biodiversity and natural habitats. The situation becomes even more serious as the studied areas are protected at both national and international levels.

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REZIME

Botanica SERBICA

Uspostavljene sastojine visoko invazivne vrste *Echinocistis lobata* na ramsarskim lokalitetima južnog dela Panonske nizije

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Kontrolisanje prisustva invazivnih vrsta u prirodnim, vlažnim staništima je veoma važno iz više razloga, uključujući negativan uticaj koje one imaju na biodiverzitet, konzervaciju i ekosistemske usluge koje ova važna, fragilna područja obezbeđuju. Cilj ovog rada je bio da se istraži prisustvo i distribucija visoko invazivne lijane *Echinocystis lobata* (divlji krastavac) i da se odredi njen cenološki odnos sa nativnim biljnim vrstama u ramsarskim područjima južnog dela Panonske nizije (jugoistočni deo Centralne Evrope, severna Srbija). Urađena su detaljna fitocenološka istraživanja odabranih zaštićenih, riparijalnih područja u periodu od šest godina (2011–2015 i 2020). Istraživanjem je utvrđeno značajno prisustvo visoko invazivne vrste *E. lobata* u istraživanim područjima. Divlji krastavac je nađen na 146 lokacija u četiri od sedam istraživanih područja. Klaster analizama su se izdvojile četiri grupe snimaka u kojima dominira *E. lobata*, koje su opisane, a njihove dominantne i konstantne vrste identifikovane. Urađena je identifikacija tipova staništa i određena preferencija staništa za vrstu *E. lobata*. Prostorna distribucija četiri grupe je takva da se one uspostavljaju u većem broju različitih tipova staništa ili lokalnih zajednica. Skup vrsta koje čine svaku od ove četiri grupe stoga zauzima veći geografski prostor nego istraživana lokalna zajednica, pa se grupe mogu smatrati kao nezavisno uspostavljeni i dobro definisani novi skupovi zajednica. Biljne zajednice u kojima je dominantna invazivna vrsta *E. lobata* nisu opisivane do sad. Ovaj rad je doprinos daljim istraživanjima i uporednim analizama koje su potrebne da bi se opisale invazivne zajednice u kojima je dominantna vrsta divlji krastavac. Osim toga, identifikovani tipovi staništa koji su najviše okupirani, mogu služiti u upravljanju zaštićenim područjima, prevenciji i uklanjanju visoko invazivne puzavice.

Ključne reči: alohtona lijana, sklop, tip staništa, panonski ekoregion, vlažna staništa, divlji krastavac