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Original Scientific Paper

Ruderal vegetation in Serbia – diversity and floristic composition

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ABSTRACT:
This study represents the first data gathering and analysis of the floristic composition of ruderal vegetation in Serbia, published over the last 70 years. The dataset included 748 relevés of ruderal communities and a total of 716 plant species and subspecies. The study showed that the most abundant were widespread taxa, especially taxa of the Eurasian area type, while alien species accounted for a relatively small proportion of the ruderal flora (about 10%). Therophytes and hemicryptophytes were most abundant in the life form spectra. Five vegetation groups were identified, corresponding to the following vegetation classes: *Bidentetea*, *Sisymbrietea*, *Digitario sanguinalis-Eragrostietea minoris*, *Artemisietea vulgaris* and *Polygono-Poetea annuae*. The analysis of similarity showed that there are small floristic differences between particular vegetation groups. The determined diagnostic species for the vegetation groups were compared with those of the corresponding anthropogenic vegetation classes, and a high degree of similarity was found for all but one group. The most frequent taxa in all five groups were *Polygonum aviculare*, *Convolvulus arvensis*, *Plantago major* subsp. *major* and *Chenopodium album*.

Keywords:
synanthropic flora and vegetation, urban habitats, vegetation classes, ruderal species richness, alien species

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INTRODUCTION

Ruderal flora and vegetation occur spontaneously, mainly in settlements, but also in other man-made environments where environmental conditions are significantly altered. Urban environments represent a mosaic of more or less isolated habitats, which are frequently anthropogenically disturbed. These disturbances, as well as the different types of habitats, have a strong influence on species composition (Lososová *et al.* 2012). Spontaneous urban flora is characterized by plants with different traits, requirements, and distribution ranges, but a common feature of many plants found in urban environments is their ability to tolerate disturbance (Godefroid & Koedam 2007). Ruderal species are generally associated with built-up, artificial areas (Panitsa *et al.* 2020), but even areas with lower anthropogenic pressure, such as mountainous regions, are prone to ruderalisation (Jovanović *et al.* 2013; Corcos *et al.* 2020).

The spontaneous flora of urban environments, especially that of cities, can be species-rich (Godefroid & Koedam 2007; Stešević *et al.* 2014). In addition, urban environments may harbour some rare and endangered species (Schmidt *et al.* 2014; Salinitro *et al.* 2018). According to Planchuelo *et al.* (2019), even severely disturbed ruderal habitats can be important for the conservation and protection of certain endangered plant species. Furthermore, ruderal flora and vegetation are particularly characterized by high proportions of non-native species (Pyšek 1998; Simonová & Lososová 2008; Lososová *et al.* 2012; Salinitro *et al.* 2018). Many studies have shown that the presence of aliens in urban areas increases over time (Prodanović *et al.* 2017; Rendeková *et al.* 2018; Salinitro *et al.* 2019), especially neophytes - aliens introduced after 1500 AD (Chocholoušková & Pyšek 2003; Knapp *et al.* 2010).

The first studies of the ruderal vegetation in Serbia began with Slavnić (1951), who investigated nitrophilous vegetation in the province of Vojvodina. After this initial study, many authors contributed to the knowledge about the ruderal vegetation in Serbia, especially in the 1980s and 1990s (Babić 1965; Šajinović 1968; Horvat *et al.* 1974; Rauš *et al.* 1980; Kojić & Pejčinović 1982; Radulović 1982; Ranđelović 1988, 1992; Jovanović & Lakušić 1990; Jovanović 1993, 1994; Milinčić 1998). In the last two decades, only a few authors have contributed to this topic (Kojić *et al.* 2004; Stanković-Kalezić 2007; Pajazitaj 2009; Jarić *et al.* 2011; Popov *et al.* 2016). What further indicates a research gap is the fact that in the last two decades only three studies have provided phytocoenological relevés for more than one ruderal community, and all of them were conducted in Belgrade and its surroundings (Kojić *et al.* 2004; Stanković-Kalezić 2007; Jarić *et al.* 2011). Furthermore, there has been no synoptic work on this vegetation type. Consequently, the syntaxonomic relationships within the ruderal vegetation in Serbia have not yet been clearly defined, and critical re-evaluation is needed. There are several classifications of European vegetation, but in a most recent classification of the vegetation of Europe (Mucina *et al.* 2016), 10 classes of anthropogenic vegetation were recognized.

In general, research in Serbia has focused more on the ruderal flora in cities, as opposed to spontaneously developing ruderal vegetation. This is also the case in other countries of Southeast Europe (Jovanović & Glišić 2021). There are available studies in Serbia which show floristic changes in a given city over 20 years (Prodanović *et al.* 2017) or summarize and compare floristic data from 11 cities (Rat *et al.* 2017). For the ruderal vegetation in Serbia, however, no such data gathering or comparisons are available.

As an unavoidable part of the human environment and because this type of flora and vegetation is very dynamic and susceptible to change, continuous research on ruderal flora and vegetation is required in order to clearly understand their characteristics and dynamics. Thus, the subject of this study was the ruderal vegetation in Serbia developed in urban and rural settlements, abandoned lots, roads and other environments which are at least somewhat exposed to anthropogenic pressure, and the main objectives were: 1) to digitize the phytocoenological relevés of the ruderal vegetation from all of the available published sources (including Ph.D. and Master's theses) from the territory of Serbia and merge all of the relevés into one phytocoenological database; 2) to distinguish between and characterize the main vegetation groups/types; and 3) to analyse the taxonomic, phytogeographical and life form spectra. This study did not include those ruderal habitats exposed to anthropozoogenic influences, developed further outside urban and rural areas (e.g. the highly nitrified vegetation of mountain cattle pens, *Chenopodietalia boni-henrici*).

MATERIALS AND METHODS

Study area. The study area is located in Southeast Europe, on the Balkan Peninsula, i.e. in its north-central part, and also occupies the south-eastern part of the Pannonian plain (province of Vojvodina) (Fig. 1). These two regions, separated by the Danube and Sava rivers, are roughly divided into two distinct geographical and orographical entities, with hills and mountains in the south and lowlands in the north. The natural northern boundary is represented by the Subotica-Horgoš Sands in Vojvodina and in the south by the Šar Planina mountain range in Kosovo and Metohija, in the east by the Balkan mountain range (Stara Planina) and in the west by the Drina River and the eastern part of the Dinarides with the Prokletije mountain range (Stevanović *et al.* 1999).

The study area covers 88361 km^2, with a continental climate in the north and southeast, humid-temperate in the west, and a semi-arid temperate-continental or subcontinental climate, with a sub-Mediterranean transitional part in the centre and east of Serbia (Stevanović & Šinžar-Sekulić 2009).

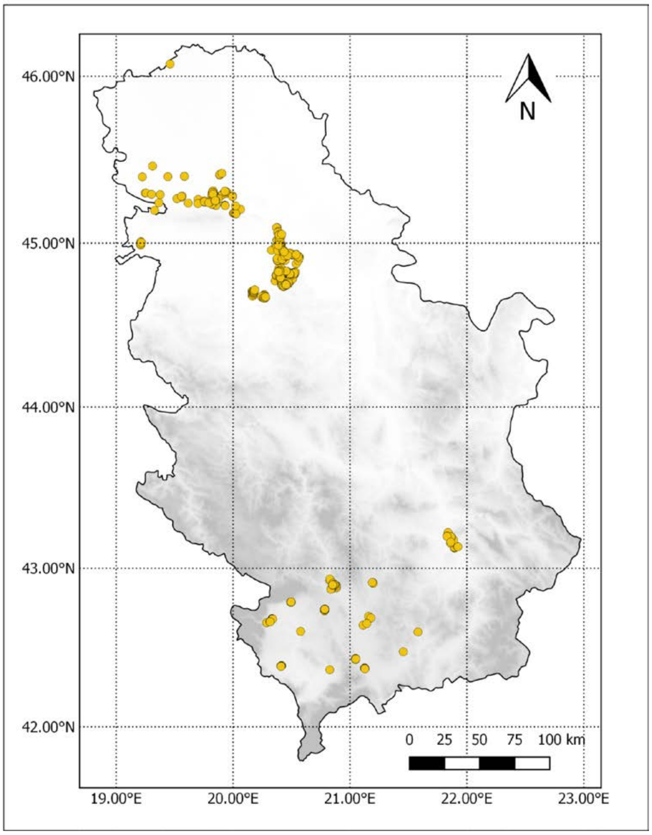


Fig. 1. Distribution of the analysed relevés of ruderal vegetation in the study area. Only those relevés which had precise information about the localities are presented.

Data preparation. The data used in this study are the phytocenological records stored in the archives of the Habitats of Serbia project (Lakušić *et al.* 2005). Additional phytocoenological relevés, which were not collected within the framework of the aforementioned project, were taken from known literature sources published after 2005. The phytocoenological tables were digitized using Microsoft Excel 2016 and database software TURBOVEG 2.0 (Hennekens & Schaminée 2001). The first dataset included 730 species and subspecies and 763 relevés published between 1951 and 2016 (Slavnić 1951; Babić 1965; Šajinović 1968; Horvat *et al.* 1974; Rauš *et al.* 1980; Kojić & Pejčinović 1982; Radulović 1982; Ranđelović 1988, 1992; Jovanović & Lakušić 1990; Jovanović 1993, 1994; Milinčić 1998; Kojić *et al.* 2004; Stanković-Kalezić 2007; Pajazitaj 2009; Jarić *et al.* 2011; Popov *et al.* 2016). All of the relevés were sampled according to the standard methodology of the Zürich-Montpellier School (Braun-Blanquet 1964; Westhoff & van der Maarel 1973) and classified by the original authors into the following vegetation classes: *Bidentetea tripartitii* Tx., Lohm. et Prsg. 1950, *Chenopodietea* Br.- Bl.1951 em. Lohm. J. et R. Tx.1961, *Artemisietea vulgaris* Lohm., Prsg. et R. Tx. 1950, *Agropyretea repentis* Oberd., Th. Muller et Gors 1967, *Plantaginetea majoris* Tx. et Prsg. 1950 and *Phragmitetea communis* R. Tx. et Preising 1942.

The nomenclature and taxonomy of the plant taxa follow the Flora Europaea Database (Tutin *et al.* 2001). The basic life forms of the plants were determined according to Mueller-Dombois & Ellenberg (1974) and Stevanović (1992a). The chorotypes were defined following the classification proposed by Meusel *et al.* (1965, 1978) and Meusel & Jäger (1992), modified for the Serbian territory by Stevanović (1992b). Additionally, all relevés with a detailed locality were georeferenced using the Google Earth Pro software, and a distribution map was made using QGIS software.

Data analysis. The affiliation of ruderal communities to basic vegetation groups was based on a combination of the diagnostic species of the classes provided in the ESL1 species list (Mucina *et al.* 2016) and expert judgment. Relevés with a similar combination of diagnostic species were combined into one vegetation group. All relevés (15 plots) originally assigned to the class *Phragmitetea communis* R. Tx. et Preising 1942 were excluded from the dataset as they were characterized by a species composition which is not typical of ruderal communities. Taxa determined at the genus level were omitted from the analyses, as were mosses, which were recorded in only three relevés. The final dataset contained 716 species and subspecies and 748 relevés within 5 vegetation groups/types.

The names of the vegetation groups were based on abbreviations of the vegetation classes to which the groups corresponded: ART = *Artemisietea vulgaris*, BID = *Bidentetea*, DIG = *Digitario sanguinalis-Eragrostietea minoris*, POL = *Polygono-Poetea annuae*, and SIS = *Sisymbrietea*, according to Mucina *et al.* (2016). The term "total flora" was abbreviated and is referred to in the text as TRF (Total Ruderal Flora). Floristic data were extracted from all of the phytocenological relevés and each vegetation group. To analyse the floristic characteristics of all the relevés and each vegetation group, taxonomic, phytogeographical, and life form analyses were carried out.

The average number of species per plot was calculated for each vegetation group in JUICE 7.1 software (Tichý 2002). The same software was used to calculate the indices of species diversity for each group: the Shannon-Wiener diversity index (*H'*) and Shannon's equitability (evenness; E_H). To compare the degree of the differences between the groups, an analysis of similarities (ANOSIM; Clarke 1993) - a non-parametric technique using Bray-Curtis distances, with 9999 permutations in PAST 2.17 software (Hammer *et al.* 2001) was performed. This outputs the test statistic, R, which varies between 0 and 1, with values close to 1 indicating any dissimilarities between the groups (Clarke 1993).

The dominant and diagnostic species for the 5 vegetation groups were defined using JUICE 7.1 software. Diagnostic species were identified for each vegetation group by means of the phi (Φ) coefficient as a fidelity measure (Chytrý *et al.* 2002). All of the groups were standardised to an equal size and those species with a phi coefficient value ≥ 0.10 were considered diagnostic. This threshold value was chosen subjectively after examining results with higher and lower thresholds. The dominant species for each vegetation group were determined as those with a cover of ≥ 35% in a minimum of 5% of the relevés. A combined synoptic table with the frequency and fidelity values of the species within the groups was prepared using JUICE 7.1 software. The mean species abundances, calculated in PAST software, were added to each synoptic column (Supplementary Table 1).

The taxa of ruderal habitats important for conservation at national level were identified in accordance with the Rulebook on the proclamation and protection of strictly protected and protected wild species of plants, animals, and fungi (SGRS 2010-2016).

Table 1. Differences among 5 vegetation groups (BID, SIS, DIG, ART, and POL); ANOSIM statistic R values (top right half) and corresponding significance values ($p<0.05$; bottom left half).

	BID	SIS	DIG	ART	POL
BID	0	0.5359	0.6159	0.572	0.6553
SIS	0.0001	0	0.3265	0.1019	0.1201
DIG	0.0001	0.0001	0	0.4291	0.6367
ART	0.0001	0.0001	0.0001	0	0.2239
POL	0.0001	0.0001	0.0001	0.0001	0

RESULTS

An overview of the dataset structure. The dataset survey showed that most of the relevés, a total of 301, were collected in north-central Serbia, more precisely in Belgrade and its surroundings, 273 in Vojvodina, 119 from Kosovo and Metohija, 26 from south-eastern Serbia, and 29 did not contain any information about locality. This indicates that the ruderal vegetation was not studied in the central part of the country, with the exception of Belgrade and its surroundings, or in the eastern and western parts. Most of these relevés were collected in settlements of various sizes, ranging from villages to cities. In addition to the aforementioned locality data, other general data pertaining to the phytocoenological relevés were also incomplete. Thus, 33% of the relevés had information on altitude, 18% on aspect (exposure), and only 16% on slope. Only 96 plots (13%) had no information on size. For the rest, the plot size varied between 0.2 and 1000 m^2 and more than 50% of the plots were between 5-50m^2.

Vegetation groups of ruderal communities. Based on the combination of diagnostic species of the classes provided in the ESL1 species list (Mucina *et al.* 2016), ruderal communities from Serbia can be classified into 5 vegetation classes: *Bidentetea* Tx. et al. ex von Rochow 1951 (BID), which includes summer-annual pioneer vegetation of seasonally flooded nutrient-rich river alluvia, lacustrine banks and heavily nutrient-loaded anthropogenic habitats of boreo-temperate Europe and North Africa; *Sisymbrietea* Gutte et Hilbig 1975 (SIS), which comprises zoo-anthropogenic and modern anthropogenic vegetation of animal shelters and disturbed ruderal sites in cool- and cold-temperate regions of Eurasia; *Digitario sanguinalis-Eragrostietea minoris* Mucina, Lososová et Šilc 2016 (DIG), which includes thermophilous grass-rich anthropogenic vegetation rich in summer-annual C4 species in the southern nemoral, mediterranean, steppe and semi-desert zones of Europe; *Artemisietea vulgaris* Lohmeyer et al. in Tx. Ex von Rochow 1951 (ART), which includes perennial (sub)xerophilous ruderal vegetation of the temperate and submediterranean regions of Europe; and *Polygono-Poetea annuae* Rivas-Mart. 1975 (POL), which includes subcosmopolitan therophyte-rich dwarf-herb vegetation of trampled habitats.

Table 2. Parameters of floristic diversity for 5 vegetation groups (BID, SIS, DIG, ART, and POL) based on vegetation data.

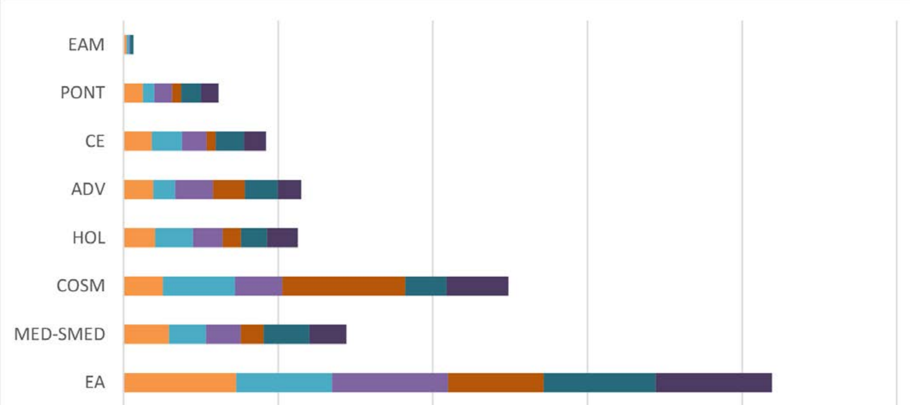
Group	Number of relevés	Avg. number species/Plot	Shannon-Wiener index (*H'*)	Evenness (*EH*)
BID	79	21.11	2.323633	0.798633
SIS	204	21.78	2.22898	0.746039
DIG	38	13.37	2.256526	0.877947
ART	307	23.72	2.268013	0.746117
POL	120	16.48	1.938092	0.716733

The analysis of similarity (ANOSIM) showed that the differences between the identified groups are statistically significant (p<0.05; Table 1). The dissimilarity between the groups, represented by the R-value, varied between 0.1-0.66 (Table 1).

Taxonomic, phytogeographical and life form analyses of total ruderal flora and vegetation groups. All 716 taxa (TRF) were classified into 326 genera, 65 families, and 3 classes. The highest number of taxa were found within the groups ART (547) and SIS (416), followed by BID (326) and POL (250). The DIG group included the lowest number of taxa (68).

The most represented class was that of Dicotyledones, which made up c. 80% of the TRF and the flora of each vegetation group. The least represented class was Pteridophyta, accounting for less than 1% of the TRF and each vegetation group, with the exception of group DIG which had no representatives of this class. The most dominant families, with the highest number of taxa in the TRF (≥ 10 taxa) are Asteraceae (102), Poaceae (86), Fabaceae (65), Brassicaceae, (54), Lamiaceae (35), Scrophulariaceae (31), Caryophyllaceae (28), Polygonaceae (27), Chenopodiaceae (25), Rosaceae (23), Apiaceae (22), Ranunculaceae (19), Boraginaceae (17), Cyperaceae (13), Euphorbiaceae (11) and Rubiaceae (10). Asteraceae and Poaceae were the most species-rich families in all of the vegetation groups. Other families with a high number of taxa in the vegetation groups were Fabaceae, Brassicaceae, and Lamiaceae, whereas group DIG had only two representatives of Fabaceae and one representative of Lamiaceae. The dominant genera with the highest number of taxa in the TRF were *Trifolium* (16 taxa), *Chenopodium* (15), *Rumex* (13), *Polygonum* (12), *Veronica* (12), *Euphorbia* (11), *Vicia* (11), *Bromus* (10), *Centaurea* (10) and *Ranunculus* (10 taxa). Genera *Polygonum* was highlighted as dominant in all the vegetation groups, *Trifolium*, *Chenopodium*, *Rumex* and *Bromus* in four vegetation groups, *Veronica* in three, *Centaurea* and *Ranunculus* in two, while *Euphorbia* and *Vicia* were only dominant in the ART group.

Based on the phytogeographical analysis, all of the ruderal taxa were classified into 8 area types (Eurasian, Mediterranean-Submediterranean, Cosmopolitan, Holarctic, Adventive, Central European, Pontic, and Eurasian mountain). The Eurasian area type was dominant in the TRF and in all the vegetation groups, except for group DIG, where the Cosmopolitan area type was dominant, followed by the Eurasian area type in second place (Fig. 2). In general, the Cosmopolitan area type was the second most represented type in groups BID, SIS, and POL, while the Mediterranean-Submediterranean type was second in the TRF and group ART. In addition, a significant percentage of the flora studied belonged to the Holarctic and Adventive area types, followed by Central European and Pontic. The least represented were taxa of the Eurasian mountain area type, which were completely absent in groups DIG and POL.



	EA	MED-SMED	COSM	HOL	ADV	CE	PONT	EAM
TRF	36.45%	14.66%	12.71%	10.20%	9.64%	9.08%	6.28%	0.98%
BID	30.98%	11.96%	23.31%	12.27%	7.06%	9.82%	3.68%	0.92%
SIS	37.50%	11.30%	15.38%	9.62%	12.26%	7.93%	5.77%	0.24%
DIG	30.88%	7.35%	39.71%	5.88%	10.29%	2.94%	2.94%	0.00%
ART	36.20%	14.81%	13.35%	8.41%	10.60%	9.14%	6.40%	1.10%
POL	37.60%	12.00%	20.00%	10.00%	7.60%	7.20%	5.60%	0.00%

Fig. 2. Comparative chorological spectra of the Total Ruderal Flora (TRF) and 5 vegetation groups (BID, SIS, DIG, ART, and POL); Eurasian area type (EA), Mediterranean-Submediterranean area type (MED-SMED), Cosmopolitan area type (COSM), Holarctic area type (HOL), Adventive area type (ADV), Central European area type (CE), Pontic area type (PONT), and Eurasian mountain area type (EAM).

The flora of ruderal habitats in Serbia was classified into 7 main plant life forms. Hemicryptophytes and therophytes dominated in the TRF and in all the vegetation groups with about 40% of the representation, except for group DIG, in which therophytes were absolutely dominant (76.47%). Other life forms were represented with a much lower percentage, with chamaephytes and hydrophytes being the least represented and completely absent in group DIG (Fig. 3).

Floristic diversity of the vegetation groups. The group sizes varied, with DIG being represented with the lowest number of relevés (38), while ART had the highest number (307) (Table 2). The Shannon-Wiener diversity index (*H'*) varied between 1.94 and 2.32, while Shannon's equitability (evenness; E_H) varied between 0.72 and 0.88 (Table 2). The BID group had the highest average values of the Shannon–Wiener diversity index and group DIG had the highest average values of species evenness. Group POL had the lowest averages for both the diversity index and species evenness.

Diagnostic and dominant species of the vegetation groups

Vegetation group BID

Diagnostic species: *Amaranthus lividus*, *Bidens cernua*, *Bidens tripartita*, *Chenopodium chenopodioides*, *Chenopodium rubrum*, *Cyperus glaber*, *Leersia oryzoides*, *Mentha pulegium*, *Polygonum brittingeri*, *Polygonum lapathifolium*, *Polygonum mite*, *Polygonum persicaria*, *Ranunculus sceleratus* subsp. *sceleratus*, and *Rumex palustris*.

Dominant species: *Amaranthus lividus*, *Leersia oryzoides*, *Mentha pulegium*, *Polygonum lapathifolium*, and *Rumex palustris*.

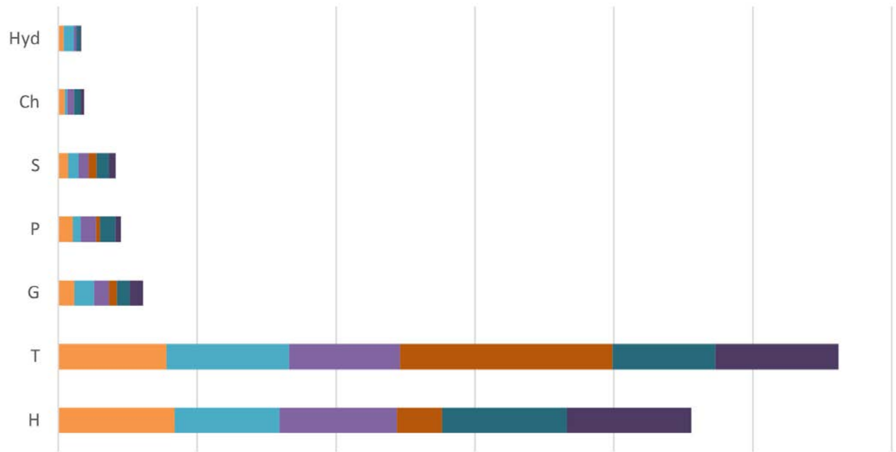
Other frequent and abundant species not identified as diagnostic or dominant of the vegetation group with relative frequency ≥ 30% were: *Polygonum aviculare* [mean abundance (hereinafter abund.) 1.71, Fr = 54%], *Plantago major* subsp. *major* (mean abund. 1.27, Fr = 53%), *Echinochloa crus-galli* (mean abund. 1.38, Fr = 53%), *Rorippa sylvestris* (mean abund. 1.56, Fr = 48%), *Rumex conglomeratus* (mean abund. 0.759, Fr = 32%), *Lycopus europaeus* (mean abund. 0.937, Fr = 32%), *Chenopodium album* (mean abund. 0.709, Fr = 30%), *Agrostis stolonifera* (mean abund. 1, Fr = 30%), *Potentilla anserina* subsp. *anserina* (mean abund. 0.785, Fr = 30%).

Vegetation group SIS

Diagnostic species: *Amaranthus crispus*, *Bassia scoparia*, *Bromus arvensis*, *Chenopodium murale*, *Elymus hispidus*, *Helianthus annuus*, *Hordeum murinum* subsp. *murinum*, and *Rubus canescens*.

Dominant species: *Chenopodium murale* and *Hordeum murinum* subsp. *murinum*.

Other frequent and abundant species not identified as diagnostic or dominant of the vegetation group with relative frequency ≥ 40%, were: *Polygonum aviculare* (mean abund. 1.71, Fr = 57%), *Convolvulus arvensis* (mean abund. 1.59, Fr = 57%), *Chenopodium album* (mean abund. 1.5, Fr = 46%), *Capsella bursa-pastoris* subsp. *bursa-pastoris* (mean abund. 1.2, Fr = 44%), *Lactuca serriola* (mean abund. 1.04, Fr = 42%), *Cirsium arvense* (mean abund. 1.33, Fr = 41%), *Taraxacum officinale* (mean abund. 0.917, Fr = 40%).



	H	T	G	P	S	Ch	Hyd
TRF	41.90%	38.97%	5.87%	5.31%	3.63%	2.37%	1.96%
BID	37.73%	44.17%	7.06%	2.76%	3.68%	0.92%	3.68%
SIS	42.31%	39.90%	5.29%	5.53%	3.61%	2.40%	0.96%
DIG	16.18%	76.47%	2.94%	1.47%	2.94%	0.00%	0.00%
ART	44.97%	36.93%	4.57%	5.48%	4.39%	2.38%	1.28%
POL	44.80%	44.40%	4.80%	2.00%	2.40%	1.20%	0.40%

TRF BID SIS DIG ART POL

Fig. 3. Comparative life-form spectra of the Total Ruderal Flora (TRF) and 5 vegetation groups (BID, SIS, DIG, ART, and POL); Hemicryptophytes (H), Therophytes (T), Geophytes (G), Phanerophytes (P), Scandentophytes (S), Chamaephytes (Ch), and Hydrophytes (Hyd).

Vegetation group DIG

Diagnostic species: *Digitaria sanguinalis*, *Eragrostis cilianensis*, *Eragrostis minor*, *Eragrostis pilosa*, *Portulaca oleracea* subsp. *oleracea*, and *Setaria verticillata*.

Dominant species: *Portulaca oleracea* subsp. *oleracea*.

Other frequent and abundant species not identified as diagnostic or dominant of the vegetation group with relative frequency ≥ 50% were: *Setaria pumila* (mean abund. 2.11, Fr = 79%), *Amaranthus retroflexus* (mean abund. 1.5, Fr = 66%), *Chenopodium album* (mean abund. 1.42, Fr = 58%), *Echinochloa crus-galli* (mean abund. 1.37, Fr = 55%), *Hibiscus trionum* (mean abund. 1.26, Fr = 55%), *Convolvulus arvensis* (mean abund. 1.68, Fr = 53%), *Polygonum aviculare* (mean abund. 1.55, Fr = 50%).

Vegetation group ART

Diagnostic species: *Arctium lappa*, *Artemisia vulgaris*, *Asclepias syriaca*, *Conium maculatum*, *Elymus repens*, *Equisetum telmateia*, *Onopordum acanthium* subsp. *acanthium*, *Sambucus ebulus*, *Solidago gigantea* subsp. *serotina*, *Tanacetum vulgare*, and *Urtica dioica*.

Dominant species: *Artemisia vulgaris*, *Asclepias syriaca*, *Cynodon dactylon*, *Elymus repens*, *Sambucus ebulus*, and *Urtica dioica*.

Other frequent and abundant species not identified as diagnostic or dominant of the vegetation group with relative frequency ≥ 30% were: *Convolvulus arvensis* (mean abund. 1.62, Fr = 51%), *Cirsium arvense* (mean abund. 1.11, Fr = 43%), *Carduus acanthoides* (mean abund. 1.05, Fr = 38%), *Cichorium intybus* (mean abund. 0.857, Fr = 35%), *Rubus caesius* (mean abund. 0.993, Fr = 34%), *Chenopodium album* (Mean abund. 0.906, Fr = 33%), *Lactuca serriola* (mean abund. 0.775, Fr = 33%), *Bromus sterilis* (mean abund. 0.948, Fr = 31%), *Polygonum aviculare* (mean abund. 0.889, Fr = 30%), *Rumex crispus* subsp. *crispus* (mean abund. 0.671, Fr = 30%).

Vegetation group POL

Diagnostic species: *Lolium perenne*, *Plantago major* subsp. *major*, *Poa annua*, *Polygonum aviculare*, *Potentilla anserina* subsp. *anserina*, and *Sclerochloa dura*.

Dominant species: *Cynodon dactylon*, *Lolium perenne*, *Plantago major* subsp. *major*, *Poa annua*, *Polygonum aviculare*, and *Sclerochloa dura*.

Other frequent and abundant species not identified as diagnostic or dominant of the vegetation group with relative frequency ≥ 30% were: *Taraxacum officinale* (mean abund. 1.82, Fr = 73%), *Capsella bursa-pastoris* subsp. *bursa-pastoris* (mean abund. 1.61, Fr = 56%), *Trifolium repens* subsp. *repens* (mean abund. 1.37, Fr = 44%), *Convolvulus arvensis* (mean abund. 1.17, Fr = 39%), *Chamomilla recutita* (mean abund. 0.858, Fr = 34%), *Plantago lanceolata* (mean abund. 0.917, Fr = 34%), *Chenopodium album* (mean abund. 0.833, Fr = 34%).

Protected taxa of ruderal habitats. Only 41 taxa (5.7%) are protected by national legislation (SGRS 2010-2016), four of which are strictly protected and 37 protected.

DISCUSSION

Floristic diversity and richness of ruderal vegetation. Considering that the flora of Serbia comprises 3662 taxa (Stevanović *et al.* 1995), the analysed dataset of the ruderal taxa (716) represents c. 20% of the total vascular flora of Serbia. If we consider that in the last two decades the study of ruderal vegetation has been carried out mainly in Belgrade and its surroundings (Kojić *et al.* 2004; Stanković-Kalezić 2007; Jarić *et al.* 2011), without data from the eastern and western parts of Serbia, we can expect an even higher floristic richness in the ruderal communities in Serbia.

The identified groups can be classified into five vegetation classes. As already mentioned, according to Mucina *et al.* (2016), there are 10 classes of anthropogenic vegetation in Europe. The vegetation types which are not dealt with in this paper include segetal weed vegetation and vegetation types that do not occur in Serbia (*Papaveretea rhoeadis* S. Brullo et al. 2001, *Oryzetea sativae* Miyawaki 1960, *Chenopodietea* Br.-Bl. in Br.-Bl. et al. 1952, *Matricario-Poetea arcticae* A. Ishbirdin in Sumina 2012).

The two groups with the lowest number of taxa are DIG and POL, which corresponded to the trampled communities of the classes *Digitario sanguinalis-Eragrostietea minoris* and *Polygono-Poetea annuae*. In general, communities of trampled habitats are generally species-poor (Jovanović 1994; Pyšek *et al.* 2004; Simonová & Lososová 2008; Stančić *et al.* 2008; Rendeková *et al.* 2018). Trampling as a frequent disturbance factor has a direct impact on plants through mechanical damage, but also changes the mechanical properties of the soil. On the other hand, the group with the highest number of taxa and the highest average number of species per plot is the ART group, which accounts for 75% of all taxa registered in ruderal communities in Serbia. This group corresponded to the class *Artemisietea vulgaris*, which may be species-rich compared to other classes (Pyšek *et al.* 2004; Simonová & Lososová 2008; Rendeková *et al.* 2018).

Families with the highest number of taxa (≥ 10 taxa) in the TRF are listed as the 20 most species-rich families of Serbian flora (Stevanović *et al.* 1995). Three families with the highest diversity of Serbian flora and TRF are Asteraceae, Poaceae and Fabaceae. The order of other families is much the same, except for the higher positioned families Polygonaceae and Chenopodiaceae in the TRF. A similar pattern of taxonomic spectra was recorded in the cities and ruderal habitats in the region (Milović & Mitić 2012; Maslo 2014; Stešević *et al.* 2014; Panitsa *et al.* 2020), in which the families of Asteraceae, Poaceae, Fabaceae and Brassicaceae were among the most dominant. On the other hand, ruderal habitats in Pilsen, the Czech Republic (Pyšek & Pyšek 1991), were characterized by more species from the families Polygonaceae and Chenopodiaceae, which were among the 5 richest families. Among the 10 genera with the highest number of taxa (≥ 10 taxa) in the TRF, 6 belong to the 15 most species-rich genera of Serbian flora (Stevanović *et al.* 1995). Additionally, 8 of them are listed as the richest genera in the city of Podgorica, Montenegro (Stešević *et al.* 2014), all except for *Centaurea* and *Polygonum*. Some of the 10 dominant genera in the TRF are typical of ruderal habitats. In general, species of the genus *Chenopodium* are characteristic of ruderal habitats and others under strong anthropogenic pressure, and within the genera *Polygonum* and *Bromus* many species are typical of ruderal and ruderal-segetal habitats (Jovanović 1994).

Phytogeographical aspects of the total ruderal flora and vegetation groups. The phytogeographical analysis showed that the Eurasian area type is absolutely dominant in the TRF and in almost all the vegetation groups, with 261 taxa (36.45%) distributed throughout most of Europe and Asia, indicating the continental character of the studied localities. The relatively high representation of the Mediterranean-Submediterranean area type is not surprising (second place in the TRF), as many ruderal habitats are often characterized as warm and sunny, with unstable water regimes, i.e. conditions favouring xerothermic plants (Jovanović 1997). In Mediterranean cities, the most dominant tend to be Mediterranean and widely-distributed species (such as cosmopolitans and aliens) (Celesti-Grapow & Blasi 1998; Stešević *et al.* 2014). In all the vegetation groups, the Cosmopolitan type stands out, which together with the Adventive area type represents an important trait of ruderal flora and vegetation in general (Jovanović 1994). The plants of the Adventive type include accidentally or intentionally introduced alien (non-native) taxa, regardless of the time of their introduction. Alien taxa are represented by slightly less than 10% in the TRF, with approximately the same percentages in each vegetation group, which corresponds to the proportion of aliens in the flora of man-made vegetation in the Balkans (Šilc *et al.* 2012). In the study carried out by Šilc *et al.* (2012), which compiled relevés from 6 countries from the former Yugoslavia, including some relevés from the territory of Serbia, alien taxa were represented with 12.7%. Also, in similar floristic studies in the Balkans, such as in Podgorica, Montenegro (Stešević *et al.* 2014) and Greece (Panitsa *et al.* 2020), the proportion of aliens was relatively low, at around 14%. Slightly higher percentages were registered in Mostar, Bosnia and Herzegovina (Maslo 2014), with the highest in Zadar, Croatia (Milović & Mitić 2012). In contrast, the proportion of aliens was higher in other regions of Europe, especially in Central Europe, ranging from 30% upwards (Pyšek 1998; Chocholoušková & Pyšek 2003; Lososová *et al.* 2012), which may be the result of a higher level of industrialisation and long tradition of research (Lambdon *et al.* 2008). In general, an increase in alien species in ruderal habitats can be observed in Central Europe (Lososová & Simonová 2008; Rendeková *et al.* 2018), and this trend may also be expected in this region. Therefore, the gathered data from this study will form a good basis to follow these changes in different ruderal habitats in Serbia.

Life form aspects of the total ruderal flora and vegetation groups. The analysis of the life forms showed that the TRF and four vegetation groups are of a therophytic-hemicryptophytic character. The high occurrence of hemicryptophytes was expected, as this life form is dominant in the flora of Serbia (Diklić 1984). The high representation of therophytes is the result of various and often intensive disturbances to which these habitats are exposed (Jovanović 1994; Šilc 2010). In other man-made vegetation types, i.e. weed vegetation on arable land, therophytes are more abundant due to uniform and regular disturbances (Lososová *et al.* 2006; Šilc 2010). A similar pattern, i.e. an almost codominant representation of therophytes and hemicryptophytes, has already been observed in some cities in Serbia (Prodanović *et al.* 2017; Rat *et al.* 2017). Codominance, with a slight predominance of therophytes, has been observed in some cities in southern Europe (Maslo 2014; Stešević *et al.* 2014; Salinitro *et al.* 2018), with an increasing proportion of therophytes moving further south (Celesti-Grapow & Blasi 1998). In contrast, in ruderal habitats in Central Europe hemicryptophytic plants dominate (Pyšek & Pyšek 1991).

Floristic differences among the vegetation groups. One-way ANOSIM showed that the differences between the groups were statistically significant (the p-values were much lower than 0.05), while the low R-value between some group pairs indicates that there are hardly any differences between the groups regardless of the p-value (Clarke & Gorley 2006). The most distinguished group is BID, which had high R-values in all of the group comparisons (R>0.5). It is not surprising that the floristic composition of this unit differs, as this group corresponded to the class *Bidentetea*, a periodically flooded ruderal vegetation characterised by hygrophilous species. The second group which stands out is DIG, which showed the most similarities with the SIS group (R=0.33). The latter corresponded to the class *Sisymbrietea* and had the lowest R-values compared to the other groups, indicating that the species composition hardly differed, especially from the groups ART and POL (the R-values were close to 0).

Comparing the diagnostic species of the identified groups with those of the corresponding anthropogenic vegetation classes according to Mucina *et al.* (2016), a high degree of similarity is shown, with the exception of group SIS. Among 14 diagnostic species of group BID, 10 are listed as diagnostic of the class *Bidentetea* in Mucina *et al.* (2016) (*Bidens cernua*, *Bidens tripartita*, *Chenopodium chenopodioides*, *Chenopodium rubrum*, *Polygonum brittingeri*, *Polygonum lapathifolium*, *Polygonum mite*, *Polygonum persicaria*, *Ranunculus sceleratus* subsp. *sceleratus* and *Rumex palustris*). Among 8 diagnostic species belonging to group SIS, only 3 are listed as diagnostic of the class *Sisymbrietea* (*Chenopodium murale*, *Helianthus annuus* and *Hordeum murinum* subsp. *murinum*). All 6 diagnostic species of group DIG are listed as diagnostic of the class *Digitario sanguinalis-Eragrostietea minoris* (*Digitaria sanguinalis*, *Eragrostis cilianensis*, *Eragrostis minor*, *Eragrostis pilosa*, *Portulaca oleracea* subsp. *oleracea* and *Setaria verticillata*). Among 11 diagnostic species belonging to group ART, 7 are listed as diagnostic of the class *Artemisietea vulgaris* (*Arctium lappa*, *Artemisia vulgaris*, *Asclepias syriaca*, *Conium maculatum*, *Elymus repens*, *Onopordum acanthium* subsp. *acanthium* and *Tanacetum vulgare*). Among 6 diagnostic species of group POL, 4 are listed as diagnostic of the class *Polygono-Poetea annuae* (*Plantago major* subsp. *major*, *Poa annua*, *Polygonum aviculare* and *Sclerochloa dura*).

Only 5% of the taxa (36) are present in all the vegetation groups. Although present in all the vegetation groups, not all of these taxa are abundant, and some of them occur only in one or a few relevés of a given vegetation group, such as *Amaranthus albus*, *Consolida regalis* subsp. *regalis* and *Fallopia convolvulus*. In the group of highly frequent taxa, which occur in all the vegetation groups, typical ruderal plants such as *Polygonum aviculare*, *Convolvulus arvensis*, *Plantago major* subsp. *major* and *Chenopodium album* are the most frequent. Due to their adaptability, these plants can be found in different types of ruderal communities with different moisture and temperature regimes and different levels of disturbance. They have already been identified as frequent in cities in Serbia (Rat *et al.* 2017) and in certain urban habitats throughout Europe (Šilc *et al.* 2020). These cosmopolitan taxa are universally adapted to urban environments, and some are more adaptable and flexible than others, such as *Polygonum aviculare*, while others, such as *Chenopodium album,* are more competitive for space (Chen *et al.* 2014). Other frequent taxa present in all the vegetation groups are *Echinochloa crus-galli*, *Amaranthus retroflexus*, *Cynodon dactylon*, *Conyza canadensis*, *Cirsium arvense*, *Capsella bursa-pastoris* subsp. *bursa-pastoris* and *Lolium perenne*. In numerous papers dealing with ruderal flora and vegetation, *Taraxacum officinale* agg. is one of the most frequent species in urban environments (e.g. Lososová & Simonová 2008; Lososová *et al.* 2012; Rat *et al.* 2017; Šilc *et al.* 2020). *Taraxacum officinale* also stands out in this study as a frequent constituent of ruderal communities, with the exception of the communities of group DIG, where it is completely absent.

Conservation aspects of the analysed flora. A small percentage of the analysed flora are protected by national legislation. This is even further diminished by the fact that many of them have been included on the list so as to restrict their trade for commercial purposes (22 out of 37 protected taxa; SGRS 2010-2016). In general, many of the commercially exploited species are widespread and numerous in ruderal habitats, such as *Achillea millefolium* subsp.

millefolium, *Arctium lappa*, and *Hypericum perforatum*, etc. Strictly protected taxa are *Centaurea orientalis*, *Cyperus longus*, *Erysimum crepidifolium* and *Lathyrus palustris* subsp. *palustris* (SGRS 2010-2016), of which *Erysimum crepidifolium* is considered extinct in Serbia (Stevanović 1999). Given the dynamics of ruderal habitats and the fact that these taxa have been recorded in individual findings (*Erysimum crepidifolium*, Kojić & Pejčinović 1982; *Cyperus longus*, Ranđelović 1992; *Centaurea orientalis*, Milinčić 1998; *Lathyrus palustris* subsp. *palustris*, Jarić *et al.* 2011), further research is needed in order to confirm their occurrence. Additionally, in the European Red List of Vascular Plants, which also includes crop wild relatives and aquatic plant species (Bilz *et al.* 2011), 36 taxa are included. *Cyperus michelianus* subsp. *michelianus*, considered as Near Threatened, is the only taxon on this list with a possible future conservation concern.

CONCLUSION

This first comprehensive study of the floristic composition of ruderal vegetation in Serbia revealed some important features of the flora of ruderal habitats. Namely, it is characterized by: 1) relatively high taxonomic richness; 2) the codominance of therophytes and hemicryptophytes; 3) high representation of species with wide distribution and relatively low representation of alien species. These characteristics can be observed in all the identified vegetation groups, with a slight variation for group DIG. Based on the comparisons of the diagnostic species of five identified vegetation groups and the floristic comparisons between the groups, it is evident that a reclassification of ruderal communities in Serbia and a critical re-evaluation of higher ruderal syntaxa is required.

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REZIME

Botanica SERBICA

Ruderalna vegetacija u Srbiji – diverzitet i floristički sastav

Milena Tabašević, Dmitar Lakušić, Nevena Kuzmanović, Snežana Vukojičić, Milan Glišić i Slobodan Jovanović

Ova studija predstavlja prvo prikupljanje podataka i analizu florističkog sastava ruderalne vegetacije u Srbiji, iz literaturnih izvora objavljenih u poslednjih 70 godina. Baza podataka sadrži 748 fitocenoloških snimaka ruderalnih zajednica i ukupno 716 biljnih vrsta i podvrsta. Studija je pokazala da su najzastupljeniji taksoni sa širokim arealima, posebno taksoni evroazijskog areal tipa, dok su strane vrste zastupljene u relativno malom broju u ruderalnoj flori (oko 10%). Terofite i hemikriptofite dominiraju u spektru životnih formi. Identifikovano je pet vegetacijskih grupa koje odgovaraju sledećim vegetacijskim klasama: *Bidentetea*, *Sisymbrietea*, *Digitario sanguinalis-Eragrostietea minoris*, *Artemisietea vulgaris* i *Polygono-Poetea annuae*. Analiza sličnosti je pokazala da postoje male razlike između pojedinih vegetacijskih grupa. Izdvojene dijagnostičke vrste vegetacijskih grupa upoređene su sa dijagnostičkim vrstama odgovarajućih antropogenih vegetacijskih klasa i visok stepen sličnosti je utvrđen za sve sem jedne grupe. Najzastupljeniji taksoni u svih pet grupa su *Polygonum aviculare*, *Convolvulus arvensis*, *Plantago major* subsp. *major* i *Chenopodium album*.

Ključne reči: sinantropna flora i vegetacija, urbana staništa, vegetacijske klase, bogatstvo ruderalnih vrsta, strane vrste