Acta Societatis Botanicorum Poloniae

DOI: 10.5586/asbp.3544

Publication history
Received: 2016-02-28
Accepted: 2017-03-08
Published: 2017-03-31

Handling editor
Joanna Zalewska-Gałosz, Faculty of Biology and Earth Sciences of the Jagiellonian University, Poland

Authors' contributions
DD: idea of the study; DD, ZD: writing the first draft of the manuscript; PE: revision of the manuscript, map and table creating; AŠ: comments to the manuscript; all the authors: field study, relevés sampling

Funding
The research was partially funded by the projects VEGA 1/0083/16 and VEGA 2/0040/17.

Competing interests
No competing interests have been declared.

Citation
Dítě D, Eliáš P Jr., Dítě Z, Šimková A. Recent distribution and phytosociological affiliation of *Ludwigia palustris* in Slovakia. Acta Soc Bot Pol. 2017;86(1):3544. https://doi.org/10.5586/asbp.3544

ORIGINAL RESEARCH PAPER

Recent distribution and phytosociological affiliation of *Ludwigia palustris* in Slovakia

Daniel Dítě[1], Pavol Eliáš Jr.[2]*, Zuzana Dítě[1], Andrea Šimková[3]

[1] Plant Science and Biodiversity Center, Institute of Botany, Slovak Academy of Sciences, Dúbravská cesta 9, 845 23 Bratislava, Slovakia
[2] Slovak University of Agriculture, A. Hlinku 2, 949 76 Nitra, Slovakia
[3] Administration of Latorica Protected Landscape Area, Záborského 1760/1, 075 01 Trebišov, Slovakia

* Corresponding author. Email: pavol.elias.jun@gmail.com

Abstract
Ludwigia palustris has always been a very rare species in Central Europe. In Slovakia, its occurrence remained unconfirmed for over 60 years and it was therefore considered extinct. The paper reports its rediscovery on two sites in SE Slovakia. Both localities were found in the Latorica River catchment area in 2015 when persistent summer droughts enabled the development of natural mudflat vegetation in the dried oxbows. Confirmation of this historic site indicates the long-term survival ability of the species. We assigned *L. palustris* dominated vegetation in the class *Isoëto-Nanojuncetea*, association *Ludwigio palustris-Lindernietum procumbentis*. This association is new to Slovakia as well as for Central Europe. The stands of this association developed on the exposed muddy shores of disconnected oxbow lake.

Keywords
pioneer wetland vegetation; periodically flooded habitats; *Isoëto-Nanojuncetea*; rare species; Central Europe

Introduction

Ludwigia is a pantropical genus of 82 species (87 taxa) currently divided into 23 sections [1–3], which is especially well represented in South and North America. In Europe, only one species, *Ludwigia palustris* (L.) Elliott is native. Six adventive species of *Ludwigia* genus occur in Europe: *Ludwigia alternifolia*, *L. grandiflora*, *L. hyssopifolia*, *L. peploides*, *L. repens*, and *L. uruguayensis* [4–7].

Ludwigia palustris is regarded as subatlantic-submediterranean-circumpolar species [8] with a large distribution range. It occurs in North America, central and northern part of South America, Africa (mainly in north and south parts of the continent), Asia (the temperate zone in the western part of the continent), and Europe. The European distribution range includes almost the entire continent except the N and NE parts. It is also known from the Caucasus (Georgia). Naturalized occurrence has been reported from Hawaii, Australia, and New Zealand [1,9,10].

In Central Europe, *L. palustris* is very rare. Most localities are situated in the western and southwestern parts of Hungary [11]. In the Hungarian red list, it is evaluated as vulnerable [12]. In Austria, the species is classified as critically endangered: although it is still present in southeastern part of the country, in western and southern regions it became already extinct [13–16]. In the Czech Republic, the plant is listed as an extinct species with unresolved historic distribution [17,18]. There are undated collections of Zahlbruckner from the vicinity of Nové Hrady (deposited in herbarium

PRC), evidently from the first half of the nineteenth century. There is no further collection or published data from the Czech Republic after that time (Grulich, personal communication, 2016). In Poland, it was found only in three locations in the western part of the country, in the Nysa Łużycka River basin. The last report of the species is from 1928. Recently, *L. palustris* has been declared extinct in Poland [19]. In Ukraine, *L. palustris* was found in a single location in the NE edge of the Pannonian lowland north of the town of Berehovo in the Čierny močiar marshland [20]. The species disappeared recently as a consequence of the marshland's drainage [21].

In Slovakia, there were known four historic sites of the species until the first half of the twentieth century, later it was considered as a missing species [8,22,23], recently as probably extinct [24].

Regarding its life form, *L. palustris* is perennial [1] but sometimes reported also as therophyte or hydrotherophyte [8,22]. Plants of the terrestrial form have more robust growth and shorter internodes, with smaller leaves than plants living in the water. The species habitat is restricted to lowland areas where it grows on shallow water bodies, e.g., in water reservoirs, ditches, and marshy banks of standing and slowly flowing waters. It requires wet, muddy, and sometimes flooded sandy soils poor in calcium and rich in nutrients and humus [8,19].

From the phytosociological point of view, in the study area, *L. palustris* is placed in the class *Isoëto-Nanojuncetea*, alliances *Nanocyperion flavescentis* and *Elatini-Eleocharition ovatae* [25,26], however, current data are lacking for Central Europe. Therefore, this study is aimed to (***i***) inform about both historical and recent localities of *L. palustris* in Slovakia, (***ii***) provide phytosociological data of stands with its presence in Slovakia, and (***iii***) compare the vegetation composition with other available published phytosociological data in the surrounding countries of Europe.

Material and methods

Study area

The field work was conducted in SE Slovakia in the Tisza River catchment area. Orographically it belongs to the Východoslovenská Lowland (SE Slovakia), which is the NE edge of the Pannonian Basin. The landscape is flat with minimal elevation difference (max. 10 m), and is formed by a dense network of the rivers Ondava, Laborec, Latorica, and Bodrog. The longest section is that of the Latorica River, which was very rich in meanders in the past. After the redirection of the riverbed between 1953 and 1965, the meanders have been preserved as oxbows and cut backwaters [27]. These places represent important areas for numerous wetland habitats rich in rare plant species within the intensively used landscape.

Collection and processing of data

The data concerning the distribution of the species were collected from herbaria BRA, BRNM, BRNU, SLO, PR, PRC, and SAV. Herbarium abbreviations are according to Vozárová and Sutorý [28]. The result of this study is presented on the grid map. The map was designed by the program ArcGis, version 9.2. Coordinates of historical localities were taken from Google Earth. Coordinates of recent localities were obtained during field research using GPS equipment (Garmin CS 60); the numbers of grid squares follow Niklfeld [29].

The phytosociological relevés were sampled according to the Zürich–Montpellier approach using the adapted 9-grade Braun-Blanquet's scale [30]. The species nomenclature for vascular plants follows *Flora Europaea* [31] and the names of syntaxa follow Jarolímek et al. [32], plant communities not included in the above-mentioned reference are supplied with author abbreviations.

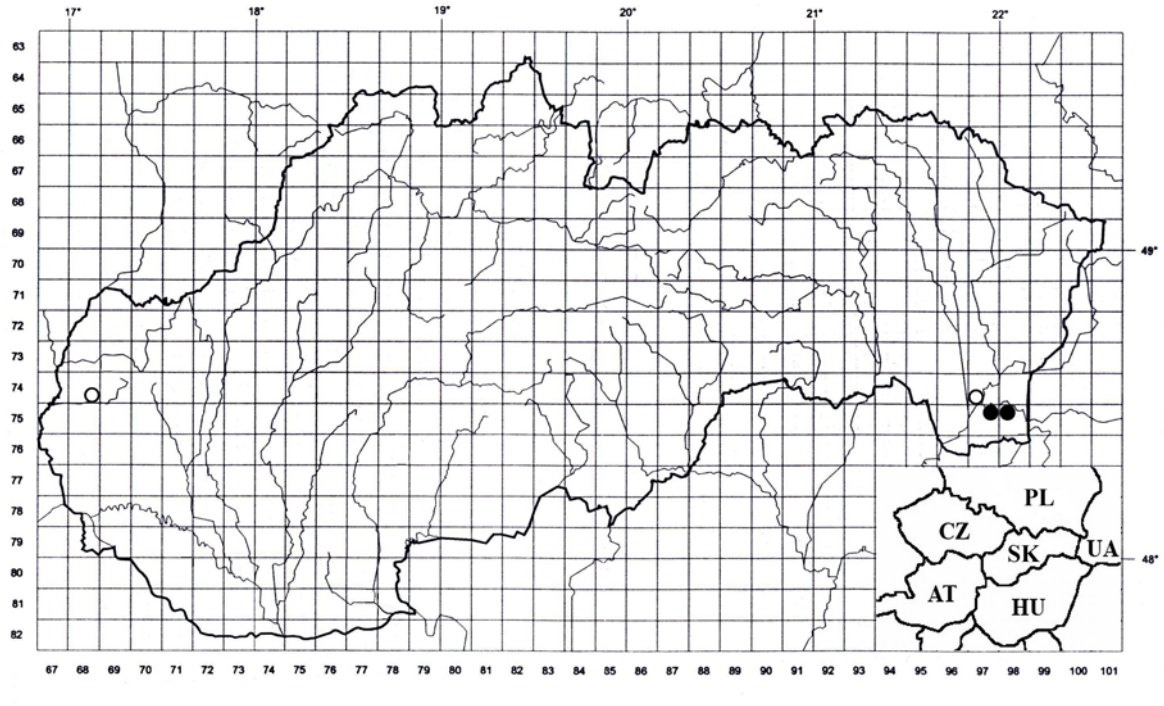

Fig. 1 Distribution of *Ludwigia palustris* in Slovakia: white circles – historical localities; black circles – recently confirmed localities.

Results

Historical occurrence of *Ludwigia palustris* in Slovakia

Based on the herbarium collections, *L. palustris* was documented in four locations in Slovakia (Fig. 1): in the Borská Lowland (W Slovakia) on the bank of the Rudava River in an area near the Studienka settlement (Staněk 1948 BRNU, SLO, PR, PRC) and in the Východoslovenská Lowland (SE Slovakia) in two sites close to each other, Zatín, oxbow of the Latorica River in the confluence area with the Laborec River (Staněk 1947 BRNM) and Oborín, in the lower part of the woodlands in the confluence area of the above-mentioned rivers (Staněk 1947 BRNM, BRNU). The fourth historical locality was found also in the bank of the Latorica River near the bridge of the road to Kráľovský Chlmec (Holub 1952 ined. in [22]), however, herbarium specimen documenting this locality is missing.

Ludwigia palustris population and vegetation composition on recent locality No. 1

The first recent locality is situated near Zatín settlement in the dried oxbow of the Latorica River inundation area. After the water decrease shallow muddy banks of the internal oxbow were densely covered with *Nuphar lutea*, and *L. palustris* grew on the margins of the oxbow accompanied by other dwarf therophytes. Stands of *L. palustris* covered ca. 70 × 20 m, while on a quarter of the occupied area its cover reached more than 25%. The populations were concentrated closer to the drier riverbank. The mentioned locality is identical with the historical site of *L. palustris* where original flow of the Latorica River was situated in the past (above-mentioned herbarium collection of Staněk). In spite of the river regulation, *L. palustris* has been preserved on the site. The vegetation is characterized by Relevés 1–3 in Tab. 1. According to the species composition, we assign Relevés 1 and 2 into the class *Isoëto-Nanojuncetea*, alliance *Elatini-Eleocharition ovatae*, association *Ludwigio palustris-Lindernietum procumbentis* Felzines, Loiseau & Portal 2002. On the same site, closer to the *Magnocaricion* belt among the dense stands of *Scirpus radicans* prostrate, low-herb stands of mudflat

Tab. 1 Phytosociological table of *Ludwigia palustris* relevés sampled during the study in Slovakia.

Relevé number	**1**	**2**	**3**	**4**
Relevé plot size m²	**16**	**16**	**16**	**16**
E_0	**0**	**5**	**0**	**0**
E_1	**98**	**90**	**95**	**95**
No. of species	**13**	**20**	**15**	**13**
Dominant and diagnostic species of the associations *Ludwigio-Lindernietum* and *Scirpetum radicantis*				
Ludwigia palustris	5	1	+	5
Eleocharis acicularis	1	+	+	.
Oenanthe aquatica	.	+	.	+
Scirpus radicans	.	.	5	.
Isoëto-Nanojuncetea				
Cyperus fuscus	+	3	+	.
Gnaphalium uliginosum	.	+	+	+
Cyperus michelianus	.	2a	+	.
Potametea				
Nuphar lutea	1	2b	+	.
Phragmito-Magno-Caricetea				
Carex acutiformis	+	.	1	+
Catabrosa aquatica	1	+	.	+
Rorippa amphibia	+	+	.	1
Eleocharis palustris	2a	.	1	.
Alisma lanceolatum	+	.	.	.
Alisma plantago-aquatica	.	.	.	+
Lysimachia vulgaris	.	.	.	+
Lythrum salicaria	+	.	.	.
Sparganium erectum	.	.	.	+
Bidentetea				
Bidens frondosus	+	+	+	+
Echinochloa crus-galli	.	2a	+	r
Persicaria hydropiper	1	1	1	.
Persicaria lapathifolia	.	.	+	.
Persicaria minor	.	.	.	r
Other species				
E_1				
Cirsium arvense	.	r	.	r

vegetation were found, together with a small population of *L. palustris* (Relevé 3; Tab. 1). The vegetation belongs to the association *Scirpetum radicantis* from the alliance *Oenanthion aquaticae* within the class *Phragmito-Magnocaricetea*. In this stand, *L. palustris* had only a marginal occurrence.

Ludwigia palustris population and vegetation composition on recent locality No. 2

The second recent locality was found between Kráľovský Chlmec and Veľké Kapušany at the bridge crossing the Latorica River. This recently found site is identical to locality mentioned by Holub. The species was observed within an 80-meter-long section of the river in about 10–18 meters wide belt of the exposed bottom reaching from the decreased water level to the oxbow shoreline overgrown with tussocks of perennial sedges (e.g., *Carex acuta*, *C. acutiformis*, *C. melanostachya*). *Ludwigia palustris* has occured here sporadically in small groups and also in large (>100 m²) carpet-like stands depending to length of flood and bottom exposure. Carpet-like stands have occurred on dryer sites which were exposed for longer time; small groups of *L. palustris* individuals have occupied wet, shortly exposed parts of river bank closer to water level. The vegetation of Relevé 4 is similar to Relevés 1 and 2 (Tab. 1), therefore, we included it to the association *Ludwigo palustris-Lindernietum procumbentis*.

Vegetation of *Ludwigia palustris* in Slovakia

There was not available phytosociological material about the vegetation of *L. palustris* in Slovakia. One remark gave Dostál [8] indicating it as part of the alliances *Nanocyperion flavescentis*, *Elatini-Eleocharition ovatae*, and *Magnocaricion elatae*, but it is not clear whether it is based on data from Slovakia. The only brief species list was available in labels of Staněk's herbarium vouchers of *L. palustris*. In SE Slovakia near Zatín, *L. palustris* occurred together with *Trapa natans*, *Alisma plantago-aquatica*, *Oenanthe aquatica*, and *Echinochloa crus-galli* (Staněk 1947 BRNM). From this poor list of species, is not clear what type of vegetation was occupied by *L. palustris*. In the same region, near Oborín, Staněk (1947 BRNM, BRNU) reported the species in low swards with *Cyperus michelianus*, *C. fuscus*, *Lindernia procumbens*, *Gnaphalium uliginosum*, *Alisma plantago-aquatica*, *Echinochloa crus-galli*, and *Eleocharis acicularis*. The species composition indicates a typical stand of the alliance *Elatini-Eleocharition ovatae* from the class *Isoëto-Nanojuncetea*.

Discussion

Occurrence in Slovakia

In Slovakia, the oldest remark of *L. palustris* was published by Polívka et al. [20] from the Latorica River (SE Slovakia) without a particular localization and dating. Shortly after

Tab. 1 Continued

Plantago major	.	1	.	.
Lycopus europaeus	.	.	+	.
Rorippa sylvestris	.	.	+	.
Sonchus arvensis	.	+	.	.
Sonchus oleraceus	.	+	.	.
E_0				
Physcomitrium pyriforme	.	1	.	.
Riccia cavernosa	.	1	.	.

Localities of relevés (for relevés, the header data are listed in the following order: number of relevé, locality, coordinates, altitude, sampling person, sampling date):
1 – Zatín, exposed muddy bottom of the Latorica oxbow. E 48°29′51.0″; N 21°56′09.6″; altitude 100 m, sampled by DD, ZM, PE, AŠ, 2015-09-09.
2 – Zatín, exposed muddy bottom of the Latorica oxbow. E 48°29′51.0″; N 21°56′09.6″; altitude 100 m, sampled by DD, ZM, PE, AŠ, 2015-09-09.
3 – Zatín, exposed muddy bottom of the Latorica oxbow. E 48°29′49.9″; N 21°56′10.6″; altitude 100 m, sampled by DD, ZM, PE, AŠ, 2015-09-09.
4 – oxbow of the Latorica River, east from the bridge of the road between Kráľovský Chlmec and Veľké Kapušany, exposed muddy bottom. E 48°29′56.8″; N 22°03′02.7″; altitude 99 m, sampled by AŠ, 2015-09-29.

WWII, Staňek collected the most data (a single site in W Slovakia as well as in two sites in the south-east). The last historic data were given in early fifties from the Latorica River, near the bridge on the road to Kráľovský Chlmec (Holub 1952 in [22]). Since 1953, it has been considered as a missing species in Slovakia [8,23], or as probably extinct [24]. Later, the botanical research in the area was scarce and has become more intensive again in the last 20 years. Several valuable records on rare plants of exposed bottoms were obtained, e.g., *Carex bohemica* [33], *Lindernia procumbens*, *Cyperus michelianus*, *Heleochloa alopecuroides* [34–36], *Elatine hungarica* [37], or *Isolepis supina* [38]. However, the origin of *L. palustris* in both recent localities is more likely to be related to the synergic effect of favorable climatic conditions and persistent seed bank than the intensity of research in the area. The late summer of the year 2015 was characterized by extremely high temperatures in Central Europe [39]. The recent occurrence of *L. palustris* is associated with the persistent summer droughts when the river oxbows provided suitable conditions for the species with optimum on exposed bottoms of water bodies, including *L. palustris*. Similarly as the re-discovery of *Cyperus glomeratus* in Slovakia, which was found after 60 years in exposed banks of the Danube River [36,40]. Analogous examples are other rare hydrophilic plants, e.g., *Elatine* species, which occurrence significantly increased with high annual rainfall and the extent of inundated area [37,41]. Extreme moist or dry conditions enable the species to supplement/renew the seed bank and increase the probability of their long-term survival [42]. It is also well known that seeds of amphibian plants are able to germinate after several decades from the soil seed bank (e.g., [43–46]).

Vegetation of *Ludwigia palustris* in Europe

In many countries of Central and South Europe, namely Austria [15], Poland [19], Slovenia [47], and Ukraine [21], *L. palustris* is considered as characteristic species of the alliance *Nanocyperion flavescentis*. It is recorded from identical vegetation in the Pannonian region of Romania (*Nanocyperetalia*; *Nanocyperion flavescentis*) but also from the alliance *Magnocaricion elateae* (e.g., subassociation *Carici-Menyanthetum ludwigietosum palustris*, class *Phragmito-Magnocaricetea*) [48–50]. Similarly in Hungary, *L. palustris* is regarded as a characteristic species of *Nanocyperion flavescentis* [51], and in addition, Borhidi [52] described the association *Ludwigio-Caricetum pseudocyperi* Borhidi & Járai-Komlódi 1959 within the alliance *Magnocaricion elatae*. This pioneer vegetation develops in banks of peaty pools after the water recedes, dominant *Menyanthes trifoliata* retreats and the vacant niche is occupied by *L. palustris*. In addition, there is a higher number of peatland species [52–54].

In the Sava River basin of Croatia, *L. palustris* is reported in the class *Isoëto-Nanojuncetea*, in the association *Cyperetum flavescentis*. It occupies wet margins of shallow flooded depressions after the water retreats. Besides *L. palustris*, *Cyperus flavescens*, *Eleocharis acicularis*, *Juncus bufonius*, and *Hypericum humifusum* occur [55].

In Western and Southern Europe, where *L. palustris* is more common, it has been recorded in numerous other communities of aquatic and wetland vegetation. A comprehensive revision of the class *Isoëto-Nanojuncetea* provided Brullo and Minissale [56]. The alliance *Elatino-Eleocharition ovatae* is included in this class, in which *L. palustris* figures in six associations, in each case with high constancy (III). The highest constancy (IV) is found in the association *Eleocharito acicularis-Lindernietum procumbentis* Pignatti 1957. *Ludwigia palustris* is also present in another three associations in the alliance *Verbenion supinae* Slavnić 1951 within the mentioned class.

Felzines et al. [57] described the association *Ludwigio palustris-Lindernietum procumbentis* based on vegetation occurred in the La Dordogne River basin (SW France), and included it in the alliance *Elatini-Eleocharition ovatae*. The vegetation occupies dried shores of river oxbows which are wet through the entire growing season. The exposed bottom is usually sandy to loamy and *L. palustris* prefers shaded areas. Both characteristic species, *L. palustris* and *Lindernia procumbens*, cover 5–75% of the patches areas [57]. The third characteristic species is *Callitriche brutia*, but this species is found only with minimal cover. According to third version of the "International code of phytosociological nomenclature", this description is not valid for improper use for the type relevé name (holotype vs. holotypus) [58]. However, some specialists suggest that essentially correctly described syntaxa would not be considered invalid for these formal errors in fourth version of the Code (L. Mucina, personal communication, 2016).

De Foucault [59] in his extensive study of periodically flooded habitats of France, added into the characteristic species of the *Ludwigio palustris-Lindernietum procumbentis* more taxa: *Eleocharis ovata*, *Cyperus fuscus*, and *Persicaria hydropiper*. He also included it in the alliance *Elatini-Eleocharition ovatae*. In the same alliance, he distinguishes one more association with dominance of *L. palustris* and determines it as *Lythro portulae-Ludwigietum palustris* Robbe ex J.-M. Royer, Felzines, Misset & Thévenin 2006. This thermophilous association was also recorded by Guillereme and Galtier [60], who observed it in periodically inundated riverbanks, depressions, and water reservoirs in the Loire River basin.

In Spain, Rivas Martinez et al. [61] described the association *Ludwigio palustris-Cyperetum micheliani* and assigned it to the alliance *Nanocyperion flavescentis*. It is included in the same alliance by Costa el at. [62]. On the contrary, Brullo and Minissale [56] include this association in the alliance *Verbenion supinae*. In the published phytosociological relevés [61] of the association *Ludwigio palustris-Cyperetum micheliani*, *Cyperus michelianus* attains the highest cover, while *C. fuscus* reaches lower levels. Other constant but less dominant species are *L. palustris*, *Cynodon dactylon*, and *Paspalum vaginatum*. This vegetation consists mainly of therophytes and occupies sandy banks of rivers and flat depressions flooded until the beginning of summer [61,63].

According to Felzines and Loiseau [64], *L. palustris* is marginally represented in the class *Bidentetea tripartitae* as well (alliance *Chenopodion glauci*) in four associations: *Leersio-Bidentetum tripartitae* (Koch 1926) Poli et J. Tx. 1960, *Polygonetum lapathifolii* Ujvarosi 1940, and in two associations described by them: *Persicario lapathifoliae-Echinochloetum crus-galli* and *Amarantho emarginati-Chenopodietum rubri*. In their relevés, *Persicaria minor*, *P. hydropiper* and the non-native *Bidens frondosa* dominate, each with high constancy (V). Another constant species (IV) are *L. palustris*, *Leersia oryzoides*, *Lycopus europaeus*, and *Aster lanceolatus*. These ruderalized stands are situated on wet, calcium-poor soils on riverbanks. This shows that the coenological optimum of *L. palustris* in Western and Southern Europe is on the interface between the classes *Isoëto-Nanojuncetea* and *Bidentetea tripartitae*. Moreover, *L. palustris* is mentioned as a rare component of oligotrophic aquatic communities of the class *Littorelletea uniflorae* in this part of Europe (especially within the alliance *Elodo palustris-Sparganion* Braun-Blanq. et Tüxen ex Oberd. 1957) [65–67].

Dimopoulos et al. [68] reported several communities with *L. palustris* over a large area of the Kalodiki Fen in Greece. As a characteristic species they indicate *Phalaris arundinacea*. The frame community of *P. arundinacea* occurs in nutrient-rich waters on mineral or organic soils with strongly fluctuating water level in summer. From the same area, they defined the plant community *Ludwigia palustris* and included it in the class *Bidentetea tripartitae*, alliance *Bidention tripartitae*. The species-poor stands are developed by the dominance of *L. palustris* and *Agrostis stolonifera*, while *Utricularia australis* appears less frequently. It occurs only rarely in moderately drying calcium-poor eutrophic marshes grazed by water birds.

From the Balkans (Skadar Lake on the Montenegro side), Lakušić and Pavlović [69] described new association *Ludwigietum palustris* as part of the class of strictly aquatic vegetation *Potametea*. This community is created by a significant dominance (>75%) of *L. palustris* and the dense stands of the submerged form of the plant are accompanied by low cover of *Persicaria amphibia*. Lakušić and Pavlović [69] mentioned

several other associations of aquatic vegetation where *L. palustris* is present in low cover, for instance, *Potametum perfoliati* and *Nyphoidetum peltatae*. The cover of *Nyphoides peltata* exceeds 50% here, while *Persicaria amphibia* and *L. palustris* are less dominant.

Conclusions

Ludwigia palustris, a missing species of Slovak flora was recently confirmed at two historical localities in SE Slovakia (Zatín, Kráľovský Chlmec), over more than 60 years. It demonstrates the long-term survival of the species on the sites due to its persistent soil seed bank. Since the local habitat conditions changed rapidly, the occurrence is probably dependent on the particular climatic conditions.

Phytosociological relevés provide the first coenological data on *L. palustris* for Slovakia. After comparison with the available European phytosociological studies, we classified our relevés dominated by *L. palustris* as the association *Ludwigio palustris-Lindernietum procumbentis* (alliance *Elatini-Eleocharition ovatae*, class *Isoëto-Nanojuncetea*). This plant community was previously known neither from Slovakia nor from the other countries of Central Europe, therefore, our data enlarges the knowledge about its recent distribution. For the first time, the species is reported from the association *Scirpetum radicantis* (*Phragmito-Magno-Caricetea* class). Reasons why *L. palustris* was not yet recorded in this community are probably related to its limited distribution as well as quite scarce occurrence of *Scirpetum radicantis* even in the countries in which it is reported [70–73].

In eastern part of the Central Europe, on the western border of its European distribution, the species has narrower ecological and coenological amplitude. Although it was rarely recorded in stands of the class *Phragmiteto-Magno-Caricetea* (alliance *Magnocaricion elateae*), its optimal vegetation conditions are in the class *Isoëto-Nanojuncetea*, in two alliances: *Nanocyperion flavescentis* and *Elatini-Eleocharition ovatae*. These plant communities have recently become very rare due to habitat destruction, river regulation and eutrophication [43,53,74]. Therefore, *L. palustris* is there more endangered than in Western and Southern Europe, where it occurs in a large variety of wetland vegetation [75], at least in five different classes (*Isoëto-Nanojuncetea*, *Bidentetea tripartitae*, *Phragmito-Magnocaricetea*, *Potametea*, and *Litorelletea uniflorae*).

Acknowledgments

We are grateful to Miloš Balla (Latorica Protected Landscape Area) for his guidance in the field and Stéphane Thevenin (Société Botanique du Centre Ouest), Laco Mucina (the University of Western Australia) as well as Ján Kliment (Botanical Garden of the Comenius University) for their fruitful discussion about syntaxonomical issues. We are indebted also to two anonymous reviewers for valuable comments to the manuscript.

References

1. Raven PH. The old world species of *Ludwigia* (including *Jussiaea*), with a synopsis of the genus (Onagraceae). Reinwardtia. 1963;6:327–427.
2. Ramamoorthy TP, Zardini EM. The systematics and evolution of *Ludwigia* sect. *Myrtocarpus* sensu lato (Onagraceae). St. Louis, MO: Missouri Botanical Garden; 1987. (Monographs in Systematic Botany from the Missouri Botanical Garden; vol 19).
3. Zardini EM, Raven PH. A new section of *Ludwigia* (Onagraceae) with a key to the sections of the genus. Syst Bot. 1992;17:481–485. https://doi.org/10.2307/2419486
4. Dandelot S, Verlaque R, Dutartre A, Cazaubon A. Ecological, dynamic and taxonomic problems due to *Ludwigia* (Onagraceae) in France. Hydrobiologia. 2005;551:131–136. https://doi.org/10.1007/s10750-005-4455-0
5. Ferrer PP, Laguna E. Sobre *Ludwigia hyssopifolia* (G. Don) Exell (Onagraceae)

como integrante de la flora subespontánea valenciana. Acta Botanica Malacitana. 2009;34:228–230.

6. Hussner A. Alien aquatic plants in European countries. Weed Res. 2012;52:397–406. https://doi.org/10.1111/j.1365-3180.2012.00926.x
7. Lukács BA., Mesterházy A, Vidéki R, Király G. Alien aquatic vascular plants in Hungary (Pannonian ecoregion): historical aspects, data set and trends. Plant Biosyst. 2014;148:1–8.
8. Dostál J. Veľký kľúč na určovanie vyšších rastlín II. Bratislava: SPN; 1992.
9. Peng CI, Schmidt CL, Hoch PC, Raven PH. Systematics and evolution of *Ludwigia* section *Dantia* (Onagraceae). Ann Mo Bot Gard. 2005;92:307–359.
10. Wagner WL, Hoch PC, Raven PH. Revised classification of the Onagraceae. Syst Bot Monogr. 2007;83:1–240.
11. Bartha D, Király G, Schmidt D, Tiborcz V, Barina Z, Csiky J, et al., editors. Magyarország edényes növényfajainak elterjedési atlasza. Sopron: Nyugat-magyarországi Egyetem Kiadó; 2015.
12. Király G, editor. Vörös lista. A magyarországiedényes flóra veszélyeztetettfajai. Sopron: Saját Kiadás; 2007.
13. Zimmermann A, Kniely G, Melzer H, Maurer W, Höllriegl R. Atlas gefährdeter Farn- und Blütenpflanzen der Steiermark. Graz: Joanneum-Verein; 1989. (Mitteilungen der Abteilung für Botanik am Landesmuseum Joanneum in Graz).
14. Melzer H. Neues zur Flora der Steiermark, XLI. Mitteilungen des Naturwissenschaftlichen Vereins für der Steiermark. 2005;134:153–188.
15. Fischer MA, Adler W, Oswald K. Exkursionsflora für Österreich, Liechtenstein und Südtirol. 2., verbesserte und erweiterte Auflage. Linz: OÖ Landesmuseen; 2005.
16. Niklfeld H, Schratt-Ehrendorfer L. Rote Liste gefährdeter Farn- und Blütenpflanzen (Pteridophyta und Spermatophyta) Österreichs. 2. Fassung. In: Niklfeld H, editor. Rote Listen gefährdeter Pflanzen Österreichs. 2nd ed. Wien: Grüne Reihe des Bundesministerium für Umwelt, Jugend und Familie; 1999. p. 33–151.
17. Čeřovský J, Feráková V, Holub J, Maglocký Š, Procházka F, editors. Červená kniha ohrozených a vzácnych druhov rastlín a živočíchov SR a ČR. Vol. 5. Vyššie rastliny. Bratislava: Príroda; 1999.
18. Grulich V. Red list of vascular plants of the Czech Republic. 3rd ed. Preslia. 2012;84:631–645.
19. Zarzycki K. *Ludwigia palustris* (L.) Elliott. In: Kaźmierczakowa R, Zarzycki K, Mirek Z, Adamowski W, Babczyńska-Sendek B. Polska czerwona księga roślin: paprotniki i rośliny kwiatowe. 3rd ed. Kraków: Instytut Ochrony Przyrody PAN; 2014. p. 346–347.
20. Polívka F, Domin K, Podpěra J. Klíč k úplné květeně ČSR. Olomouc: Promberger; 1928.
21. Pryadko AL, Andrienko TL. Lyudvihiya bolotna – *Ludwigia palustris* (L.) Elliott. In: Didukh JP, editor. Červona kniga Ukrajiny. Kiiv: Globalkonsalting; 2009. p. 528.
22. Zahradníková K. *Ludwigia* L. In: Bertová L, editor. Flóra Slovenska vol IV/4. Bratislava: Veda; 1988. p. 431.
23. Feráková V, Maglocký Š, Marhold K. Červený zoznam papraďorastov a semenných rastlín. Ochrana Prírody. 2001;20(suppl):44–76.
24. Eliáš P jun, Dítě D, Kliment J, Hrivnák R, Feráková V. Red list of ferns and flowering plants of Slovakia. 5th edition (October 2014). Biologia. 2015;70(2):218–228.
25. Oberdorfer E. Pflanzensoziologische Exkursionsflora. Stuttgart: Eugen Ulmer Verlag; 1990.
26. Ellenberg H. Vegetation Mitteleuropas mit den Alpen. Stuttgart: Eugen Ulmer Verlag; 1996.
27. Šimková A, Plačková A, Molitoris Ľ. Všeobecná prírodovedná charakteristika okresu Trebišov. Bulletin Slovenskej Botanickej Spoločnosti. 2014;36(1 suppl):5–25.
28. Vozárová M, Sutorý K, editors. Index herbariorum Reipublicae bohemicae et Reipublicae slovacae. Praha: Česká botanická společnost; 2001. (Bulletin Slovenskej Botanickej Spoločnosti pri Slovenskej Akadémii Vied. Supplement; vol 7).
29. Niklfeld H. Bericht über die Kartierung der Flora Mitteleuropas. Taxon. 1971;20:545–571. https://doi.org/10.2307/1218258
30. Barkman JJ, Doing H, Segal S. Kritische Bemerkungen und Vorschläge zur

quantitativen Vegetationsanalyse. Acta Botanica Neerlandica. 1964;13:394–419. https://doi.org/10.1111/j.1438-8677.1964.tb00164.x

31. Tutin GT, Heywood VH, Burges NA, Moore, DM, Valentine DH, Walters S, et al., editors. Flora Europaea, Vol. 5: Alismataceae to Orchidaceae (Monocotyledones). Cambridge: Cambridge University Press; 1980.
32. Jarolímek I, Šibík J, Hegedüšová K, Janišová M, Kliment J, Kučera P, et al. A list of vegetation units of Slovakia. In: Jarolímek I, Šibík J, editors. Diagnostic, constant and dominant species of the higher vegetation units of Slovakia. Bratislava: Veda; 2008. p. 295–329.
33. Dítě D, Eliáš P, Melečková Z. Ostrica česká (*Carex bohemica* Schrad.), známy-neznámy druh slovenskej flóry. Bulletin Slovenskej Botanickej Spoločnosti. 2015;37(2):169–179.
34. Bogoly J. Királyhelmec és Felső-Bodrogköz természetrajza és történelme. Bratislava: Madách; 1992.
35. Bubíková K, Hrivnák R, Slezák M. Zajímavé nálezy vodních a mokřadních rostlin z území Slovenska. Bulletin Slovenskej Botanickej Spoločnosti. 2016;38:47–62.
36. Dítětová Z, Dítě D, Letz RD, Eliáš P jun. New records of rare species on exposed river banks and pools in southern Slovakia. Thaiszia. 2016;26(1):57–75.
37. Takács A, Schmotzer A, Jakab G, Deli T, Mesterházy A, Király G, et al. Key environmental variables affecting the distribution of *Elatine hungarica* in the Pannonian Basin. Preslia. 2013;85:193–207.
38. Zlacká S, Sádovský M, Dítě D, Eliáš P ml. Súčasné poznatky o výskyte a cenologických väzbách *Schoenoplectus supinus* (Cyperaceae) na Slovensku. Bulletin Slovenskej Botanickej Spoločnosti. 2006;28:149–158.
39. Ionita M, Tallaksen LM, Kingston DG, Stagge JH, Laaha G, van Lanen HAJ, et al. The European 2015 drought from a climatological perspective. Hydrology and Earth System Sciences. 2017;21:1397–1419. https://doi.org/10.5194/hess-21-1397-2017
40. Melečková Z, Dítě D, Eliáš P jun, Schmidt D. *Cyperus glomeratus* L. – rediscovered in Slovakia. Hacquetia. 2016;15(1):93–100.
41. Popiela A, Łysko A. The distribution of *Elatine macropoda* Guss. (Elatinaceae). Acta Soc Bot Pol. 2010;79(1):81–86. https://doi.org/10.5586/asbp.2010.011
42. Eliašová M, Eliáš P, Zuzulová V, Šiška B. The positive effect of extreme weather: the new localities of selected endangered plant species found during extremely moist year 2010. Mendel and bioclimatology. Brno: Masaryk University; 2014.
43. Šumberová K. MA *Isoëto-Nano-Juncetea* Br.-Bl. et Tüxen ex Br.-Bl. et al. 1952. In: Chytrý M, editor. Vegetace ČR. 3. Vodní a mokřadní vegetace. Praha: Academia; 2011. p. 309–312.
44. Šumberová K, Lososová Z, Fabšičová M, Horáková V. Variability of vegetation of exposed pond bottoms in relation to management and environmental factors. Preslia. 2006;78:235–252.
45. Molnár VA, Sonkoly J, Lovas-Kiss Á, Fekete R, Takács A, Somlyay L, et al. Seed of the threatened annual legume, *Astragalus contortuplicatus*, can survive over 130 years of dry storage. Preslia. 2015;87:319–328.
46. Richert E, Achtziger R, Dajdok Z, Günther A, Heilmeier H, Hübner A, et al. Rare wetland grass *Coleanthus subtilis* in Central and Western Europe – current distribution, habitat types, and threats. Acta Soc Bot Pol. 2016;85(3):3511. https://doi.org/10.5586/asbp.3511
47. Jogan N, Kotarac M, Lešnik A, editors. Opredelitev območij evropsko pomembnih negozdnih habitatnih tipov s pomočjo razširjenosti značilnih rastlinskih vrst. Naročnik: MOPE and Center za kartografijo favne in flore, Miklavž na Dravskem polju; 2004.
48. Karácsonyi C. Flora și vegetația județului Satu Mare. Satu Mare: Editura muzeului Sătmărean; 1995.
49. Dihoru G, Negrean G. *Ludwigia palustris* (L.) Elliott. In: Dihoru G, Negrean G, editors. Cartea roșie a plantelor vasculare din România. București: Editura academiei Române; 2009. p. 329–330.
50. Sanda V, Öllerer K, Burescu P. Fitocenozele din România. Sintaxonomie, structură, dinamică și evoluție. București: Editura Ars Docendi; 2008.
51. Soó R. A magyar flóra és vegetáció rendszertani-növényföldrajzi kézikönyve. VI. Budapest: Akadémiai Kiadó; 1980.
52. Borhidi A. An annotated checklist of the Hungarian plant communities. I. The non-forest

vegetation. In: Borhidi A, editor. Critical revision of the Hungarian plant communities. Pécs: Janus Pannonius Univesity; 1996. p. 43–94.

53. Csiky J, Bagi I, Pfeiffer N, Lájer K, Tímár G, Molnár Z. I1 – Nedves felszínek természetes pionír növényzete. In: Bölöni J, Molnár Z, Kun A, editors. Magyarország Élőhelyei. Vegetációtípusok leírása és határozója. Vácrátót: MTA Ökológiai és Botanikai Kutatóintézete; 2011. p. 188–191.
54. Borhidi A, Kevey B, Lendvai G. Plant communities of Hungary. Budapest: Akadémiai Kiadó; 2012.
55. Topić J, Ilijanić LJ, Tvrtković N. Amfibijske zajednice vegetacije niskihšiljeva. In: Topić J, Vukelić J, editors. Priručnik za određivanje kopnenih staništa u Hrvatskoj premadirektivi o staništima EU. Zagreb: Državni zavod za zaštitu prirode; 2009.
56. Brullo S, Minissale P. Considerazioni sintassonomiche sulla classe *Isoëto-Nanojuncetea*. Itinera Geobotánica. 1998;11:263–290.
57. Felzines JC, Loiseau JE, Portal R. Observations sur les groupements pionniers herbacés des alluvions du lit apparent de la Dordogne quercynoise. Le Monde de Plantes. 2002;476:26–32.
58. Weber HE, Moravec J, Theurillat JP. International code of phytosociological nomenclature. 3rd ed. J Veg Sci. 2000;71:739–768. https://doi.org/10.2307/3236580
59. de Foucault B. Contribution au prodrome des végétations de France: les *Isoëtetea velatae* de Foucault 1988 et les *Juncetea bufonii* de Foucault 1988 ("*Isoëto-Nanojuncetea bufonii*") (Partie 2). Journal de Botanique de la Société Botanique de France. 2013;63:63–109.
60. Guillerme N, Galtier J. Les espèces végétales protégées des étangs de la plaine du Forez (Loire). Bull Mens Soc Linn Lyon. 2009;78(7–8):187–200.
61. Rivas Martínez S, Costa M, Castroviejo S, Valdés E. Vegetación de Doñana (Huelva, España). Lazaroa. 1980;2:5–189.
62. Costa JC, Neto C, Aguiar C, Capelo J, Espírito Santo MD, Honrado J, et al. Vascular plant communities in Portugal (Continental, Azores and Madeira). Global Geobotany. 2012;2:1–180.
63. Rivas-Martínez S, Fernández-González F, Loidi J, Lousã M, Penas A. Syntaxonomical check-list to association level of Spain and Portugal (Iberian Peninsula, Balearic, Madeira, Azorean and Canary Islands). Itinera Geobotánica. 2001;14:5–341.
64. Felzines JC, Loiseau JE. Les groupements fluviatiles des Bidentetea de la Loire moyenne, du bas Allier et de la Dordogne moyenne. Modifications apportées à la synsystématique de la classe des *Bidentetea*. Bulletin de la Société Botanique du Centre-Ouest, N.S. Tom. 2005;36:159–204.
65. Rodríguez-Oubiña J, Romero MI, Ortiz S. Communities of the class *Littorelletea uniflorae* in the northwest Iberian Peninsula. Acta Bot Gallica. 1997;144(1):155–169. https://doi.org/10.1080/12538078.1997.10515762
66. Klotz S, Kühn I, Durka W. BIOLFLOR – eine Datenbank mit biologisch-ökologischen Merkmalen zur Flora von Deutschland. Bonn: Bundesamt für Naturschutz, 2002.
67. de Foucault B. Contribution au prodrome des végétations de France: les *Littorelletea uniflorae* Braun-Blanq. & Tüxen ex Westhoff, Dijk & Passchier & Sissingh 1946. Journal de Botanique de la Société Botanique de France. 2010;52:43–78.
68. Dimopoulos P, Sykora K, Gilissen C, Wiecherink D, Georgiadis T. Vegetation ecology of Kalodiki fen (NW Greece). Biologia. 2005;60(1),69–82.
69. Lakusić R, Pavlović D. Vegetacija Skadarskog jezera. Glasnik Reickog Zavoda za Zastitu Prirode i Prirodnjackog Muzeja Titogradu. 1976;9:45–50.
70. Hroudová Z, Ekrt L, Ekrtová E, Šumberová K. MCC05 *Scirpetum radicantis* Nowiński 1930. In: Chytrý M, editor. Vegetace České republiky. 3. Vodní a mokřadní vegetace. Praha: Academia; 2011. p. 462–465.
71. Oťaheľová H, Hrivnák R, Valachovič M. *Phragmito-Magnocaricetea*. In: Valachovič M, editor. Rastlinné spoločenstvá Slovenska 3. Vegetácia mokradí. Bratislava: Veda; 2001. p. 51–183.
72. Spałek K, Nowak A. *Scirpetum radicantis* Hejný in Hejný et Husák 1978 em. Zahlh. 1979, a plant association new to Poland. Acta Soc Bot Pol. 2003;72(4):347–350. https://doi.org/10.5586/asbp.2003.046
73. Spałek K. *Scirpetum radicantis* Hejný in Hejný et Husák 1978 in Poland. Thaiszia. 2005;15:43–51.

74. Valachovič M, Oťahelová H, Hrivnák R. *Isoëto-Nanojuncetea*. In: Valachovič M, editor. Rastlinné spoločenstvá Slovenska 3. Vegetácia mokradí. Bratislava: Veda; 2001. p. 345–347.

75. Popiela A. *Isoëto-Nanojuncetea* species and plant communities occurring on their eastern distribution range (Poland). Phytocoenologia. 2005;35(2–3):283–303. https://doi.org/10.1127/0340-269X/2005/0035-0283