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Article

Formalised classification of the annual herb vegetation of wetlands (Isoëto-Nano-Juncetea class) in the Czech Republic and Slovakia (Central Europe)

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with 5 figures, 3 tables and 3 appendices

Abstract: Vegetation of ephemeral wetlands (class Isoëto-Nano-Juncetea) was studied in the Czech Republic and Slovakia using a formalised classification approach. We analysed a set of phytosociological relevés recorded in the study region comprising 17583 relevés of wetlands and some types of ruderal vegetation. Formal definitions of particular associations were completed using a dataset of 1580 relevés, originally assigned by their authors into the Isoëto-Nano-Juncetea class. 770 of these relevés were classified into one of the three alliances (Verbenion supinae, Eleocharition ovatae and Radiolion linoidis) and nine associations: Ranunculetum lateriflori (south-eastern Slovakia), Cerastio-Ranunculetum sardoi (mainly southern Slovakia and southern Moravia), Veronico anagalloidis-Lythretum hyssopifoliae (southern Moravia), Pulicario vulgaris-Menthetum pulegioidis (southern parts of both republics, especially in Slovakia), Polygono-Eleocharitetum ovatae (mainly southern Bohemia and the Bohemian-Moravian Uplands in the Czech Republic), Cyperetum micheliani (both republics), Stellario uliginosae-Isolepidetum setaceae (mainly in southern Bohemia and Bohemian-Moravian Uplands in the Czech Republic, less frequently in Slovakia), Centunculo-Anthoceretum punctati (only two relevés in both republics) and Junco tenageiae-Radioletum linoidis (southern Bohemia in the Czech Republic, Borská lowland in western and Orava region in northern Slovakia). The main environmental gradient of the studied vegetation expressed by Ellenberg indicator values (EIV) is moisture (Spearman correlation coefficient with the first DCA axes -0.666, $p < 0.001$), followed by light (-0.656, $p < 0.001$). Comparison of clusters based on EIV showed significant differences in several cases, mainly: 1) the significantly lowest EIV for temperature was detected for Stellario uliginosae-Isolepidetum setaceae and Junco tenageiae-Radioletum linoidis; 2) Polygono-Eleocharitetum ovatae had the highest EIV for moisture; and 3) Junco tenageiae-Radioletum linoidis had the lowest EIV for nutrients. Our study is one of the first attempts at formal classification of Isoëto-Nano-Juncetea vegetation in a relatively large area and to compare the ecology of the communities defined by this approach.

Keywords: Ellenberg indicator values, ephemeral wetlands, exposed pond bottoms, fishpond management, syntaxonomical revision

Introduction

Vegetation of ephemeral wetlands has attracted the attention of scientists since the beginning of modern systematic flora and vegetation research. Whereas studies of large-scale vegetation types, such as forests or grasslands, often had an economically motivated basis, studies of dwarf wetland annuals were motivated by the very interesting nature of the subject. Their occurrence in specific, highly dynamic habitats, the speed of plant development, short life cycles and long-term survival in dormant propagules and, related to these traits, that they are commonly subject to "disappearance" and "rediscovery" after several years, or even decades, are only some of the characteristics typical of wetland ephemeral herbs (Koch 1926, Ambrož 1939, Deil 2005). Most species and communities belonging to this group are considered to be rare. However, besides the extremely rare, even endemic taxa and syntaxa, there are also those with a large distribution range which are present in hundreds of localities on several continents (Lampe 1996). Nevertheless, due to its specific habitat ecology, it is only possible to observe ephemeral wetland vegetation for a relatively short period in each separate locality. There are usually only a few localities in a relatively large area where this vegetation can be observed at the same time. Large sections of the populations and/or communities of these particular species are at any time hidden in the soil propagule bank: repeated observations are therefore necessary to record them accurately (Poschlod 1993).

The rarity (independently of whether it is real or only apparent) of ephemeral wetland vegetation has promoted specialised studies in various parts of Europe (e.g. Pietsch 1963, Rivas Goday 1970, Popiela 1997, Täuber 2000), and also less frequently in non-European regions (e.g. Taran 2001, Sinelnikova & Taran 2006, Deil et al. 2011). As a result, thousands of relevés have been collected to date, and numerous associations have been described, with the earliest representing valid descriptions from the second and third decades of the 20th century (e.g. Allorge 1921, Horvatić 1931, Libbert 1932, Eggler 1933). In Europe, where this vegetation has been best described, and also in some parts of Asia, Africa and Northern America, ephemeral wetland communities are

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traditionally assigned to the class Isoëto-Nano-Juncetea Br.-Bl. et Tüxen ex Br.-Bl. et al. 1952. It is generally split into two orders, Isoëtetalia Br.-Bl. 1936, comprising the Mediterranean vegetation of therophytes and geophytes on temporarily waterlogged oligotrophic rocky habitats; and Nano-Cyperetalia Klika 1935, containing communities with prevailing therophytes on periodically flooded and exposed, mesotrophic to eutrophic habitats. According to Brullo & Minissale (1998), the Isoëto-Nano-Juncetea class in Europe has altogether 128 associations. However, this number did not include, for example, some Central European communities, which were probably unknown to the authors. Additionally, since the extensive review of Brullo & Minissale (1998) was published, further new associations were described. On one hand, this illustrates the large diversity of the Isoëto-Nano-Juncetea class in Europe; on the other hand, there is a rather large discrepancy between the number of characteristic species and associations described, especially within some alliances of the Nano-Cyperetalia order. In other words, some of the associations are probably defined too narrowly and not floristically well-distinguished from some other communities. This situation is related to the fact that most of the associations are "national associations", i.e. they were described on the basis of the data gathered in the territory of a single country, rather than across the whole area in which that community is distributed, which in many cases includes a large part of the continent. These problems on the levels of associations are replicated at the level of alliances. This confusing situation, among others, is a barrier to identification of conservation priorities within the Isoëto-Nano-Juncetea class.

A detailed revision of Isoëto-Nano-Juncetea, based on a large dataset of relevés from the whole of Europe, would therefore not only elucidate the syntaxonomical diversity of this class, but would also provide a better basis for habitat and vegetation conservation. In the last decade, formalised classification of vegetation (Bruelheide & Chytrý 2000, Chytrý 2000) has successfully been used for both small-scale and large-scale vegetation studies (e.g. Havlová 2006, Chytrý 2007, 2009, 2011, Janišová 2007, Janišová & Dúbravková 2010, Landucci et al. 2013, Svitková & Šibík 2013). In our opinion, it is also an optimal method for pan-European Isoëto-Nano-Juncetea classification, or for revision of the current classification.

The first attempt to classify this vegetation type on the basis of the Cocktail algorithm (produced by Bruelheide 1995, 2000) was done by Täuber (2000) and Täuber & Petersen (2000). The algorithm enables classification of large datasets under a supervision of an expert. The Cocktail algorithm was later included into more sophisticated programme JUICE (Tichý 2002) which is nowadays probably the most frequently used software for vegetation classification in Europe. Since the results of the classification process were strongly influenced by specific database characteristics (size, the number of various vegetation types, species richness, etc.), certain methodological improvements were needed (e.g. Chytrý et al. 2002, Kočí et al. 2003) to enable the application of this methodological approach even in ambitious projects, including the monograph Vegetation of the Czech Republic (Chytrý 2007, 2009, 2011).

To test the method on the dataset from different countries, to describe our experience of the method, and therefore provide a platform for European Isoëto-Nano-Juncetea revision, we chose the territory of Czech Republic and Slovakia. Although both countries were a part of one state until 1993 (Czechoslovakia), the classification of Isoëto-Nano-Juncetea on a national level was lacking. It was elaborated later, but after the countries had separated, and by different authors and on different datasets. This situation therefore provides a good opportunity to test the formalised classification.

At commencement of our study, the situation was as follows. In the Czech Republic, the first national overview of the Isoëto-Nano-Juncetea class was published by Hejný (in Moravec et al. 1995), using the method of "traditional phytosociology". It found in total 13 associations belonging to three alliances. Description of the class Isoëto-Nano-Juncetea for the third volume of the monograph Vegetation of the Czech Republic (Chytrý 2011), using the method of formalised classification, altogether revealed six broadly-defined associations of three alliances (Šumberová 2011). Some of the narrowly defined associations distinguished in an overview by Hejný (in Moravec et al. 1995) were merged with others.

In Slovakia, a comprehensive overview of the class Isoëto-Nano-Juncetea was published in 2001 (Valachovič et al. 2001). It summarised all the known information and relevé material about this vegetation type in the Slovak territory. In the last decade, several new papers covering the syntaxonomy and ecology of this vegetation have been published (e.g. Zaliberová & Májeková 2004, Májeková & Zaliberová 2008) and a number of new, unpublished data have been gathered. These facts point to the necessity of a new syntaxonomical classification of Isoëto-Nano-Juncetea on the Slovak territory, using the method of formalised classification.

Testing of the method of formalised classification on the dataset from the Czech Republic and Slovakia gave us an opportunity to improve determination of similarities and differences in the vegetation of the Isoëto-Nano-Juncetea class between both countries. The Slovak dataset had not yet been classified using formalised classification, and thus it was of interest to understand what the results of this approach would be in contrast to "classic" classification. Although the formalised classification of Isoëto-Nano-Juncetea on the territory of the Czech

Republic had been produced recently (Šumberová 2011), we considered its repetition using the larger dataset from a geographically more extensive and variable area might show its strong and weak points. This especially applied to communities which, in the Czech Republic, occur on the north-western border of their geographic distribution and are therefore not so well-developed floristically that they could be unequivocally formally defined.

The aims of our study were: (1) to classify the dataset of relevés of Isoëto-Nano-Juncetea from the Czech Republic and Slovakia, using a formalised classification approach; (2) to test the ecological differences between distinct associations using ordinations and Ellenberg indicator values; (3) to give a comprehensive description of species composition, ecology, dynamics, and distribution of all the communities, with particular attention to differences between the two countries; (4) to compare the new results with the currently accepted Czech and Slovak classifications, and discuss its possible implications for the pan-European Isoeto-Nano-Juncetea classification.

Methods

We analysed a set of phytosociological relevés recorded in the territories of the Czech Republic and Slovakia (Fig. 1). This dataset included 17 583 phytosociological relevés, both published and unpublished, of wetland and some types of ruderal vegetation obtained from national vegetation databases of the Czech Republic and Slovakia (Dengler et al. 2011), stored in the format of the phytosociological database software, Turboveg (Hennekens & Schaminée 2001). The relevés were originally assigned by their authors to one of the following classes: Littorelletea uniflorae, Isoëto-Nano-Juncetea, Bidentetea tripartitae, Phragmito-Magno-Caricetea and Stellarietea mediae (= Chenopodietea). Additionally, we used a separate dataset of 1580 relevés, originally assigned by their authors into the Isoëto-Nano-Juncetea class. Most of these relevés (about 60%) were of a plot size of 1 m², or, in several cases less than 1 m². The rest included mainly the relevés of plot size up to 16 m². Rarely, also the relevés of larger plot size were included into the dataset. These plots were made mainly in fishponds with frequent occurrence of large homogenous Isoëto-Nano-Juncetea stands. Under such circumstances even the larger plot size should not affect the classification. About 70% of relevés were gathered after 1990. The rest included mainly the relevés from the period between 1950's and 1980's. Older relevés were exceptional.

For further analysis, we exported both datasets separately from the Turboveg format into JUICE software, which enables phytosociological data processing (Tichý 2002). We firstly merged some narrowly defined species or subspecies (Appendix 1).

We then used the larger dataset for preliminary testing of the formal definitions of Isoëto-Nano-Juncetea associations delimited in the third volume of the Vegetation of the Czech Republic (Chytrý 2011). For distinct vegetation types which did not correspond to any definition, we produced new formal definitions, as follows. Firstly, we created new sociological species groups using the supervised classification method Cocktail (Bruelheide 2000) modified according to Kočí et al. (2003). The larger dataset was used for the analysis because a broader spectrum of different vegetation types is important for obtaining sociological species groups of more general validity (Kočí et al. 2003). These groups, together with groups adopted from the second and third volumes of the Vegetation of the Czech Republic (Chytrý 2009, 2011),

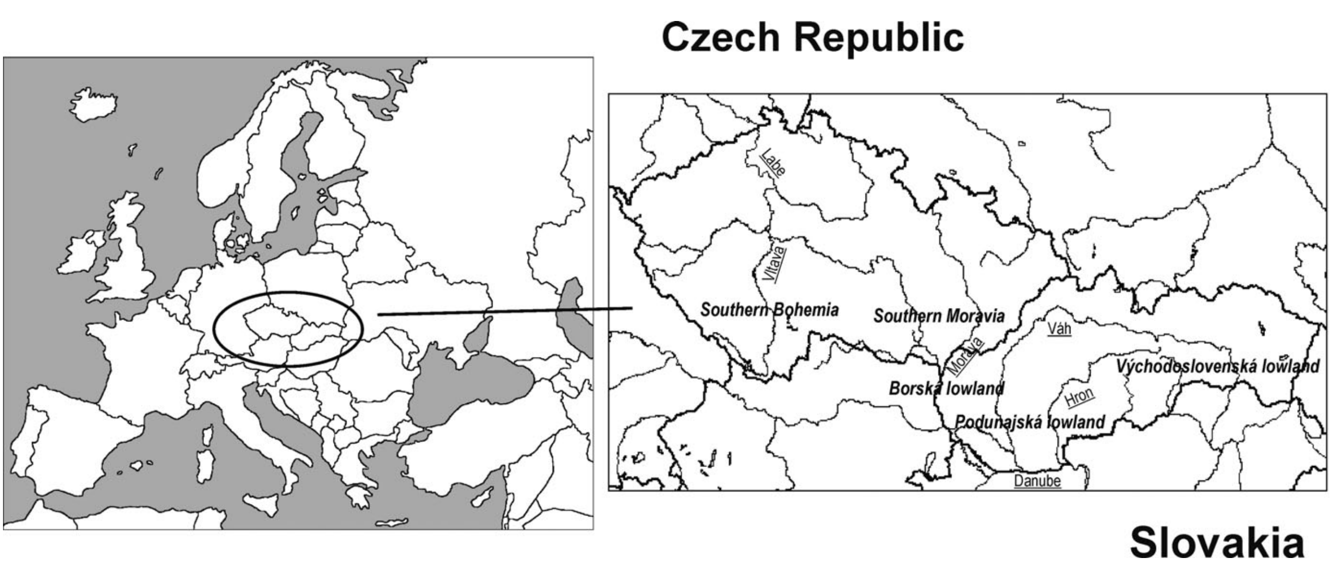

Fig. 1. Study area and its location in Europe.

are presented in the Appendix 2. Secondly, using Cocktail, we reviewed the smaller dataset containing only Isoëto-Nano-Juncetea communities. In this dataset, we produced formal definitions of individual associations. We used the logical operators AND, OR and NOT for determining which sociological groups must be present or absent in a relevé in order to assign this relevé to a particular association. Similarly as other authors (e.g. Havlová 2006, Chytrý 2007, 2009, 2011), we used the rule that the species group is considered to be present in the relevé if at least one half of its members is present.

As each of the classification steps was supervised by an expert, the process of formal definition creation simulated the expert-based method of "classical" phytosociological classification. However, the Cocktail method enables statistical control of the significance. In the presented definitions, sociological species groups were combined with species cover criteria, or species cover only was used for some definitions. Due to the common co-occurrence of ephemeral wetland vegetation and perennial wetland vegetation (e.g. Phragmito-Magno-Caricetea) in stands of which it often forms the lower herb layer, these perennials have to be eliminated by the operator NOT from the definitions. Formal definitions adopted from Chytrý (2011) were optimised for our dataset. This means that only the species groups and selected species with high cover (in the case of delimitation using species' cover value) occurring in our dataset, were used in our definitions. The definitions therefore demonstrated the main features of the associations; however, if applied to another dataset, some modifications might be necessary, e. g. in order to exclude some other perennials than those present in our dataset. In the characteristics of associations we present the definitions in the reader-friendly "text form", similarly as e.g. Chytrý (2007, 2009, 2011) or Landucci et al. (2013). At the same time, to allow the readers easy testing and modifying of our definitions on their own datasets, in the Appendix 3 we included the definitions in the form acceptable directly by JUICE program (Tichý 2002). This software was used for all above mentioned operations and for calculation of diagnostic, constant and dominant species. In accordance with the published volumes of the Vegetation of the Czech Republic (Chytrý 2007, 2009, 2011), species with a phi coefficient greater than 0.25 were considered diagnostic for a particular association. This threshold was determined subjectively in order to obtain appropriate numbers of diagnostic species, i.e. neither too many nor too few (cf. Chytrý 2007, 2009, 2011). In addition to the phi coefficient for each species and association, the statistical significance of the fidelity prior to equalization was calculated using Fisher's exact test (Chytrý et al. 2002). Based on this calculation, only species whose occurrence concentration in relevés of a particular association did differ from random occurrence at a level of significance of $P < 0.001$ were included in the group of diagnostic species. Constant and dominant species were those with a frequency of over 40% and with a cover value exceeding 25% in at least 5% of relevés, respectively. Within the group of diagnostic, constant and dominant species we differentiated highly diagnostic, highly constant and highly dominant species with threshold values of phi > 0.5, frequency > 80% and with cover value > 25% in at least 10% of relevés, respectively. All the diagnostic, constant and dominant species are listed alphabetically at characteristics of all detected associations (see Results and discussion, section Annotated checklist of syntaxa). Results of our analysis are presented in a shortened synoptic table, where each cluster represents a single association (Table 1).

Ecological gradients of detected associations were evaluated by Detrended Correspondence Analysis (DCA) using Canoco for Windows 4.5 software (ter Braak & Šmilauer 2002). For interpretation of the main environmental gradients, average non-weighted Ellenberg indicator values for light, temperature, continentality, soil reaction, moisture and nutrients (Ellenberg et al. 1992) were used as supplementary variables. Spearman correlation coefficients were used to determine interactions between position of relevé at the first two DCA axes and indicator values using Statistica software (Statsoft Inc. 2006). Nonparametric multiple comparisons computed by Kruskal-Wallis ANOVA test were used to find differences in EIV among clusters using Statistica software (StatSoft Inc. 2006). Distribution maps of all associations were prepared using D-map software (Morton 2005).

The nomenclature of plant communities, both original and synonymous names, follows the Vegetation of the Czech Republic (Šumberová 2011) and is in accordance with the International Code of Phytosociological Nomenclature (Weber et al. 2000). For names which were not presented in the mentioned vegetation survey, their original descriptions were checked so that we could ensure that the names are valid. The most widely-used synonymous names are presented too. In some cases, several associations were merged into one broadly defined association; and in comparison to other Isoëto-Nano-Juncetea studies (e.g. Pietsch 1973, Hejný in Moravec et al. 1995, Traxler 1993, Täuber & Petersen 2000, Valachovič et al. 2001), substantial changes in nomenclature were needed. In such cases, the oldest valid name had to be chosen, even if the name did not reflect well the association's content (e.g. Cyperetum micheliani, Stellario uliginosae-Isolepidetum setacei; see also Šumberová 2011). However, according to the Code (Weber et al. 2000), such cases are not the reason for rejection of the name. Nomenclature of plant taxa corresponds to the Central-European species list of vascular plants and bryophytes used in the JUICE software for data from Austria, the Czech Republic, Hungary and Slovakia (Tichý et al. 2011). The nomenclature of this checklist was not published, but is freely available on http://www.sci.muni.cz/botany/juice/newflora.txt.

Table 1. Synoptic table of the *Isoëto-Nano-Juncetea* plant communities in the Czech and Slovak Republic. Only species with a frequency > 10% in the whole dataset and species with a frequency > 20% in particular associations were presented. Diagnostic species of clusters are in bold and ordered by decreasing fidelity, expressed through Φ values multiplied by 100 (upper index).

Plant community	Ran	Ce-Ra	Ve-Ly	Pu-Me	Po-El	Cyp	St-Is	Ce-An	Ju-Ra
No. of relevés	4	41	14	10	356	198	122	2	23
Diagnostic species of associations									
Elatine alsinastrum	**100** $^{96.8}$	5 ---	. ---	. ---	. ---	1 ---	. ---	. ---	. ---
Ranunculus lateriflorus	**100** $^{94.9}$	10 ---	. ---	. ---	. ---	. ---	. ---	. ---	. ---
Alopecurus geniculatus	**75** $^{56.7}$	34 $^{17.4}$	. ---	20 ---	1 ---	5 ---	2 ---	. ---	9 ---
Ranunculus sardous	25 ---	**71** $^{68.6}$	. ---	. ---	. ---	. ---	1 ---	. ---	. ---
Capsella bursa-pastoris	. ---	**29** $^{48.1}$	. ---	. ---	1 ---	4 ---	. ---	. ---	. ---
Apera spica-venti	. ---	**22** $^{42.5}$	. ---	. ---	1 ---	. ---	2 ---	. ---	. ---
Cerastium dubium	25 ---	**37** $^{41.6}$	. ---	. ---	. ---	. ---	. ---	. ---	. ---
Polygonum aviculare agg.	. ---	**56** $^{36.4}$	14 ---	40 ---	3 ---	16 ---	17 ---	. ---	9 ---
Viola arvensis	. ---	**15** $^{36.4}$	. ---	. ---	. ---	. ---	. ---	. ---	. ---
Anagallis arvensis	. ---	**27** $^{33.5}$	7 ---	10 ---	. ---	1 ---	4 ---	. ---	. ---
Vicia tetrasperma	. ---	**12** $^{29.9}$	. ---	. ---	. ---	1 ---	2 ---	. ---	. ---
Convolvulus arvensis	. ---	**10** $^{29.6}$	. ---	. ---	. ---	. ---	. ---	. ---	. ---
Poa trivialis	. ---	**15** $^{28.7}$	. ---	. ---	1 ---	5 ---	2 ---	. ---	. ---
Tripleurospermum inodorum	50 ---	**78** $^{28.4}$	71 ---	40 ---	15 ---	29 ---	54 $^{11.0}$	. ---	13 ---
Elymus repens	. ---	**24** $^{27.7}$	14 ---	. ---	1 ---	3 ---	6 ---	. ---	4 ---
Triticum aestivum	. ---	**10** $^{27.2}$	. ---	. ---	1 ---	. ---	. ---	. ---	. ---
Thlaspi arvense	. ---	**10** $^{26.6}$	. ---	. ---	1 ---	2 ---	. ---	. ---	. ---
Helianthus annuus	. ---	**7** $^{25.6}$	. ---	. ---	. ---	. ---	. ---	. ---	. ---
Raphanus raphanistrum	. ---	**7** $^{25.6}$	. ---	. ---	. ---	. ---	. ---	. ---	. ---
Juncus ranarius	. ---	10 ---	**86** $^{86.2}$	. ---	. ---	. ---	. ---	. ---	. ---
Veronica anagalloides	. ---	17 $^{2.3}$	**93** $^{77.8}$	20 ---	. ---	3 ---	. ---	. ---	. ---
Ranunculus rionii	. ---	. ---	**36** $^{55.6}$	. ---	. ---	2 ---	. ---	. ---	. ---
Veronica catenata	. ---	. ---	**36** $^{54.9}$	. ---	1 ---	3 ---	. ---	. ---	. ---
Physcomitrium pyriforme	. ---	. ---	**43** $^{52.6}$	. ---	6 ---	5 ---	4 ---	. ---	. ---
Epilobium tetragonum	. ---	. ---	**29** $^{43.8}$	. ---	1 ---	2 ---	1 ---	. ---	4 ---
Pulicaria vulgaris	. ---	7 ---	. ---	**100** $^{86.8}$	1 ---	5 ---	2 ---	. ---	13 ---
Mentha pulegium	. ---	7 ---	. ---	**40** $^{54.0}$	. ---	2 ---	. ---	. ---	. ---
Potentilla anserina	. ---	2 ---	. ---	**40** $^{44.2}$	. ---	10 $^{3.7}$	5 ---	. ---	9 ---
Elatine triandra	. ---	. ---	. ---	. ---	**50** $^{64.4}$	. ---	1 ---	. ---	4 ---
Carex bohemica	. ---	. ---	7 ---	10 ---	**83** $^{62.1}$	9 ---	17 ---	. ---	26 ---
Eleocharis ovata	. ---	. ---	. ---	. ---	**77** $^{59.0}$	21 ---	6 ---	. ---	39 ---
Coleanthus subtilis	. ---	. ---	. ---	. ---	**57** $^{57.1}$	. ---	30 ---	. ---	. ---
Elatine hydropiper	. ---	. ---	. ---	. ---	**38** $^{52.7}$	. ---	4 ---	. ---	4 ---
Bidens radiata	. ---	. ---	. ---	20 ---	**64** $^{48.0}$	20 ---	34 ---	. ---	. ---
Callitriche palustris agg.	25 ---	7 ---	7 ---	. ---	**71** $^{47.7}$	25 ---	26 ---	. ---	4 ---
Rumex maritimus	. ---	7 ---	7 ---	10 ---	**67** $^{42.4}$	29 ---	28 ---	. ---	26 ---
Limosella aquatica	25 ---	12 ---	50 ---	. ---	**69** $^{35.8}$	34 ---	23 ---	. ---	13 ---
Rorippa palustris	. ---	7 ---	57 ---	10 ---	**75** $^{32.0}$	56 ---	55 ---	. ---	35 ---
Alopecurus aequalis	25 ---	12 ---	71 ---	20 ---	**80** $^{30.0}$	33 ---	72 ---	. ---	35 ---
Riccia huebeneriana	. ---	. ---	. ---	. ---	**7** $^{25.1}$	. ---	. ---	. ---	. ---
Leersia oryzoides	. ---	. ---	. ---	. ---	4 ---	**51** $^{60.3}$	. ---	. ---	9 ---
Nostoc commune	. ---	. ---	. ---	. ---	11 ---	**32** $^{40.8}$	3 ---	. ---	4 ---
Plantago uliginosa	. ---	49 ---	64 ---	60 ---	10 ---	**87** $^{36.8}$	33 ---	. ---	30 ---
Salix sp.	. ---	2 ---	. ---	. ---	23 ---	**38** $^{36.3}$	4 ---	. ---	13 ---
Eleocharis palustris s. lat.	. ---	5 ---	. ---	. ---	2 ---	**17** $^{31.8}$	. ---	. ---	. ---
Persicaria minor	. ---	. ---	. ---	. ---	1 ---	**16** $^{28.6}$	2 ---	. ---	4 ---

Table 1. Cont.

Plant community	Ran	Ce-Ra	Ve-Ly	Pu-Me	Po-El	Cyp	St-Is	Ce-An	Ju-Ra
No. of relevés	4	41	14	10	356	198	122	2	23
Veronica anagallis-aquatica	. ---	2 ---	7 ---	10 ---	11 ---	**31** 28.5	11 ---	. ---	4 ---
Spergularia rubra	. ---	5 ---	. ---	30 ---	13 ---	4 ---	**78** 54.6	. ---	35 ---
Juncus bufonius	. ---	54 ---	7 ---	40 ---	69 ---	56 ---	**93** 32.1	50 ---	57 ---
Gypsophila muralis	. ---	20 ---	. ---	40 ---	5 ---	2 ---	**45** 29.3	. ---	26 ---
Trifolium hybridum	. ---	12 ---	. ---	20 ---	19 ---	18 ---	**46** 27.7	. ---	35 ---
Stellaria alsine	. ---	. ---	. ---	. ---	2 ---	5 ---	**14** 27.5	. ---	. ---
Trifolium campestre	. ---	. ---	. ---	10 ---	1 ---	2 ---	**20** 25.5	. ---	9 ---
Hypericum humifusum	. ---	. ---	. ---	. ---	. ---	. ---	3 ---	**100** 98.2	. ---
Centunculus minimus	. ---	. ---	. ---	. ---	. ---	. ---	1 ---	**100** 90.9	17 4.5
Isolepis setacea	. ---	. ---	. ---	. ---	1 ---	2 ---	1 ---	. ---	**83** 87.5
Tillaea aquatica	. ---	. ---	. ---	. ---	6 ---	3 ---	2 ---	. ---	**57** 65.6
Pseudognaphalium luteoalbum	. ---	. ---	. ---	. ---	. ---	. ---	. ---	. ---	**43** 63.7
Juncus tenageia	. ---	. ---	. ---	. ---	1 ---	1 ---	. ---	. ---	**39** 58.6
Sagina procumbens	. ---	. ---	. ---	20 ---	1 ---	22 12.9	11 ---	. ---	**43** 37.1
Juncus alpinoarticulatus	. ---	. ---	. ---	. ---	. ---	. ---	. ---	. ---	**13** 34.3
Alisma gramineum	. ---	5 ---	. ---	. ---	3 ---	. ---	. ---	. ---	**17** 31.6
Rumex acetosella	. ---	2 ---	. ---	. ---	. ---	1 ---	1 ---	. ---	**13** 29.2
Carex viridula	. ---	. ---	. ---	. ---	. ---	. ---	. ---	. ---	**9** 27.9
Filago minima	. ---	. ---	. ---	. ---	. ---	. ---	. ---	. ---	**9** 27.9
Species diagnostic for more than one column									
Myosurus minimus	25 ---	**68** 50.6	**43** 26.0	. ---	1 ---	2 ---	5 ---	. ---	. ---
Lythrum hyssopifolia	50 ---	**76** 42.8	7 ---	**70** 38.2	1 ---	5 ---	2 ---	. ---	4 ---
Cyperus fuscus	. ---	10 ---	**71** 40.0	30 ---	4 ---	**91** 56.2	1 ---	. ---	4 ---
Other species with higher frequency									
Persicaria lapathifolia	. ---	29 ---	86 ---	50 ---	73 20.5	66 ---	61 ---	. ---	35 ---
Gnaphalium uliginosum	25 ---	39 ---	43 ---	50 ---	66 ---	60 ---	77 22.2	. ---	52 ---
Ranunculus sceleratus	25 ---	15 ---	71 ---	10 ---	48 16.9	31 ---	33 ---	. ---	9 ---
Peplis portula	25 ---	12 ---	. ---	20 ---	40 ---	33 ---	35 ---	. ---	43 ---
Persicaria hydropiper	25 ---	7 ---	. ---	30 ---	26 ---	40 17.7	32 ---	. ---	22 ---
Bidens tripartita	75 ---	20 ---	. ---	50 ---	15 ---	41 6.7	36 ---	. ---	57 ---
Echinochloa crus-galli	. ---	37 ---	29 ---	60 ---	11 ---	56 24.8	17 ---	. ---	17 ---
Eleocharis acicularis	. ---	2 ---	. ---	30 ---	30 15.9	31 ---	9 ---	. ---	26 ---
Juncus articulatus	. ---	12 ---	29 ---	10 ---	28 ---	27 ---	15 ---	. ---	30 ---
Alisma plantago-aquatica	25 ---	2 ---	. ---	. ---	33 24.1	30 ---	2 ---	. ---	9 ---
Oenanthe aquatica	25 ---	5 ---	14 ---	. ---	35 22.7	12 ---	17 ---	. ---	9 ---
Lythrum salicaria	. ---	12 ---	7 ---	10 ---	21 ---	27 ---	13 ---	. ---	4 ---
Epilobium sp.	. ---	5 ---	. ---	. ---	17 ---	19 ---	9 ---	. ---	4 ---
Potentilla supina	. ---	12 ---	50 ---	30 ---	8 ---	21 ---	19 ---	. ---	9 ---
Taraxacum sect. *Ruderalia*	. ---	22 ---	7 ---	10 ---	10 ---	25 20.6	4 ---	. ---	. ---
Agrostis stolonifera	25 ---	10 ---	7 ---	50 ---	4 ---	18 ---	15 ---	. ---	43 21.9
Riccia cavernosa	. ---	5 ---	43 ---	. ---	11 ---	18 11.7	. ---	. ---	. ---
Trifolium repens	25 ---	24 ---	. ---	10 ---	4 ---	13 ---	17 ---	. ---	26 ---
Bolboschoenus maritimus s. lat.	. ---	20 ---	29 ---	. ---	7 ---	9 ---	8 ---	. ---	17 ---
Bidens frondosa	. ---	5 ---	. ---	30 ---	5 ---	18 13.9	9 ---	. ---	. ---
Lycopus europaeus	. ---	. ---	. ---	. ---	6 ---	16 16.7	5 ---	. ---	22 ---
Poa annua	. ---	22 ---	. ---	20 ---	3 ---	16 10.2	11 ---	. ---	. ---
Bryum argenteum	. ---	5 ---	. ---	10 ---	2 ---	22 21.3	4 ---	. ---	17 ---
Chenopodium rubrum	. ---	. ---	29 ---	10 ---	5 ---	14 10.8	2 ---	. ---	. ---

Table 1. Cont.

Plant community No. of relevés	Ran 4	Ce-Ra 41	Ve-Ly 14	Pu-Me 10	Po-El 356	Cyp 198	St-Is 122	Ce-An 2	Ju-Ra 23
Rorippa sylvestris	25 ---	32 $^{20.3}$	7 ---	30 ---	. ---	12 ---	3 ---	. ---	4 ---
Phalaris arundinacea	25 ---	. ---	. ---	. ---	6 ---	10 ---	4 ---	. ---	. ---
Veronica scutellata	25 ---	2 ---	. ---	10 ---	5 ---	1 ---	15 $^{8.0}$	. ---	17 ---
Ranunculus aquatilis agg.	25 ---	2 ---	. ---	. ---	11 $^{10.2}$	1 ---	2 ---	. ---	. ---
Plantago major	. ---	27 $^{24.3}$	. ---	20 ---	2 ---	5 ---	11 ---	. ---	9 ---
Ranunculus repens	50 ---	10 ---	7 ---	20 ---	1 ---	8 ---	8 ---	. ---	9 ---
Persicaria maculosa	. ---	7 ---	21 ---	. ---	3 ---	5 ---	4 ---	. ---	4 ---
Rumex crispus	25 ---	17 $^{13.6}$	14 ---	. ---	1 ---	6 ---	2 ---	. ---	. ---
Glyceria fluitans s. lat.	25 ---	7 ---	. ---	. ---	4 ---	2 ---	2 ---	. ---	. ---
Juncus compressus	. ---	7 ---	. ---	20 ---	1 ---	8 $^{6.9}$	2 ---	. ---	. ---
Persicaria amphibia	25 ---	10 ---	7 ---	10 ---	2 ---	3 ---	2 ---	. ---	9 ---
Medicago lupulina	. ---	5 ---	. ---	20 ---	. ---	8 $^{7.8}$	2 ---	. ---	. ---
Amblystegium humile	. ---	. ---	. ---	20 ---	. ---	8 $^{7.4}$	1 ---	. ---	4 ---
Ranunculus flammula	50 ---	5 ---	. ---	. ---	1 ---	1 ---	6 ---	. ---	9 ---
Rorippa amphibia	50 ---	. ---	. ---	. ---	. ---	7 ---	1 ---	. ---	. ---
Glyceria maxima	25 ---	. ---	. ---	. ---	4 $^{1.3}$	1 ---	. ---	. ---	. ---
Centaurium pulchellum	. ---	12 $^{12.1}$	7 ---	20 ---	. ---	4 ---	1 ---	. ---	. ---
Alisma lanceolatum	25 ---	7 ---	7 ---	10 ---	1 ---	2 ---	1 ---	. ---	. ---
Lysimachia nummularia	25 ---	. ---	. ---	10 ---	1 ---	2 ---	2 ---	. ---	. ---
Symphytum officinale	25 ---	10 $^{10.5}$	. ---	. ---	. ---	1 ---	. ---	. ---	. ---
Gratiola officinalis	. ---	5 ---	. ---	20 ---	. ---	1 ---	1 ---	. ---	. ---
Radiola linoides	. ---	. ---	. ---	. ---	. ---	. ---	2 ---	50 ---	13 $^{8.0}$
Poa pratensis s. lat.	25 ---	2 ---	. ---	. ---	. ---	1 ---	2 ---	. ---	. ---
Rumex palustris	25 ---	2 ---	. ---	10 ---	. ---	1 ---	. ---	. ---	. ---
Stachys palustris	25 ---	. ---	. ---	. ---	. ---	1 ---	2 ---	. ---	. ---
Barbarea vulgaris	25 ---	. ---	. ---	. ---	1 ---	1 ---	. ---	. ---	. ---
Drosera rotundifolia	. ---	. ---	. ---	. ---	. ---	. ---	2 ---	50 ---	4 ---
Cardamine parviflora	25 ---	2 ---	7 ---	. ---	. ---	. ---	. ---	. ---	. ---
Polytrichum sp.	. ---	. ---	. ---	. ---	. ---	. ---	. ---	50 ---	9 ---
Ranunculus baudotii	25 ---	. ---	. ---	10 ---	. ---	. ---	. ---	. ---	. ---
Puccinellia distans	25 ---	. ---	. ---	. ---	. ---	1 ---	. ---	. ---	. ---
Anthemis arvensis	25 ---	. ---	. ---	. ---	. ---	1 ---	. ---	. ---	. ---
Iris pseudacorus	25 ---	. ---	. ---	. ---	1 ---	. ---	. ---	. ---	. ---
Matricaria sp.	25 ---	2 ---	. ---	. ---	. ---	. ---	. ---	. ---	. ---
Ranunculus circinatus	25 ---	. ---	. ---	. ---	. ---	1 ---	. ---	. ---	. ---
Juncus capitatus	. ---	. ---	. ---	. ---	. ---	. ---	. ---	50 ---	4 ---
Cardamine pratensis agg.	25 ---	. ---	. ---	. ---	. ---	. ---	. ---	. ---	. ---
Ranunculus polyphyllus	25 ---	. ---	. ---	. ---	. ---	. ---	. ---	. ---	. ---
Sium latifolium	25 ---	. ---	. ---	. ---	. ---	. ---	. ---	. ---	. ---
Juncus atratus	25 ---	. ---	. ---	. ---	. ---	. ---	. ---	. ---	. ---
Carex riparia	25 ---	. ---	. ---	. ---	. ---	. ---	. ---	. ---	. ---
Euphorbia palustris	25 ---	. ---	. ---	. ---	. ---	. ---	. ---	. ---	. ---
Stellaria palustris	. ---	. ---	. ---	. ---	. ---	. ---	. ---	50 ---	. ---
Lycopodiella inundata	. ---	. ---	. ---	. ---	. ---	. ---	. ---	50 ---	. ---
Carex stenophylla	. ---	. ---	. ---	. ---	. ---	. ---	. ---	50 ---	. ---

Study area

Our study was conducted in two Central European countries, the Czech and Slovak Republics (12° 5‘ 25“ – 22° 33‘ 5“ E, 47° 43‘ 52“ – 51° 3‘ 20“ N). The study area belongs to three different regions. A hilly landscape type predominates in the Czech Republic, whereas in Slovakia mountainous and lowland types of landscape are prevalent, which is also reflected in higher altitudinal variability of the country (Götz 1966). Pannonian lowland, the warmest part of the study area, is characterised by mean annual temperatures > 9 °C and relatively low total precipitation (< 600 mm). In contrast, mean annual temperatures are lower than 5 °C in the coldest parts of the study area, and are accompanied by high total precipitation (about 1000 mm). These conditions occur in the Carpathian mountain ranges in Slovakia, and also in some boundary mountain ranges in the Czech Republic (e.g. Krkonoše, Šumava, Hrubý Jeseník). In the largest part of the study area, the mean annual temperatures and total precipitation range between 5–9 °C and 600–1000 mm, respectively (Götz 1966).

Geological composition of the study area is very diverse. In the Czech Republic, rocks of the Proterozoic era (Moldanubicum) predominate, mainly paragneisses and migmatites in the central and southern part, as well as rocks of the Mesozoic (Cretaceous) of the Bohemian massif in the northern part of the national territory. Additionally, the fishpond basins (e.g. in southern Bohemia) and large river floodplains are usually formed by freshwater unstabilised sediments of the Mesozoic Era and Neogene (mainly non-calcareous clays, sands and gravels), and rarely also by marine sediments of the Neogene (e.g. in southern Moravia), and Quarternary sediments (Götz 1966, Chlupáč et al. 2011). In Slovakia, rocks of the Cenozoic (Neogene and Paleogene) are more common. These are in particular the brackish and fresh-water basin deposits in the south, flysch facies in the north, and Mesozoic, marine and continental Triassic bedrocks in the central part of the national territory (Götz 1966, Miklós 2002).

Prevailing soil types in the Czech Republic are podzols and brown forest soils; however, brown soils and chernozems are also common. In Slovakia, brown forest soils and rendzina soils are the prevailing soil-types in the mountains, and floodplain soils prevail in the southern lowlands (Götz 1966, Miklós 2002). Although the predominant bedrocks and the developed soils over them largely influence overall vegetation composition in the entire study area, small-scale environmental conditions are of special importance to the distribution of small-scale vegetation types such as Isoëto-Nano-Juncetea. For instance, soils on many of the studied wetland habitats typically include pseudo-clays and clays, the bottoms of water bodies are usually formed by subhydric soils of sapropel type, and peaty soils occur on the margins of some fishponds (Hauptman et al. 2009). However, the communities of shortly flooded habitats, such as wet fields and road margins, can also occur on widely distributed terrestrial soil types (see above).

The largest part of the study area belongs to the catchment basins of two large rivers, the Danube (Dunaj) river (Black Sea drainage area) and the Labe (North Sea drainage area). Small area of the studied territory belongs to the catchment basin of the Odra and Wisla rivers (Baltic Sea drainage area). Our phytosociological data originate from all the mentioned catchment basins; however, they were usually gathered from smaller rivers (e.g. Vltava, Berounka, Morava, Dyje) and small water bodies.

Specific habitats of Isoëto-Nano-Juncetea communities and their management

Isoëto-Nano-Juncetea species and communities occupy a broad range of various habitats with low cover of perennial herbs. The succession of perennials is limited by relatively long inundation periods and short exposure of the substrate, and/or mechanical disturbance (Poschlod et al. 1999, Täuber 2000, Deil 2005). Sufficient moisture during early development is also crucial for Isoëto-Nanojuncetea species, some of which germinate on moist or waterlogged substrata, while for others shallow water (up to several centimetres) is optimal (Hejný 1960, Lampe 1996). The relevés in this study originated from both natural and man-made habitats; however, the latter were much more frequent. The natural habitats were represented by river banks, alluvial deposits and cut backwaters. The man-made habitats included fishponds, fish storage ponds, wet arable fields, field and forest tracks, sand and clay pits, forest clearings, water reservoirs etc. Most of these habitats, or those parts of them in which Isoëto-Nano-Juncetea vegetation occurs, are without regular management and are therefore quickly altered by succession (Müller & Cordes 1985, Bagi 1987, Müller 1996). The most important man-made habitats of the target vegetation, enabling the development of its stands on areas of many square metres or even hectares, were in this study fishponds and fish storage ponds. They are used for fish, mainly common carp production (fishponds) or subsequent short term storage of marketable fish between its harvesting from fishponds and sale (fish storage ponds). Summer drainage of ponds had originally been widely used, particularly for increasing fishpond productivity through mineralisation of nutrients stored in muddy sediments (Hejný 1978, Čítek et al. 1998). More recently, summer drainage was eliminated for economic reasons (when the fishpond is empty during the vegetation season, the one year of fish production is lost; Hejný 1978, Čítek et al. 1998). Summer drainage is now regularly used only in two types of ponds: fish storage ponds and in fry ponds (for more information on fishpond and fish storage pond management in the study area see Šumberová 2003, Šumberová et al. 2006, 2012a, 2012b). The ponds used in fishpond management are concentrated mainly in particular parts of the study area, especially southern Bohemia and some other parts of the Czech Republic with a flat landscape and relatively humid climate. In Slovakia, the natural conditions did not allow the development of a fishpond culture to the same extent as in the Czech Republic, and therefore the fishponds are relatively rare there.

Results and discussion

Based on formal definitions, three alliances with nine plant communities were identified in our dataset. Altogether, eight and seven associations were documented by phytosociological relevés from Czech and Slovak Republic, respectively (Tables 1, 2 and Fig. 5). Six associations were documented from both countries, two and one association from only the Czech or the Slovak Republic, respectively. In total, 770 relevés were assigned to particular associations according to formal definitions, representing about 49% from all used relevés assigned by their authors to Isoëto-Nano-Juncetea (1580 in total). A substantial part of the phytosociological relevés (more than 88%) classified into particular associations originated from the territory of Czech Republic, and less than a quarter from Slovakia (Table 2). This reflected the considerably smaller number of all Isoëto-Nano-Juncetea relevés from Slovakia, amounting to 237 (i.e. 15% of the total of 1580).

Stands of some associations were probably more frequent in the field than shown in our dataset, but may be poorly sampled due to their occurrence in very small-scale microhabitats (smaller than 1 m²), the high representation of non-wetland species in the stands, poor predictability of their occurrence and/or accessibility. Typically, the vegetation of temporarily flooded depressions on arable land, or on extensively used field and forest tracks, belongs to this category of microhabitats (Prach 1999, Němec et al. 2012). In contrast, the stands in fishponds are usually large-scale, conspicuous, with a prevalence of habitat specialists. These stands were considered already to be attractive for study in the past, and therefore were documented in a large number of relevés by the first generation of Czech phytosociologists in the first decades of the 20th century (e.g. Klika 1935, Ambrož 1939; southern Bohemia and southern Moravia).

Table 2. Number of relevés of detected plant communities of the Isoëto-Nano-Juncetea class in the Czech and Slovak Republic.

Association / Number of relevés	Czech R.	Slovak R.	Both R.
Ranunculetum lateriflori	0	4	4
Cerastio-Ranunculetum sardoi	5	36	41
Veronico anagalloidis-Lythretum hyssopifoliae	14	0	14
Pulicario vulgaris-Menthetum pulegioidis	4	6	10
Polygono-Eleocharitetum ovatae	356	0	356
Cyperetum micheliani	170	28	198
Stellario uliginosae-Isolepidetum setaceae	114	8	122
Centunculo-Anthoceretum punctati	1	1	2
Junco tenageiae-Radioletum linoidis	17	6	23
Totally	**681**	**89**	**770**

Annotated checklist of syntaxa

In this part we present the descriptions of the distinguished syntaxa, associations in particular. Each description includes also formal definitions and list of diagnostic, constant and dominant species. The species of herb and moss layer in each list are separated by a semicolon and ordered alphabetically. The species printed in bold are considered to be highly diagnostic, constant or dominant (for details see the Methods).

Verbenion supinae Slavnić 1951
Original name (Slavnić 1951): Verbenion supinae foed. nov.
Synonymous names: Nano-Cyperion flavescentis Koch 1926 p. p. (§ 2b, nomen nudum), Nano-Cyperion Libbert 1932 p. p. (§ 3f)

This alliance includes low-growing vegetation of summer or winter annuals, or short-lived perennial species, which are weak competitors. Its communities have submediterranean-subcontinental distribution (Deil 2005). In Europe, it grows in regions with a relatively warm climate (from northern Mediterranean to Pannonian), occupying deeper to shallow wetlands on slowly drying muddy or clay soils rich in nutrients. Especially typical for communities of this alliance are higher contents of calcium and soluble mineral salts in the substrate (Bodrogközy 1958, Pietsch 1973). Four associations were distinguished within our phytosociological data: Cerastio-Ranunculetum sardoi, Pulicario vulgaris-Menthetum pulegioidis and Ranunculetum lateriflori are typical communities of this alliance, and Veronico anagalloidis-Lythretum hyssopifoliae represents a transition to the Eleocharition ovatae alliance.

Ranunculetum lateriflori Pop 1962
Original name (Pop 1962): Asoc. de *Ranunculus lateriflorus*, Ranunculetum lateriflori
Synonymous names: Limosello-Ranunculetum lateriflori Pop 1968

Formal definition: Group *Ranunculus lateriflorus*

Diagnostic species: ***Alopecurus geniculatus*, *Elatine alsinastrum*, *Ranunculus lateriflorus***

Constant species: *Alopecurus geniculatus*, *Bidens tripartita*, ***Elatine alsinastrum***, *Lythrum hyssopifolia*, *Ranunculus flammula*, ***Ranunculus lateriflorus***, *Ranunculus repens*, *Rorippa amphibia*, *Tripleurospermum inodorum*

Dominant species: ***Alisma lanceolatum*, *Alopecurus geniculatus*, *Callitriche palustris* agg.** (mainly *Callitriche palustris* s. str.), ***Elatine alsinastrum*, *Myosurus minimus*, *Ranunculus aquatilis* agg.** (mainly *Ranunculus aquatilis* s. str.), ***Ranunculus flammula*, *Ranunculus lateriflorus***

The community is formed by low, slightly open stands. Taller wetland grasses and herbs may constitute the upper layer of the community; however, its cover is usually small. The species *Ranunculus lateriflorus*, *Alopecurus geniculatus* and *Elatine alsinastrum* often predominate in the stands and thus determine their physiognomy. Additionally, other species of shallow waters, e.g. *Alisma lanceolatum* or *Ranunculus aquatilis* agg., have higher cover in places. The species composition is relatively variable. Besides the three dominant species mentioned above, there occur only several other species (e.g. *Bidens tripartitus*, *Lythrum hyssopifolia* and *Ranunculus flammula*; Table 1) which have a higher frequency.

Analysis of the ecological characteristics of this community is problematic due to the small number of relevés. Position of the relevés in the DCA ordination diagram and their relationship to the Ellenberg indicator values is similar to that of two other communities of the Verbenion supinae alliance: Cerastio-Ranunculetum sardoi and Pulicario vulgaris-Menthetum pulegioidis (Figs. 2, 4).

The stands of this community colonise shallow terrain depressions within alluvial meadows which are flooded in the spring. This habitat characteristic is reflected in the typical species composition: hydrophytes of shallow, periodically desiccating waters (e.g. *Ranunculus aquatilis*, *Elatine alsinastrum*) are combined with other wetland species. In the second half of summer, after the decrease of the water level below the soil surface, mesophilous species and some weeds (e.g. *Anthemis arvensis*, *Matricaria* spec. div., *Trifolium repens*) penetrate into the stands. In contrast, hydrophytes disappear soon after the water drawdown or they shortly survive in terrestrial forms and then die-off.

All the presented relevés of Ranunculetum lateriflori were collected in the south-eastern part of Slovakia, in the Východoslovenská lowland (Fig. 5). Our delimitation of this association, including its distribution characteristics, is similar to that published by VALACHOVIČ et al. (2001).

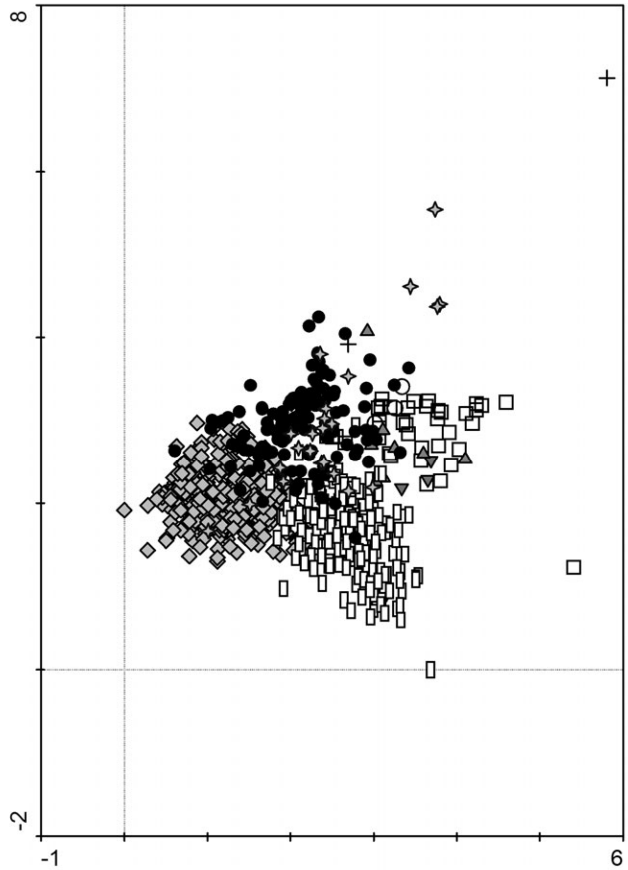

Fig. 2. DCA ordination diagram of samples of detected *Isoëto-Nano-Juncetea* plant communities. The first two ordination axes explain 5.7% and 3.5% (n = 770) of the total species variability, respectively. Open circles – *Ranunculetum lateriflori*, empty squares – *Cerastio-Ranunculetum sardoi*, shaded down-triangles – *Veronico anagalloidis-Lythretum hyssopifoliae*, shaded up-triangles – *Pulicario vulgaris-Menthetum pulegioidis*, shaded diamonds – *Polygono-Eleocharitetum ovatae*, boxes – *Cyperetum micheliani*, black circles – *Stellario uliginosae-Isolepidetum setaceae*, crosses – *Centunculo-Anthoceretum punctati*, shaded stars – *Junco tenageiae-Radioletum linoidis*.

Cerastio-Ranunculetum sardoi Oberdorfer ex Vicherek 1968

Original name (Vicherek 1968): Cerastio-Ranunculetum sardoi Oberdorfer 1957 emend. Vicherek

Synonymous names: Cerastio-Ranunculetum sardoi Oberdorfer 1957 prov. (§ 3b)

Formal definition: Group *Cerastium dubium* NOT Group *Ranunculus lateriflorus*

Diagnostic species: *Anagallis arvensis*, ***Apera spica-venti*, *Capsella bursa-pastoris*, *Cerastium dubium***, *Cirsium arvense*, *Convolvulus arvensis*, *Elymus repens*, *Equisetum arvense*, *Helianthus annuus*, *Chenopodium album* agg., ***Lythrum hyssopifolia*, *Myosurus minimus***, *Plantago major*, *Poa trivialis*, *Polygonum aviculare* agg., ***Ranunculus sardous***, *Raphanus raphanistrum*, *Rorippa sylvestris*, *Setaria pumila*, *Sonchus arvensis*, *Thlaspi arvense*, *Tripleurospermum inodorum*, *Triticum aestivum*, *Vicia tetrasperma, Viola arvensis*

Constant species: *Juncus bufonius*, *Lythrum hyssopifolia*, *Myosurus minimus*, *Plantago uliginosa, Polygonum aviculare* agg., *Ranunculus sardous*, *Tripleurospermum inodorum*

Dominant species: *Gypsophila muralis*, ***Juncus bufonius***, *Lythrum hyssopifolia*, ***Myosurus minimus***, ***Ranunculus sardous***, *Secale cereale*, *Triticum aestivum*

This community includes mainly open, more rarely closed, stands of wetland annuals and arable weeds. To the most common dominants belong *Ranunculus sardous*, *Lythrum hyssopifolia*, *Juncus bufonius* and *Myosurus minimus*. According to the individual dominant and co-occurring species, the height of the stands varies between about 5 and 30 cm. In some of our relevés, originating from cereal cultures, *Triticum aestivum* or other cereals represented a dominant and formed a higher layer of the stands, whereas the typical species of Cerastio-Ranunculetum sardoi occurred in the lower layer of the stands.

The overall species composition highly varies according to the periodicity of substrate flooding and drainage, habitat, and surrounding vegetation. A longer period of shallow flooding promotes the development of stands with a high frequency of wetland plants (e.g. species of various types of reed vegetation). If flooding occurs only in the spring, only wetland annuals with lower moisture demands are represented in the stands; however, the number of arable weeds increases. Stands occurring in alluvial meadow complexes usually include some species of wet grasslands (Table 1).

Most of the relevés of Cerastio-Ranunculetum sardoi in our dataset were collected on arable and young fallow fields. More rarely, this vegetation has been documented on the margins of flooded sand pits, exposed bottoms of water reservoirs, cut backwaters, depressions within the alluvial meadows and margins of unpaved roads. It does not occur in fishponds or fish storage ponds. These habitat characteristics are also reflected in the Ellenberg indicator values: Cerastio-Ranunculetum sardoi belongs to the communities with the lowest moisture demands (Fig. 4, Table 3). The EIV for pH and temperature are relatively high (Table 3), which corresponds with the occurrence of the community on base-rich, sometimes slightly saline habitats, in warm regions (Oberdorfer 1957, Vicherek 1968).

Cerastio-Ranunculetum sardoi is much more frequent in Slovakia than in the Czech Republic (Table 2). The distribution map (Fig. 5) shows the affinity of this community to the southern part of the study area. In Slovakia, taking into consideration existing phytosociological data, it possibly occurs in the lowlands and warm colline areas throughout the southern part of its national territory. However, until now it has been recorded only in four regions of Slovakia, situated in western, southern and south-eastern part of the country. Its occurrences in Borská lowland in western Slovakia are geographically connected with the localities in southern Moravia, the most important region for occurrence of this community in the Czech Republic. In Bohemia, Cerastio-Ranunculetum was documented in only one relevé from its southern part, where further stands of this community are also probable, due to the relatively common occurrence of some diagnostic species (e.g. *Myosurus minimus* and *Ranunculus sardous*). However, in comparison to Slovak and Moravian stands, the southern Bohemian stands are impoverished in some highly thermophilous or continental elements, e.g. *Lythrum hyssopifolia* and *Cerastium dubium* which are non-native and very rare in southern Bohemia (Hejný & Slavík 1990, Hejný 1995, Šumberová, unpublished data 2011).

This association was described by Vicherek (1968) from Slovakia. Although during work on the monograph, Vegetation of the Czech Republic (Šumberová 2011), delimitation of more associations of the Verbenion supinae alliance was attempted, it was extremely difficult to define formally the Cerastio-Ranunculetum sardoi as opposed to Veronico-Lythretum hyssopifoliae, using the Czech dataset. Only the relatively well-documented Veronico-Lythretum hyssopifoliae was therefore finally included in the monograph, and a small number of relevés with significantly different species composition remained unclassifiable. After merging of the relevés from the Czech Republic and Slovakia, revision of the original concept of a Verbenion supinae alliance, used in the third volume of the Vegetation of the Czech Republic, was possible. All the relevés of Vicherek (1968) that had originally been assigned to this association could be fitted into the newly created definition (as they originated from two regions of Slovakia, and were relatively uniform). In contrast, none of Vicherek's relevés from the Czech Republic (assigned to other communities but in some cases similar to Cerastio-Ranunculetum sardoi) corresponded to this formal definition. However, there were several newer relevés, mainly from southern Moravia, which could be now classified due to incorporation into the larger dataset.

Veronico anagalloidis-Lythretum hyssopifoliae Wagner ex Holzner 1973

Original name (Holzner 1973): Veronico anagalloidis-Lythretum hyssopifoliae Wagner 1942

Synonymous names: Veronico anagalloidis-Lythretum hyssopifoliae Wagner 1942 (§ 1), Juncetum bufonii Felföldy 1942 subass. Juncus bufonius-Echinochloa crus-galli Felföldy 1942, Cypero-Juncetum Soó et Csűrös (1936) 1944 Gnaphalietosum luteoalbi Bodrogközy 1958 (subassociation), Lythro hyssopifoliae-Gnaphalietum luteoalbi (Bodrogközy 1958) Pietsch 1973

Formal definition: Group *Juncus ranarius* NOT Group *Cerastium dubium*

Diagnostic species: *Cyperus fuscus*, ***Epilobium tetragonum***, ***Juncus ranarius***, *Myosurus minimus*, ***Ranunculus rionii***, ***Veronica anagalloides***, ***Veronica catenata***; ***Physcomitrium pyriforme***

Constant species: *Alopecurus aequalis*, *Cyperus fuscus*, *Gnaphalium uliginosum*, ***Juncus ranarius***, *Limosella aquatica*, *Myosurus minimus*, ***Persicaria lapathifolia***, *Plantago uliginosa*, *Potentilla supina*, *Ranunculus sceleratus*, *Rorippa palustris*, *Tripleurospermum inodorum*, ***Veronica anagalloides***; *Physcomitrium pyriforme*, *Riccia cavernosa*

Dominant species: *Cyperus fuscus*, ***Juncus ranarius***, ***Limosella aquatica***, ***Myosurus minimus***, ***Plantago uliginosa***, *Veronica anagallis-aquatica*; ***Physcomitrium pyriforme***

This community is formed by open to nearly closed stands of thermo- and basiphilous wetland annuals. The most important diagnostic species are *Juncus ranarius, Veronica catenata* and *Veronica anagalloides*. The first of these species dominates in the stands fairly frequently. Other dominants are e.g. *Cyperus fuscus* and *Limosella aquatica*; however, in some stands with overall low cover, there is no clear dominant species.

The majority of the mentioned species are relatively moisture-demanding. This is reflected in Ellenberg indicator values: there is a significant difference between Veronico-Lythretum hyssopifoliae and Cerastio-Ranunculetum sardoi, the two most frequent communities of the Verbenion supinae alliance. Whereas the moisture values in Veronico-Lythretum hyssopifoliae are similar to that of Cyperetum micheliani from the Eleocharition ovatae alliance, the mean moisture values of Cerastio-Ranunculetum sardoi are the lowest within the whole dataset (although the difference in some cases is not significant; Table 3). Similarly to all the Verbenion supinae communities, Veronico-Lythretum hyssopifoliae has high Ellenberg indicator values for temperature. Temperature is an important differentiating factor, especially in regard to the Cyperetum micheliani association. Comparison of the Ellenberg indicator values for light shows that Veronico-Lythretum hyssopifoliae is also more light-demanding than Cyperetum micheliani. Veronico-Lythretum hyssopifoliae has its phenological optimum in full summer and early autumn (Traxler 1993). It can develop on large areas of exposed bottoms of fishponds in warm regions (e.g. Vicherek 1968), but more frequently occurs in small-scale wetland types, e.g. in periodically flooded depressions in arable fields (Traxler 1993). High moisture is important during the major part of the vegetation period. Therefore, the community colonises only deep, longer-flooded depressions with heavy clay-based soils where the substrate remains wet for a long time, even under conditions of warm and dry climate (Šumberová 2011). Shallower puddles on arable land are usually colonised by Cerastio-Ranunculetum sardoi, which, at least in its spring form, is better able to tolerate drier conditions. The habitats of Veronico-Lythretum hyssopifoliae have to be exposed to full sunshine. Probably due to partial shading by woody vegetation, Veronico-Lythretum hyssopifoliae is only very rare on natural habitats in lowland river alluvia. In cut backwaters it is usually replaced by Cyperetum micheliani. Additionally, Veronico-Lythretum hyssopifoliae can be considered as slightly halophilous (Traxler 1993, Šumberová 2011) and the habitats suitable for salt marsh vegetation in the study area occur mainly outside the large river alluvia.

This association has been documented only on sites in southern Moravia. Surprisingly, there is no record of this community from Slovakia, although some of the Moravian localities are situated near the Slovakian border. Such absence of data can probably not be explained by insufficient research intensity on habitats typical of Veronico-Lythretum hyssopifoliae, because there are several dozens of relevés documenting annual wetland vegetation of field depressions. However, most of these relevés in our analysis were classified as Cerastio-Ranunculetum sardoi, the rest remaining unclassified. It is possible that eastwards the relatively moisture-demanding Veronico-Lythretum hyssopifoliae is replaced by Cerastio-Ranunculetum sardoi, which seems to be better adapted to more continental conditions. While it is surprising that such large differences in frequency of these two communities can occur in areas only several kilometres apart, local climatic, edaphic and geomorphological conditions may play an important role. Further field investigations are necessary to clarify this.

Pulicario vulgaris-Menthetum pulegioidis Slavnić 1951

Original name (Slavnić 1951): Ass. Pulicaria vulgaris-Mentha pulegium ass. nova

Synonymous names: Lythro-Pulicarietum vulgaris Tímár 1954

Formal definition: *Pulicaria vulgaris* cover > 5%

Diagnostic species: *Lythrum hyssopifolia*, ***Mentha pulegium***, ***Potentilla anserina***, ***Pulicaria vulgaris***

Constant species: *Agrostis stolonifera*, *Bidens tripartita*, *Echinochloa crus-galli*, *Gnaphalium uliginosum*, *Lythrum hyssopifolia*, *Persicaria lapathifolia*, *Plantago uliginosa*, ***Pulicaria vulgaris***

Dominant species: *Agrostis stolonifera*, *Cyperus fuscus*, *Eragrostis pilosa*, *Gypsophila muralis*, ***Lythrum hyssopifolia***, ***Peplis portula***, ***Plantago uliginosa***, ***Pulicaria vulgaris***, *Spergularia rubra*, *Trifolium hybridum; Amblystegium humile*

This community is relatively species-poor (the relevés contained 17 species on average), with slightly open to closed stands. The most frequent dominant species is *Pulicaria vulgaris*, often co-dominated by several other species of the Isoëto-Nano-Juncetea class (e.g. *Lythrum hyssopifolia*, *Peplis portula* and *Plantago uliginosa*). Besides the diagnostic species *Pulicaria vulgaris*, *Mentha pulegium* and *Potentilla anserina*, other species represented in the composition with higher frequency are common species of exposed bottoms (*Gnaphalium uliginosum*, *Juncus bufonius*, *Plantago uliginosa*), species of eutrophic substrates (*Bidens tripartitus*, *Echinochloa crus-galli*, *Persicaria lapathifolia*) and also some species of wet grasslands (*Agrostis stolonifera*; Table 1 and Fig. 3).

Considering the ecological demands (expressed as EIV) of the association, it is obvious that Pulicario vulgaris-Menthetum pulegioidis has, together with other communities of Verbenion supinae alliance, relatively high EIV for temperature and soil reaction. Conversely, the EIV for moisture are relatively low. The EIV for nutrients in Verbenion supinae communities and Cyperetum micheliani are the highest within the compared vegetation types (however, some of these differences are not significant; Fig. 4 and Table 3). The high nutrient amount is reflected in the occurrence of nitrophilous herbs (see above).

Distribution patterns of the relevés, and also our field observations, show that Pulicario vulgaris-Menthetum pulegioidis is confined to the warmest, relatively precipitation-poor regions (southern Moravia, south-central and south-eastern parts of Slovakia; Fig. 5) what is in accordance with literature data from other European countries (e.g. Slavnić 1951, Pop 1962). The only exceptions are the occurrences of this community in fishponds (only historically) and fish storage ponds (recently) in Českobudějovická basin (southern Bohemia). Their species composition slightly differs from that of the relevés from other regions, e.g. by the absence of the species *Mentha pulegium* (it probably never occurred in southern Bohemia; cf. Chán 1999) and *Lythrum hyssopifolia* (considered as rare alien species in southern Bohemia; Hejný 1995).

Pulicario vulgaris-Menthetum pulegioidis grows on various habitats, e.g. exposed river, sand pit and fishpond banks, exposed bottoms of fish storage ponds, pastures and shallow depressions in the complexes of alluvial meadows. The habitats are supplied with a high amount of nutrients, either by means of regular floods, or by management (e.g. livestock or geese grazing).

Besides the localities presented in this study, there are also recent occurrences of Pulicario vulgaris-Menthetum pulegioidis reported in the Borská lowland and Lučenská basin (Zaliberová & Májeková in Šibík 2011, Slezák et al. 2012). Both regions are situated in southern Slovakia and have a relatively warm climate.

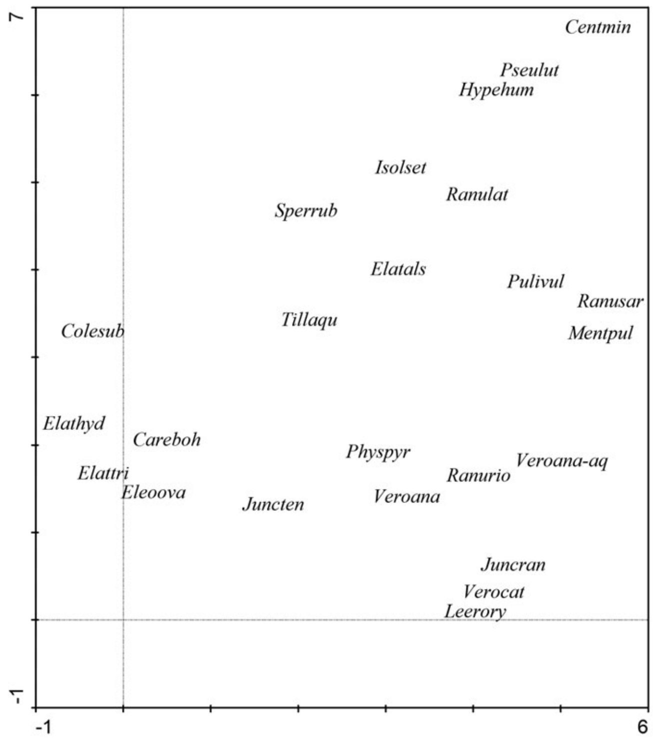

Fig. 3. DCA ordination diagram of species of detected *Isoëto-Nano-Juncetea* plant communities. Only diagnostic species of associations with phi > 50 are displayed. Abbreviations of species: Careboh – *Carex bohemica*, Centmin – *Centunculus minimus*, Colesub – *Coleanathus subtilis*, Elatals – *Elatine alsinastrum*, Elathyd – *E. hydropiper* s. lat., Elattri – *E. triandra*, Eleoova – *Eleocharis ovata*, Hypehum – *Hypericum humifusum*, Isolset – *Isolepis setacea*, Juncran – *Juncus ranarius*, Juncten – *J. tenageia*, Leerory – *Leersia oryzoides*, Mentpul – *Mentha pulegium*, Physpyr – *Physcomitrium pyriforme*, Pseulut – *Pseudognaphalium luteoalbum*, Pulivul – *Pulicaria vulgaris*, Ranulat – *Ranunculus lateriflorus*, Ranunrio – *R. rioinii*, Ranusar – *R. sardous*, Sperrub – *Spergularia rubra*, Tillaqu – *Tillaea aquatica*, Veroana – *Veronica anagalloides*, Veronag-aq – *V. anagallis-aquatica*, Verocat – *V. catenata*.

Pulicario vulgaris-Menthetum pulegioidis was described by Slavnić (1951) from Vojvodina, a region in northern Serbia. The original description is related to the stands on slightly saline or non-saline soils in river alluvia. Besides the species *Pulicaria vulgaris* and *Mentha pulegium*, Slavnić's relevés include some species which are missing in our phytosociological material. These are in particular some thermophilous and, in our study area, rare weeds (e.g. *Abutilon theoprasti*, *Malva pusilla*), or some halophytes (e.g. *Juncus gerardii*). In contrast, the group of species typical of Isoëto-Nano-Juncetea communities is better represented in our relevés, whereas the relevés from Vojvodina include only three species of this group, *Gnaphalium uliginosum*, *Heliotropium supinum* and *Verbena supina*; the two latter species do not occur in Central Europe, but their frequency in material from Slavnić was low. The overall species composition of our and Serbian relevés is very

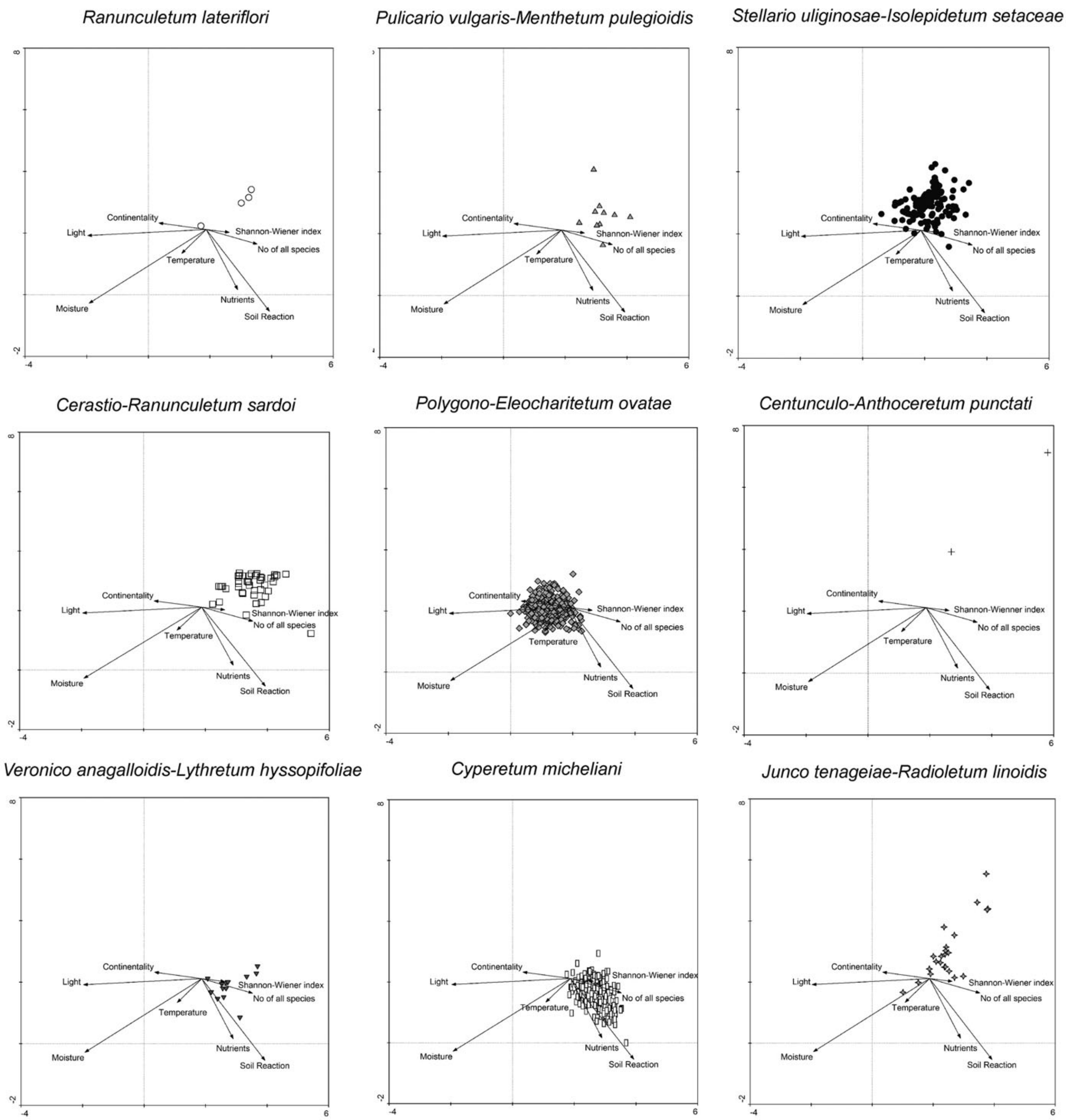

Fig. 4. DCA ordination diagram of samples of detected *Isoëto-Nano-Juncetea* plant communities with Ellenberg indicator values as supplementary environmental variables.

similar, including e.g. many common Bidentetea tripartitae species.

From the territory of Slovakia, the association Lythro-Pulicarietum vulgaris Tímár 1954 has been published by VALACHOVIČ et al. (2001). However, we consider these associations to be identical in their content and therefore list the name Lythro-Pulicarietum vulgaris as a synonym of Pulicario vulgaris-Menthetum pulegioidis. In the Czech Republic this community has not yet been reported (cf. ŠUMBEROVÁ 2011), a fact connected with the small number of phytosociological relevés of all Verbenion supinae communities from its territory, and difficulties in formal delimitation of more than one Verbenion supinae association.

Table 3. Mean±standard deviation of Ellenberg indicator values of individual clusters. Cluster number is the same as in Table 1. Clusters with the same letter in a given column do not differ significantly (P ≤ 0.05). *Ranunculetum lateriflori* (clusters 1) and *Centunculo-Anthoceretum punctati* (cluster 8) were not evaluated, because they contained too low number of relevés.

EIV / Community	Ce-Ra	Ve-Ly	Pu-Me	Po-El	Cyp	St-Is	Ju-Ra
E_Light	7,34±0,35[bc]	7,58±0,23[ab]	7,48±0,26[abc]	7,69±0,19[a]	7,37±0,20[c]	7,40±0,25[bc]	7,45±0,20[bc]
E_Temperature	6,06±0,17[ab]	6,15±0,15[a]	6,11±0,19[ab]	5,97±0,13[bc]	5,93±0,14[bc]	5,82±0,21[d]	5,85±0,23[cd]
E_Continentality	4,21±0,40[a]	4,24±0,22[a]	4,10±0,29[ab]	4,17±0,26[a]	3,98±0,31[b]	4,06±0,37[ab]	3,73±0,30[b]
E_Moisture	6,74±0,68[c]	7,71±0,49[b]	7,04±0,52[bc]	8,22±0,37[a]	7,62±0,55[b]	7,27±0,63[bc]	7,33±0,64[bc]
E_Soil_Reaction	5,73±0,50[a]	5,97±0,49[a]	5,61±0,45[ab]	5,34±0,59[b]	5,96±0,57[a]	4,87±0,66[c]	5,11±0,55[bc]
E_Nutrients	5,76±0,46[b]	5,98±0,35[ab]	5,74±0,36[b]	5,70±0,61[b]	6,14±0,58[a]	5,50±0,73[b]	4,59±0,91[c]

Eleocharition ovatae Philippi 1968

Original name (Philippi 1968): Eleocharition soloniensis (all. nov.)

Synonymous names: Nano-Cyperion flavescentis Koch 1926 p. p. (2b, nomen nudum), Nano-Cyperion Libbert 1932 p. p. (3f), Elatino-Eleocharitenion ovatae Müller-Stoll et Pietsch 1968 (sub-alliance), Elatino-Eleocharition ovatae Pietsch 1973

Vegetation of this alliance is dominated by low-growing annual graminoids and dicots. It has a Eurosiberian distribution (Deil 2005), but it is most frequently reported from Central Europe (Šumberová 2011). Relatively long-term duration of floods and short-term exposure of soils are typical of this vegetation type (Pietsch 1973). It occurs mainly on exposed bottoms of fishponds and fish storage ponds, river oxbows and fine sediment deposits directly in watercourses, and rarely also in field depressions with sandy substrate. We detected three associations, Polygono-Eleocharitetum ovatae as a central association, the more thermophilous Cyperetum micheliani in transition to the Verbenion supinae alliance, and Stellario uliginosae-Isolepidetum setaceae with occurrence on relatively short-term flooded habitats, which represents a transition to the Radiolion linoidis alliance.

Polygono-Eleocharitetum ovatae Eggler 1933

Original name (Eggler 1933): Polygono-Heleocharetum ovatae (*Heleocharis ovata* = *Eleocharis ovata*, *Polygonum hydropiper* = *Persicaria hydropiper*, *Polygonum lapathifolium* = *Persicaria lapathifolia*, *Polygonum minus* = *Persicaria minor*, *Polygonum tomentosum* = *Persicaria lapathifolia* subsp. *pallida*)

Synonymous names: Caricetum cyperoidis Eggler 1933 (§ 25), Eleocharito ovatae-Caricetum cyperoidis Klika 1935, Cypero fusci-Limoselletum aquaticae (Oberdorfer 1959) Korneck 1960 p. p., Lindernio-Eleocharitetum ovatae Pietsch 1961 ms., Riccio cavernosae-Limoselletum aquaticae Philippi 1968 p. p., Coleantho-Spergularietum echinospermae Vicherek 1972 prov. p. p., Peplido-Eleocharitetum ovatae Pietsch 1973

Formal definition: Group *Eleocharis ovata*

Diagnostic species: *Alisma plantago-aquatica*, *Alopecurus aequalis*, ***Bidens radiata***, ***Callitriche palustris* agg. (mainly *C. palustris* s. str.)**, ***Carex bohemica***, ***Coleanthus subtilis***, ***Elatine hydropiper* s. lat.**, ***Elatine triandra***, ***Eleocharis ovata***, *Limosella aquatica*, *Oenanthe aquatica*, *Persicaria lapathifolia*, *Rorippa palustris*, ***Rumex maritimus***; *Botrydium granulatum*, *Physcomitrium sphaericum*, *Riccia canaliculata*, *Riccia huebeneriana*

Constant species: *Alopecurus aequalis*, *Bidens radiata*, *Callitriche palustris* agg. (mainly *C. palustris* s. str.), ***Carex bohemica***, *Coleanthus subtilis*, *Elatine triandra*, *Eleocharis ovata*, *Gnaphalium uliginosum*, *Juncus bufonius*, *Limosella aquatica*, *Persicaria lapathifolia*, *Ranunculus sceleratus*, *Rorippa palustris*, *Rumex maritimus*

Dominant species: ***Callitriche palustris* agg. (mainly *C. palustris* s. str.)**, *Carex bohemica*, ***Coleanthus subtilis***, ***Eleocharis ovata***, ***Juncus bufonius***, *Limosella aquatica*

This association comprises either low stands dominated by *Coleanthus subtilis* and/or by procumbent or creeping herbs, e.g. *Limosella aquatica*, *Elatine triandra*, *E. hydropiper*, *Callitriche palustris* (terrestrial form), or taller stands with *Carex bohemica* and *Eleocharis ovata* as dominants. Quite frequently, both physiognomic types form distinct layers of one stand, whereas the lower stands are phenologically earlier. Some species typical of the Bidentetea tripartitae class, e.g. *Bidens radiata*, *Rumex maritimus* and *Rorippa palustris*, are also represented in the species composition of Polygono-Eleocharitetum ovatae (see Table 1 and Fig. 3). In the habitats with high moisture and nutrient amounts, these species increase their cover during the growing season and the stands of Polygono-Eleocharitetum ovatae are replaced later in summer by Corrigiolo-Bidentetum radiatae, Ranunculo scelerati-Rumicetum maritimae or some of the other Bidentetea tripartitae communities (Šumberová 2011).

In comparison with the other Isoëto-Nano-Juncetea communities, analysis of Ellenberg indicator values has shown that Polygono-Eleocharitetum ovatae

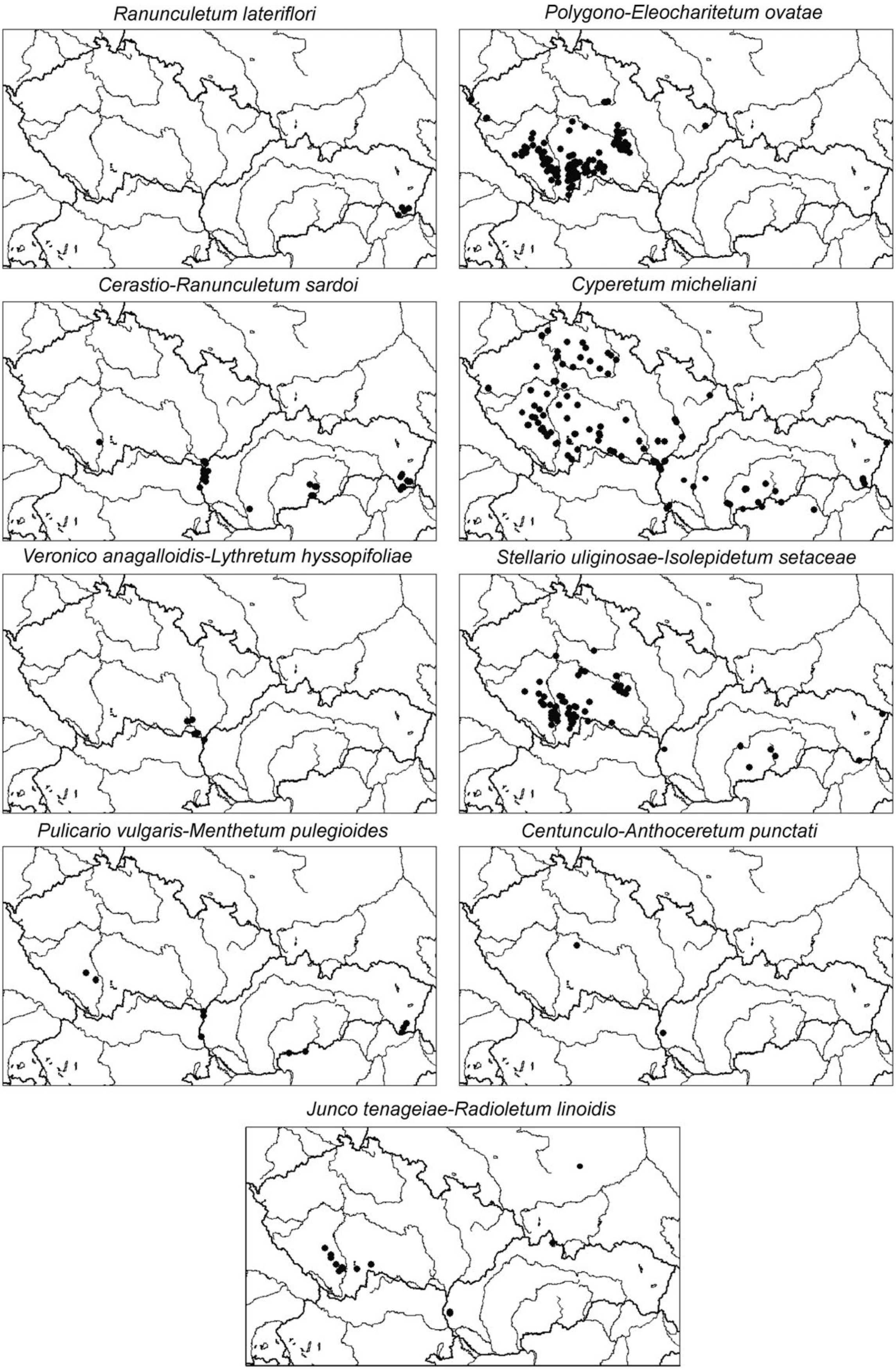

Fig. 5. Maps of plant communities of the *Isoëto-Nano-Juncetea* class in the Czech and Slovak Republic.

has the highest demands on moisture and light. However, the differences in light requirements are only small and not significant, compared to most other communities (Table 3). The analysis further shows the medium demands of Polygono-Eleocharitetum ovatae on temperature and nutrients. In comparison with some other associations, especially Cyperetum micheliani, it shows an affinity for substrata with a lower pH value (Tab. 2, Fig. 4).

Our field experiences, as well as literature data concerning the habitat conditions of this community in other countries (e.g. MÜLLER-STOLL & PIETSCH 1985, TRAXLER 1993, TÄUBER 2000) are consistent with the results of the analysis: Polygono-Eleocharitetum ovatae usually grows on wet fine-grained substrata, e.g. loamy or clay-based mud. The upper layer of the substrate is often black-coloured and rich in organic substances. The depth of this organic mud layer can vary between several centimetres and about 1 m. These substrata have a high water-retaining capacity, i.e. they remain wet for a long time after pond bottom drainage. Such conditions occur mainly in fishponds which are drained for several months in the vegetation period. The pond bottom is exposed to full sunshine and fast warming-through of the black mud promotes rapid germination of seeds. In recent decades, partial drainage continuing from March/April to May/June has been the most frequent situation. This regime supports development of low-growing stands of species with an extremely short life cycle (e.g. *Coleanthus subtilis*) or species which can survive shallow flooding (e.g. *Elatine* spec. div.). Stands of taller herbs, e.g. *Eleocharis ovata*, survive mainly in fishponds with limited water supply. In suitable moisture conditions, Polygono-Eleocharitetum ovatae forms large stands, covering hectares of pond bottoms.

Within the study area, the association Polygono-Eleocharitetum ovatae was concentrated into fishpond basins in southern and south-western Bohemia, and into hilly country with chains of small fishponds in the Bohemian-Moravian Uplands (Fig. 5). From this location, its distribution stretches within western, central and eastern Bohemia, and northern Moravia. In southern Moravia and Slovakia, the community is lacking. We suppose that in some regions, e.g. in western Bohemia and northern Moravia, the community is probably more frequent but has been only rarely detected due to insufficient field data sampling. In these regions there are numerous carp ponds, acidic bedrocks and a relatively humid and moderately warm climate, which is optimal for Polygono-Eleocharitetum ovatae. Conversely, the rare occurrences in eastern Bohemia represent isolated "islands" of Polygono-Eleocharitetum ovatae in warm regions formed mainly by basic, calcareous bedrocks. The community occurs there in fishponds situated in small areas with acidic bedrocks and surrounded by forests.

Cyperetum micheliani Horvatić 1931

Original name (Horvatić 1931): Cyperetum micheliani

Synonymous names: Cypero fusci-Chenopodietum glauci Klika 1935, Cypero fusci-Juncetum bufonii Soó et Csűrös (1936) 1944, Cypero fusci-Limoselletum aquaticae (Oberdorfer 1959) Korneck 1960 p. p., Eleocharito-Caricetum bohemicae cyperetosum fusci Pietsch et Müller-Stoll 1968, Riccio cavernosae-Limoselletum aquaticae Philippi 1968 p. p., Dichostyli-Gnaphalietum uliginosi Horvatić 1931 (phantom)

Formal definition: Group *Cyperus fuscus* NOT Group *Cerastium dubium* NOT Group *Eleocharis ovata* NOT Group *Isolepis setacea* NOT Group *Juncus ranarius* NOT *Pulicaria vulgaris* cover > 5%

Diagnostic species: ***Cyperus fuscus***, *Echinochloa crus-galli*, *Eleocharis palustris* s. lat., ***Leersia oryzoides***, *Persicaria minor*, *Plantago uliginosa*, *Salix* sp., *Taraxacum* sect. *Ruderalia*, *Urtica dioica*, *Veronica anagallis-aquatica*; *Bryum argenteum*, ***Nostoc commune***

Constant species: *Bidens tripartita*, ***Cyperus fuscus***, *Echinochloa crus-galli*, *Gnaphalium uliginosum*, *Juncus bufonius*, *Leersia oryzoides*, ***Plantago uliginosa***; *Persicaria lapathifolia*, *Rorippa palustris*

Dominant species: ***Cyperus fuscus***, ***Juncus bufonius***, *Plantago uliginosa*; ***Nostoc commune***

In this community we include usually open stands with the diagnostic species *Cyperus fuscus*, *Plantago uliginosa*, *Leersia oryzoidis* and some other wetland plants (Table 1). The first two of these are at the same time frequent dominants in the stands. The community can also be dominated by other species, e.g. *Juncus bufonius* or *Peplis portula*. Within the Isoëto-Nano-Juncetea class, the Cyperetum micheliani represents relatively species-rich vegetation (Fig. 4). According to geographic location and habitat type, the overall species spectrum of Cyperetum micheliani may be enriched by species typical of Polygono-Eleocharitetum ovatae (e.g. the stand in southern Bohemian fish storage ponds) or some others of the Isoëto-Nano-Juncetea class, or the species of ruderal grasslands, reed beds, etc. The name-giving species of the association, *Cyperus michelianus*, occurs only rarely in the study area (ČEŘOVSKÝ et al. 1999). It is a species with high demands on temperature and in the study area, especially in its Czech distribution, it occurs in limiting ecological conditions. In South-Eastern Europe, from where the association was firstly described by HORVATIĆ (1931), it is much more frequent. However, the overall species composition of South-East European and Central European stands is so similar that we consider them to be a part of one association (see also ŠUMBEROVÁ 2011). According to Ellenberg indicator values, Cyperetum micheliani grows on substrata richer in nutrients and basic ions than the stands of the remaining two associations of the Eleocharition ovatae alliance. In comparison to Polygono-Eleocharitetum ovatae it is also significantly less moisture-demanding (Table 3, Fig. 4). Ellenberg indicator values further point to a relationship between Cyperetum micheliani and the Verbenion supinae alliance.

According to our field investigations, the community occupies a wide range of habitats, including river banks and alluvial deposits, exposed bottoms or margins of fishponds, fish storage ponds, alluvial pools, cut backwaters and water reservoirs and periodically flooded sand and gravel pits. The substrate is mainly sand or gravel, sometimes clay or loam without a layer of organic mud. It usually dries up quite quickly, either due to the predominance of course-grained particles, a longer period of bottom exposure or warm climate. Although the community can also occur on wet mud with high organic content, we documented it only rarely in such conditions. It is probably a consequence of the competition of early-germinating Bidentetea tripartitae species or some wetland perennials such as *Typha latifolia*. Thus, our observations of Cyperetum micheliani on wet mud with deeper organic layer originate mainly from fish storage ponds, where the competition from vegetation with a larger biomass is strongly eliminated by management. The community is optimally developed in summer or in autumn, depending on time of substrate exposure.

Soil analyses and other environmental data presented in the studies from other Central-European countries (e.g. Philippi 1968, Müller-Stoll & Pietsch 1985, Bagi 1988, Täuber 2000) are corresponding with our findings. In some cases, nitrogen content was lower in Cyperetum micheliani than in Polygono-Eleocharitetum ovatae (Müller-Stoll & Pietsch 1985, Täuber 2000). In our opinion, it is caused by a different spectrum of studied habitats in cited publications in comparison with our investigations.

Cyperetum micheliani is widely distributed in lowlands and colline areas within the whole study area (Fig. 5). Although it is concentrated particularly into river basins with a warm and relatively continental climate, on calcareous substrata it can also be found in colder and humid regions (Šumberová 2011). In Slovakia, such occurrences are documented on more or less natural habitats in the Carpathians, and are probably more frequent than is shown on the map (cf. Valachovič et al. 2001). In the Carpathian part of the Czech Republic, similar stands were not documented at all, although their occurrence in that location can be assumed.

Stellario uliginosae-Isolepidetum setaceae Libbert 1932

Original name (Libbert 1932): *Stellaria uliginosa-Scirpus setaceus*-Assoziation (*Scirpus setaceus* = *Isolepis setacea*)

Synonymous names: Eleocharito ovatae-Caricetum cyperoidis Klika 1935 subass. *Juncus bufonius-Gypsophila muralis* Ambrož 1939, Gypsophilo-Potentilletum supinae (Ambrož 1939) Pietsch 1963, Hyperico humifusi-Spergularietum rubrae Wojcik 1968 p. p., Coleantho-Spergularietum echinospermae Vicherek 1972 prov. p. p., Gypsophilo muralis-Potentilletum norvegicae (Ambrož 1939) Hejný in Dykyjová et Květ 1978, Junco bufonii-Gypsophiletum muralis (Ambrož 1939) Pietsch 1996, Gypsophilo muralis-Juncetum bufonii (Ambrož 1939) Hejný in Dykyjová et Květ 1978 (phantom)

Formal definition: Group *Gypsophila muralis* NOT Group *Cerastium dubium* NOT Group *Cyperus fuscus* NOT Group *Eleocharis ovata* NOT Group *Isolepis setacea* NOT *Agrostis stolonifera* cover > 25% NOT *Pulicaria vulgaris* cover > 5% NOT *Rorippa amphibia* cover > 5%

Diagnostic species: *Gnaphalium uliginosum*, *Gypsophila muralis*, *Juncus bufonius*, ***Spergularia rubra***, *Stellaria alsine*, *Trifolium campestre*, *Trifolium hybridum*

Constant species: *Alopecurus aequalis*, *Gnaphalium uliginosum*, *Gypsophila muralis*, ***Juncus bufonius***, *Persicaria lapathifolia*, *Rorippa palustris*, *Spergularia rubra*, *Trifolium hybridum*, *Tripleurospermum inodorum*

Dominant species: *Coleanthus subtilis*, *Gnaphalium uliginosum*, ***Juncus bufonius***, ***Trifolium hybridum***

The association Stellario uliginosae-Isolepidetum setaceae involves usually open stands with *Juncus bufonius* as a dominant and diagnostic species. Further diagnostic species, occurring with only small abundance, are e.g. *Spergularia rubra, Gypsophila muralis* and *Stellaria alsine*. The most frequent accompanying species is *Gnaphalium uliginosum* (Table 1). Specific types of this community are the stands where these species occur in the lower herb layer, while the upper layer is formed by *Trifolium* species (mainly *T. hybridum* or *T. campestre*). These stands occur only on fishpond margins. In contrast to Bidentetea species, which occur in Stellario uliginosae-Isolepidetum setaceae only as young plants, and fully develop later, forming their own communities, the *Trifolium* species phenologically correspond to Isoëto-Nano-Juncetea species.

Analysis of Ellenberg indicator values shows that Stellario uliginosae-Isolepidetum setaceae has the significantly lowest demands on temperature (Table 3). The mean Ellenberg indicator value for pH was also the lowest within the compared communities, but the differences were not significant in some cases. In comparison with Polygono-Eleocharitetum ovatae, Stellario uliginosae-Isolepidetum setaceae has significantly lower moisture demands. This is reflected in the zonation, which can be observed especially on the fishponds drained in summer: drier sandy pond margins are colonised by stands of Stellario uliginosae-Isolepidetum setaceae, whereas Polygono-Eleocharitetum ovatae occupies the sites with deeper wet mud. Besides the fishponds, which were the most frequent habitat of Stellario uliginosae-Isolepidetum setaceae in our dataset, the community also develops on bottoms or margins of other water bodies and on disturbed habitats, such as fish storage ponds and water reservoirs, wet arable fields, forest tracks etc. This community grows only very rarely on habitats in river alluvia. The substrate is usually sand, non-calcareous clay or loam. The layer of organic mud is usually lacking or it is very shallow (e.g. in fishponds, in the contact zone with Polygono-Eleocharitetum ovatae).

The findings on ecology of this community published from neighbouring countries, including soil analyses (e.g. Pietsch & Müller-Stoll 1974, Müller-Stoll & Pietsch 1985, Wnuk 1989, Täuber 2000), are in agreement with our results.

Distribution of Stellario uliginosae-Isolepidetum setaceae within the study area is very similar to that of Polygono-Eleocharitetum ovatae (Fig. 5). However, the total number of relevés and documented localities of Stellario uliginosae-Isolepidetum setaceae is lower, and in the Czech Republic it seems to be more restricted to southern Bohemia and the Bohemian-Moravian Uplands, with a small overlap into central Bohemia. It has also been documented in several parts of Slovakia, where, according to our analysis, the Polygono-Eleocharitetum ovatae does not occur at all. Most regions with occurrence of Stellario uliginosae-Isolepidetum setaceae are characterised by moderately warm to moderately cold and humid climate conditions.

Radiolion linoidis Pietsch 1973

Original name (Pietsch 1973): Radiolion linoidis (Rivas Goday 1961) Pietsch 1965

Synonymous names: Nano-Cyperion flavescentis Koch 1926 p. p. (§ 2b, nomen nudum), Nano-Cyperion flavescentis Malcuit 1929 (§ 3f), Nano-Cyperion Libbert 1932 p. p. (§ 3f), Radiolion linoidis Rivas Goday 1961 (phantom), Radiolion linoidis Pietsch 1965 (phantom)

High amount of precipitation before, and possibly also during, the growing season of its characteristic species are very important for development of this vegetation. For this reason, it is mainly found in the areas of Western Europe that are influenced by an oceanic climate (Deil 2005, Šumberová 2011). Habitats of this vegetation are mostly only moistened by water or rarely flooded (Pietsch 1973). Typical habitats are field depressions, exposed fishpond margins or other short-term flooded wetlands. Only two associations were distinguished: Centunculo-Anthoceretum punctati and Junco tenageiae-Radioletum linoidis.

Centunculo-Anthoceretum punctati Koch ex Libbert 1932

Original name (Libbert 1932): Centunculo-Anthoceretum punctati (Walo Koch 1926.) (*Centunculus minimus*)

Synonymous names: Centunculo-Anthoceretum punctati Koch 1926 (§ 2b, nomen nudum), Hyperico humifusi-Spergularietum rubrae Wójcik 1968 p. p.

Formal definition: Group *Centunculus minimus*

Diagnostic species: ***Centunculus minimus***, ***Hypericum humifusum***

Constant species: *Carex stenophylla*, ***Centunculus minimus***, *Drosera rotundifolia*, ***Hypericum humifusum***, *Juncus bufonius*, *Juncus capitatus*, *Lycopodiella inundata*, *Radiola linoides*, *Stellaria palustris*; *Polytrichum* sp.

Dominant species: –

This community is formed by open stands of wetland annual graminoids, dicotyledonous herbs and bryophytes. In our study it is represented only by two relevés (Figs. 2 and 4, Table 1). The cover of this vegetation in our relevés did not exceed 30%. Diagnostic species of this association occurring in our relevés are *Centunculus minimus* and *Hypericum humifusum* (Table 1). Another species, the bryophyte *Anthoceros agrestis*, was not found in our stands, but may occur on the same habitat in another period of the year, mainly in the autumn. *Juncus capitatus*, *Lycopodiella inundata* and *Radiola linoides* are rare species of the Radiolion linoidis alliance which occurred in one of the relevés.

This community colonises mainly small-scale temporary wetlands, especially wet parts of arable fields. It is ecologically similar to the next Radiolion linoidis community, Junco tenageiae-Radioletum linoides (Fig. 4). These two communities differ in their habitat preference, which is probably related to lower moisture demands in Centunculo-Anthoceretum punctati.

Centunculo-Anthoceretum punctati has been documented from both the Czech Republic (here in central Bohemia) and Slovakia (Borská lowland; Fig. 5). In each country, only one relevé within the dataset was consistent with the formal definition of the community. There were also several impoverished relevés, assigned by their authors to Centunculo-Anthoceretum punctati, which, however, did not fulfil the formal criteria. Some of the relevés which would be classified as this community were probably not included at all because of their original assignment to other classes than Isoëto-Nano-Juncetea. This is probably the case of one relevé from southern Bohemia (see Šumberová 2011).

Junco tenageiae-Radioletum linoidis Pietsch 1963
Original name (Pietsch 1963): Junco tenageiae-Radioletum Pietsch 1961 (*Radiola linoides*)
Synonymous names: Junco tenageiae-Radioletum Pietsch 1961 ms. (§ 1), Elatino alsinastri-Juncetum tenageiae Libbert 1932 (§ 2b, nomen nudum), *Tillaea aquatica* comm. (sensu Valachovič et al. 2001)

Formal definition: Group *Isolepis setacea* NOT Group *Eleocharis ovata*
Diagnostic species: *Agrostis stolonifera*, *Alisma gramineum*, *Carex viridula*, *Filago minima*, ***Isolepis setacea***, *Juncus alpinoarticulatus*, ***Juncus tenageia***, ***Pseudognaphalium luteoalbum***, *Rumex acetosella* s. lat., *Sagina procumbens*, ***Tillaea aquatica***
Constant species: *Agrostis stolonifera*, *Bidens tripartita*, *Gnaphalium uliginosum*, ***Isolepis setacea***, *Juncus bufonius*, *Peplis portula*, *Pseudognaphalium luteoalbum*, *Sagina procumbens*, *Tillaea aquatica*
Dominant species: *Bolboschoenus maritimus* s. lat., *Eleocharis ovata*, *Gnaphalium uliginosum*, ***Isolepis setacea***, ***Juncus bufonius***, *Juncus tenageia*, *Peplis portula*, *Trifolium arvense*

This community is usually formed by open stands of graminoids (e.g. *Isolepis setacea*, *Juncus bufonius*, *J. tenageia*) and dicotyledonous herbs of various growing form, e.g. procumbent species like *Sagina procumbens* or *Tillaea aquatica*, or taller plants, including *Pseudognaphalium luteoalbum* and *Radiola linoides* (Table 1). Due to either relatively late germination (e.g. in *Radiola linoides*) or long development (e.g. *Pseudognaphalium luteoalbum*), the stands reach their phenological optimum no earlier than mid-summer.

According to analysis of Ellenberg indicator values, Junco tenageiae-Radioletum linoidis has the lowest nutrient demands among all the separate communities. Nutrients differentiate this community clearly even from Stellario uliginosae-Isolepidetum setaceae, the vegetation type ecologically closest to Junco tenageiae-Radioletum linoidis (Figs. 2 and 4, Table 3). The results of soil analyses from Germany (e.g. Müller-Stoll & Pietsch 1985) suggest opposite relationship as indicated by EIV analysis in our study: Junco-Radioletum should grow on nutrient richer soils than Stellario-Isolepidetum. This contradiction can be related to the fact that Junco-Radioletum occurs in the Czech Republic and Slovakia on the margin of its distributional range and hence might be more sensitive to nutrient content in soil. However, no soil analyses are available from the study area for the comparison with EIV.

Stands of this association colonise various types of habitats with exposed, wet or waterlogged substrate, e.g. the margins of fishponds and water reservoirs, fish storage pond bottoms or forest clearings. The substrata are usually sands or sands with a thin layer of loamy mud.

As shown on the map (Fig. 5), most records of Junco tenageiae-Radioletum linoidis come from southern Bohemian fishpond basins. However, most of these records are historic. The community has never been recorded in any other part of the Czech Republic, although recent occurrence in the north-western part of Bohemian-Moravian Uplands cannot be excluded. In Slovakia, there are only two regions where Junco tenageiae-Radioletum linoidis occurs: the Borská lowland (western Slovakia, surrounding the towns of Malacky and Plavecký Štvrtok) and Orava basin (northern Slovakia, Orava water reservoir). All the regions where Junco tenageiae-Radioletum linoidis has been mapped are characterised by local climatic and edaphic conditions typical of Atlantic areas; this is reflected in frequent occurrence of Atlantic elements, including the Radiolion linoidis species and communities (Valachovič et al. 2001, Deil 2005, Šumberová 2011).

Environmental gradients

The main environmental gradient expressed by Ellenberg indicator values (EIV) is the EIV for moisture (Spearman correlation coefficient with the first DCA axes -0.67, $p < 0.001$), followed by the EIV for light (-0.66, $p < 0.001$). Similarly, all other values, i.e. the EIV for soil reaction, continentality, temperature and nutrients, are statistically significant ($p \leq 0.05$), but correlations are weak (all less than 0.36 with negative or positive course; cf. Fig. 4). Comparison of clusters based on EIV showed important differences in several cases (Table 3). EIV for temperature are significantly different and the lowest values were detected for Stellario uliginosae-Isolepidetum setaceae and Junco tenageiae-Radioletum linoidis. EIV for moisture of Polygono-Eleocharitetum ovatae is significantly different from others, and was the highest. Furthermore, Junco tenageiae-Radioletum linoidis had the lowest EIV for nutrients, significantly different from all compared clusters/communities.

Similar results were obtained from the evaluation of vegetation of Isoëto-Nano-Juncetea class in the Czech Republic, based on EIV (Šumberová 2011). For example, similarly to our results, Stellario uliginosae-Isolepidetum setaceae and Junco tenageiae-Radioletum linoidis had the lowest EIV for temperature, while Polygono-Eleocharitetum ovatae had the highest EIV for moisture. However, similar results for both studies are related to similar phytosociological data, as most of the relevés in our dataset originate only from Czech Republic. In our analysis, Junco tenageiae-Radioletum linoidis had the lowest EIV for nutrients and continentality. In general, nutrient-poor soils and preference for atlantic–subatlantic climate is typical of Radiolion linoidis communities (Deil 2005). In contrast, the highest nutrients EIV values were found for Cyperetum michelliani (Eleocharition ovatae). This corresponds with the fact that communities of Eleocharition ovatae grow on eutrophic to hypertrophic soils in the western Palaearctic region (Deil 2005).

In addition, we compared the results of EIV analysis for the communities with published data on soil properties (e.g. Philippi 1968, Müller-Stoll & Pietsch 1985, Bagi 1988, Traxler 1993, Täuber 2000). In most cases, our results were consistent with the findings presented in literature. However, there are missing data published on soil properties which would be relevant for the study area; and therefore we had to compare our results with literature sources originating from other Central-European countries. Additionally, there are no available data on soil chemistry for some communities from any part of their distributional range. Our results point out the necessity to carry out more specific research focused on detailed analysis of local conditions on various habitats and in various regions with the occurrence of Isoëto-Nano-Juncetea stands. If done in larger part of the distributional range, such an analysis could better elucidate e.g. the relationship of particular communities to soil properties in different climatic conditions.

Distribution and frequency changes in Isoëto-Nanojuncetea communities

During the 20th century, which was characterised by large changes in land use and management intensity, some of the Isoëto-Nanojuncetea communities significantly changed their frequency and distribution within the study area. For instance, the associations Stellario-Isolepidetum setacei and Junco tenageiae-Radioletum linoidis were quite common in the past on sandy margins of fishponds and on wet arable fields in regions with slightly warm and humid climate and acidic bedrocks, e.g. in southern Bohemia (Ambrož 1939, Jílek 1956). Some species typical of these communities, e.g., *Gypsophila muralis*, *Juncus tenageia*, *Pseudognaphalium luteoalbum* and *Tillaea aquatica* are sensitive to eutrophication; and therefore their frequency considerably decreased in the landscape during the last decades. The elimination of summer drainage of fishponds, and the fertilising and liming of pond bottoms at the same time were probably the most important factors contributing to decline or disappearance of these species (cf. Šumberová 2003). On most fishponds, the summer drainage is currently too short in timing, especially to allow development of Junco tenageiae-Radioletum linoidis (Šumberová et al. 2012a). Even if the sandy margins of larger fishponds are exposed during the whole growing season (e.g. due to water shortage), they do not provide suitable conditions for most of typical species of this community, because of high competition from herbs with larger biomass and higher nutrient demands (e.g. *Bidens frondosa*, *Epilobium ciliatum* and *Matricaria perforata*). As a consequence of such trends, recent Isoëto-Nanojuncetea stands on fishpond margins are often formed only by species with broader ecological range; and these stands usually remain unclassifiable.

A decline has been presumed for some other communities, too, but there is no sufficient historical material which would enable us to make such unequivocal conclusions. Pulicario vulgaris-Menthetum pulegioidis was probably more frequent in the whole study area before landscape use and management changes. For instance, large areas of river alluvia were drained. As indicated by Hejný (in Moravec et al. 1995), the stands of *Pulicaria vulgaris*, in the past also quite common in southern Bohemia, disappeared due to conversion of highly eutrophic village ponds, originally used for geese or duck grazing, to "ornamental" water bodies. However, no historical relevés exist to allow the re-construction of the community distribution in the past. Similar case is Centunculo-Anthoceretum punctati. Unlike most of the Isoëto-Nanojuncetea communities, it probably never occurred in fishponds (cf. Ambrož 1939, Jílek 1956) and was more or less limited to wet, nutrient poor arable fields. It is not known how frequent or rare the community has been in the study area in the past, because historical relevés are lacking. However, its diagnostic species (especially *Centunculus minimus*) were reported more frequently than today, at least in some regions with a relatively humid and moderately warm climate (e.g. southern Bohemia – cf. Kovanda 1992, Chán 1999). It is likely that even well-developed stands were not recorded by phytosociologists in the first half of the 20th century, because they concentrated their attention on other habitat types than arable land. Recently, this community is extremely rare in the landscape of the whole study area, probably due to eutrophication, abandonment of extensively used fields and succession of perennial herbs.

Cyperetum micheliani, despite the river regulations which probably led to destruction of some of its localities in natural habitats, is still a common association within the study area. This community enlarged its distributional range as a consequence of fishpond management changes. For those parts of Bohemian Massif formed by non-calcareous acidic bedrocks, Cyperetum micheliani is an untypical vegetation type, and in the past occurred there only in ponds most strongly impacted by humans, e.g. in small highly eutrophic fishponds situated directly in settlements (cf. Ambrož 1939, Jílek 1956). At the present time, the community can also be found there in larger fishponds where the substrate chemistry has been strongly altered due to fish-duck farming. In these fishponds, Cyperetum micheliani replaced the ecologically vicariant association of Polygono-Eleocharitetum ovatae; similar processes can also be observed locally in the surroundings of dung and lime heaps on fishpond bottoms. Despite the management and vegetation changes, Polygono-Eleocharitetum ovatae still strongly dominates over Cyperetum micheliani in fishponds in regions with acidic bedrocks and it shows stable occurrence in area of its historical distribution. However, even in the regions with predominating Polygono-Eleocharitetum ovatae in fishponds, the fish storage ponds are regularly colonised by stands of Cyperetum micheliani. We presume that this is caused by a specific management regime, above all by relatively strong liming of fish storage ponds (Šumberová et al. 2006). The trend to enlarge the distributional range was observed also in Cerastio-Ranunculetum sardoi, whose impoverished stands have been found rarely in southern Bohemia. Considering the recent introduction of *Cerastium dubium* and *Lythrum hyssopifolium* in southern Bohemia (Hejný 1995, Šumberová, unpublished data 2011), it is not excluded that in future, there might develop the stands of similar species composition as in southern Moravia and in Slovakia. On the other hand, changes in management of wet arable fields might have led to local decline of this community in some parts of its historical distribution in southern Moravia and lowlands of Slovakia.

Ranunculetum lateriflori is an example of the community with very limited distribution in the study area. This association belongs to very rare vegetation types in Slovakia (Valachovič et al. 2001) and existing phytosociological data are relatively old, recorded in the second half of 20th century (Hindáková 1965, Oťaheľová et al. 1985, Mochnacký 1988). The absence of recent data is probably more related to a lack of phytosociological survey of marshland vegetation in the Východoslovenská lowland in the last two decades than to the decline of this community. Appropriate habitats still exist in the region, and have not suffered from considerable environmental or management changes. However, confirmation of the recent status of this association in Východoslovenská lowland would be useful. Similarly to previous community, Veronico-Lythretum hyssopifoliae might always been rare within the study area, as well. There are no available historical data allowing a comparison of historical and recent distribution. It is likely that elimination of summer drainage of fishponds in warm regions, changes in management on arable land (e.g. drainage of wet fields) and river regulations could negatively influence frequency of Veronico-Lythretum in study area. However, impact of some of these changes can be mitigated by natural processes, for instance by inter-annual climatic fluctuations. In extremely dry years, the water level in fishponds and other water bodies falls naturally. In years with extraordinary high precipitation, the conditions are optimal for development of Veronico-Lythretum on arable land, including the places which are in "normal" years suitable for crop cultivation (Němec et al. 2012). Thus, the stands may be observed in the same locality at intervals of more than one year and this also might contribute to lack of data and impossibility to evaluate the recent frequency of this community in a field.

Our syntaxonomical concept in relation to the European context

Using the formalised classification on a national level, generally a substantial number of the relevés assigned by their authors to particular associations remains unclassified (cf. Chytrý 2007, 2009, 2011). These are the relevés from the edge of the variability of each of the associations, which do not contain enough species from a particular species group. The same principle also operates in classification of larger datasets from more countries. In our dataset from the Czech Republic and Slovakia, the relevés of Polygono-Eleocharitetum ovatae were originally represented from both countries, although in the Czech Republic the community was much more frequent. After the reclassification using the formalised approach, all the relevés from Slovakia assigned to this association by their authors fell into the "unclassifiable" category. The formal definition, produced during the previous analysis of the Czech dataset, was "too strict" for the relevés from Slovakia. Although in Slovakia three of six species of the particular species group occurred (cf. Appendix 2), i.e. *Carex bohemica*, *Eleocharis ovata* and *Limosella aquatica*, such a combination was not represented in any of the analysed relevés. This is not surprising, however, because in large parts of the Czech Republic, especially in southern Moravia, only the three above-mentioned species of Polygono-Eleocharitetum ovatae occur, and they are very scattered in the landscape, thus their joint occurrence in one stand is very rare.

According to Chytrý (2007, 2009, 2011), it is possible to classify all the relevés. Once the formal classification of the dataset is performed, the unclassified relevés can be assigned to particular community on the basis of the similarity to the classified groups (Kočí et al. 2003, Tichý 2005). However, this approach is useful for specific purposes only, e.g. in vegetation mapping of small areas (Chytrý 2007, 2009, 2011). In this study, we aim to use an approach we believe is suitable for large-scale classification; and therefore we present only the results based on formal definitions. Such results will be then comparable with the classification from other countries produced by the same method, and thus will contribute to discussion on future pan-European Isoëto-Nano-Juncetea classification.

Following the same methodology is of high importance, because even small methodological differences might make any reasonable comparison impossible. For instance, the results of the formalised classification of Isoëto-Nano-Juncetea communities of Germany (TÄUBER 2000, TÄUBER & PETERSEN 2000) are incomparable with our results for several reasons. Firstly, as is obvious from the methods described in papers cited above, the dataset that was used for all the analyses, including the formation of sociological species groups, contained only the relevés of Isoëto-Nano-Juncetea. This is the major obstacle for potential comparison of the results. Nowadays, the species groups are usually formed on the basis of large dataset containing not only the relevés from studied vegetation type, but also from other vegetation types of the same plant formation (e.g. of non-forest vegetation; cf. HAVLOVÁ 2006, CHYTRÝ 2007, 2009, 2011) or at least of contact vegetation units (as in this study). It ensures that the species groups will have more general validity (KOČÍ et al. 2003), i.e. they will be applicable in different datasets, too. Many species can occur in more than one vegetation type. Therefore, it is necessary to estimate properly their syntaxonomical value for their evaluation in broader context (= larger and more variable dataset). In case the dataset contains only the relevés of the studied vegetation type (e.g. of a class), only the narrow ecological specialists can be evaluated correctly. Species with broader ecological range, overlapping within several vegetation types, might be incorrectly interpreted as the species with high positive relationship to a community of the studied class. For instance, Phragmito-Magno-Caricetea species frequently occur in Isoëto-Nano-Juncetea communities. Since some diagnostic species of Phragmito-Magno-Caricetea have specific demands on moisture or substrate, they show positive relationship to particular Isoëto-Nano-Juncetea communities with similar ecological demands. Despite this fact, if the analysis was performed on the basis of large dataset containing both, Isoëto-Nano-Juncetea and Phragmito-Magno-Caricetea classes, most of the Phragmito-Magno-Caricetea species would never be significant for Isoëto-Nanojuncetea species groups. One of the exceptions, confirmed on large variable dataset in ŠUMBEROVÁ (2011), as well as in this study, is *Leersia oryzoides* – the short-reed species with optimum in more vegetation types preferring disturbed habitats. The species groups published by TÄUBER (2000) and TÄUBER & PETERSEN (2000) include many species with broad ecological range, in particular the species of various types of grasslands, common ruderal weeds, etc.

Secondly, the problem with some of the Täuber's groups is a large number of the member species (9 or even more). However, the proportion of the species necessarily present in the relevé to consider the relevé as containing the particular group was set very low (TÄUBER 2000, TÄUBER & PETERSEN 2000). Following CHYTRÝ (2007, 2009, 2011), we used the rule that at least half of the group members must be present in the relevé to be considered as containing the particular group. Also, we tried to form reasonably large species groups, with 6 members of the group as the largest. When we tested the applicability of some of the groups presented by TÄUBER & PETERSEN (2000) on our large dataset containing various vegetation types, most of the groups were split into two parts. The first one contained habitat specialists and the second one the species with broad ecological range. Therefore, it is not possible to use these groups for classification of Czech and Slovak Isoëto-Nano-Juncetea. To the contrary, the testing of originally Czech groups on Czech-Slovak dataset did not reveal such problems, but it detected if some of the communities occur only in one of the both countries (details see below).

Thirdly, whereas TÄUBER (2000) and TÄUBER & PETERSEN (2000) used u-value as a phidelity measure, we preferred phi-value in our study, similarly as some other authors (HAVLOVÁ 2006, CHYTRÝ 2007, 2009, 2011, SVITKOVÁ & ŠIBÍK 2013). As shown by CHYTRÝ et al. (2002), various fidelity measures can lead to different classification results. For the above mentioned reasons, the comparison of our results, in sense of the sociological species groups, with the results of German formal classification is very difficult. Therefore, we used mainly overall species composition (TÄUBER 2000 published also the tables of individual relevés) and descriptions in the text for identification of equivalent communities in German synopsis.

The total area of both studied countries is relatively small, but the natural conditions regarding climate, bedrocks, soils etc. are very diverse. This is reflected in the vegetation, including the communities of the class Isoëto-Nano-Juncetea. Even after formalised classification, leading to significant reduction of overall number of associations (originally 21 various associations from both countries; cf. HEJNÝ in MORAVEC 1995, VALACHOVIČ et al. 2001) nine associations, with distinct species' composition and ecology, remained. These associations are included in three alliances. In comparison with the vegetation overviews of some other Central European countries, e. g. Germany (POTT 1995, OBERDORFER 1998, TÄUBER & PETERSEN 2000, HILBIG 2001) and Poland (MATUSZKIEWICZ 2007) where the Verbenion supinae vegetation is absent, the diversity represented in our dataset is remarkably high. Conversely, the vegetation overview of Isoëto-Nano-Juncetea for Austria (TRAXLER 1993) shows very similar representation of individual communities as found in our data, i.e. there might also be distinguished three alliances, independently of the original classification.

Some of the associations in our study were represented only by a very small number of relevés, which could influence the analysis. This applies above all for communities of the Radiolion linoidis alliance. The formal definitions, primarily used for the Czech dataset, also detected analogous communities in Slovakia. It is important to note that in both countries, Radiolion linoidis communities occur on the margin of their distribution range (Valachovič et al. 2001, Šumberová 2011). Therefore, it can also be supposed that this represents the margin of their variability. It is likely that, if using datasets from more oceanic parts of Europe, our formal definitions would not function satisfactorily. Additionally, the definitions based on the western European datasets would be probably "too strict" for our relevés. The stands represented by relevés within the Verbenion supinae alliance can be impoverished in comparison with the vegetation in countries southwards of Slovakia and, especially, the Czech Republic. Therefore the classification of the relevés from Hungary, Romania or the northern Balkans where the Verbenion supinae communities are the most frequent within Isoëto-Nano-Juncetea (cf. Coldea 1997, Borhidi 2003), would probably require some modifications of the formal definitions published in this paper.

The plot size and the period in which the relevés were collected may be two important factors influencing the analysis. For instance, the authors in the past had a tendency to sample their data on larger plots than do the phytosociologists today. However, our dataset includes mainly recent data of recommended plot size (cf. Chytrý & Otýpková 2003). We did not observe any special pattern in our classification which could be a consequence of too large or too old plots. In each differentiated association, there are represented all types of relevés according to plot size and period of sampling. For the communities which were more frequent in the past we have also other evidences about their decrease (e.g. disappearance of their diagnostic species) and thus the recently lower number of their records should not be explained as a consequence of different classification of plots from various periods.

The specific traits of many Isoëto-Nano-Juncetea communities are quite large, sometimes even the disjunctive distributional ranges on one hand, and, on the other hand, relatively high species-richness within one stand (at least in comparison with aquatic or reed vegetation). This results in a very interesting mixture of different communities and transitions between them across relatively small regions of Europe. As a consequence of this pattern, European checklists of Isoëto-Nano-Juncetea (e.g. Pietsch 1973, Brullo & Minissale 1998) include dozens of associations described from various parts of Europe. The content of many of these associations are likely to overlap one another, as indicated by the syntaxa names, and also by our revision of a small number of European Isoëto-Nano-Juncetea associations. Formalised classification of the data from the whole of Europe could elucidate how many syntaxa within the Isoëto-Nano-Juncetea class it is yet reasonable to differentiate, the location of "hot-spots" of Isoëto-Nano-Juncetea diversity, and where and how this diversity can best be maintained.

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Appendix 1

Narrowly defined species or subspecies merged for analysis in JUICE software

Bolboschoenus maritimus s. lat. *(B. laticarpus, B. maritimus, B. planiculmis, B. yagara), Callitriche palustris* agg. (mainly *Callitriche palustris* s. str., in some cases *C. cophocarpa*, *C. platycarpa*, *C. stagnalis* or *Callitriche* sp.), *Cardamine pratensis* agg. (*C. dentata*, *C. matthioli* and *C. pratensis*), *Dactylis glomerata* agg. (*D. glomerata*, *D. polygama*), *Drepanocladus revolvens* agg. (*D. cocconii*, *D. revolvens*), *Eleocharis palustris* s. lat. (*E. mamillata*, *E. palustris*, *E. vulgaris*), *Festuca rubra* agg. (*F. nigrescens*, *F. rubra*), *Galeobdolon luteum* agg. (*G. luteum*, *G. montanum*), *Galium palustre* agg. (*G. elongatum*, *G. palustre*), *Galium verum* agg. (*G. verum*, *G. wirtgenii*), *Glyceria fluitans* s. lat. (*G. fluitans*, *G. nemoralis*, *G. notata*), *Juncus bufonius* agg. (*J. minutulus*, *J. bufonius*), *Luzula multiflora* s. lat. (*L. campestris*, *L. multiflora*), *Odontites vulgaris* agg. (*O. vulgaris*, *O. vernus*), *Poa pratensis* s. lat. (*P. angustifolia*, *P. pratensis*), *Polygonum aviculare* agg. (*P. arenastrum*, *P. aviculare*), *Potamogeton pusillus* s. lat. (*P. berchtoldii*, *P. pusillus*), *Quercus petraea* agg. (*Q. dalechampii*, *Q. petraea*), *Ranunculus aquatilis* agg. (*R. aquatilis*, *R. peltatus*), *Salix* sp. (included all species within the genera recorded in the relevés as seedlings), *Senecio nemorensis* agg. (*S. fuchsii*, *S. germanicus*, *S. ovatus*), *Valeriana officinalis* agg. (*V. officinalis*, *V. procurrens*, *V. sambucifolia*), *Veronica hederifolia* agg. (*V. hederifolia*, *V. sublobata*, *V. triloba*), *Vicia sativa* agg. (*V. angustifolia*, *V. sativa*).

Appendix 2

Sociological species groups included in formal definition of associations within the *Isoëto-Nano-Juncetea* class using the Cocktail method

Groups adopted from the 2nd and 3rd volume of the Vegetation of the Czech Republic (Chytrý 2009, 2011)
Group *Centunculus minimus*: *Anthoceros agrestis*, *Centunculus minimus*, *Hypericum humifusum*
Group *Cyperus fuscus*: *Cyperus fuscus*, *Leersia oryzoides*, *Plantago uliginosa*
Group *Gypsophila muralis*: *Gypsophila muralis*, *Juncus bufonius*, *Spergularia rubra*
Group *Isolepis setacea*: *Isolepis setacea*, *Juncus tenageia*, *Pseudognaphalium luteoalbum*, *Tillaea aquatica*
Group *Eleocharis ovata*: *Carex bohemica*, *Coleanthus subtilis*, *Elatine hydropiper*, *E. triandra*, *Eleocharis ovata*, *Limosella aquatica*
Group *Juncus ranarius*: *Juncus ranarius*, *Veronica anagalloides*, *Veronica catenata*

Newly created groups
Group *Cerastium dubium*: *Cerastium dubium*, *Lythrum hyssopifolium*, *Myosurus minimus*, *Ranunculus sardous*
Group *Ranunculus lateriflorus*: *Elatine alsinastrum*, *Ranunculus lateriflorus*, *R. polyphyllus*

Appendix 3

Formal definitions of individual associations – form acceptable by JUICE software (Tichý 2002)

Ranunculetum lateriflori: <### *Ranunculus lateriflorus*>AND<### *Ranunculus lateriflorus*>

Cerastio-Ranunculetum sardoi: <### *Cerastium dubium*>NOT<### *Ranunculus lateriflorus*>

Veronico anagalloidis-Lythretum hyssopifoliae: <### *Juncus ranarius*>NOT<### *Cerastium dubium*>

Pulicario vulgaris-Menthetum pulegioidis: <*Pulicaria vulgaris*UP05>AND<*Pulicaria vulgaris*UP05>

Polygono-Eleocharitetum ovatae: <### *Eleocharis ovata*>AND<### *Eleocharis ovata*>

Cyperetum micheliani: <### *Cyperus fuscus*>NOT(((<### *Cerastium dubium*>OR<### *Eleocharis ovata*>)OR(<### *Isolepis setacea*>OR<### *Juncus ranarius*>))OR<*Pulicaria vulgaris*UP15>)

Stellario uliginosae-Isolepidetum setaceae: <### *Gypsophila muralis*>NOT(((<### *Cerastium dubium*>OR<### *Cyperus fuscus*>)OR(<### *Eleocharis ovata*>OR<### *Isolepis setacea*>))OR((<*Agrostis stolonifera*UP25>OR<*Pulicaria vulgaris*UP05>)OR<*Rorippa amphibia*UP05>))

Centunculo-Anthoceretum punctati: <### *Centunculus minimus*>AND<### *Centunculus minimus*>

Junco tenageiae-Radioletum linoidis: <### *Isolepis setacea*>NOT<### *Eleocharis ovata*>