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# Vegetation of the aquatic and marshland habitats in the Orava region, including the first records of *Potametum alpini*, *Potametum zizii* and *Ranunculo-Juncetum bulbosi* in the territory of Slovakia

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**Abstract:** The vegetation of the aquatic and marshland habitats of the Orava region (north of Slovakia) was studied in 2009, using traditional phytosociological methods. Sixteen aquatic and eighteen marsh plant communities were described within 96 phytosociological relevés by using TWINSPAN with the application of the dominance principle. Three associations, *Potametum alpini*, *Potametum zizii* and *Ranunculo-Juncetum bulbosi*, were found as new communities for Slovakia. *Myriophylletum verticillati*, *Potametum nodosi*, *Potametum graminei* and *Alisma gramineum* community were recorded in the northernmost localities in Slovakia. Among marsh communities, *Calletum palustris* is very rare, both in the Orava region and in Slovakia as a whole. According to Ellenberg's indicator values (EIV), moisture was evaluated as the main ecological gradient. Plant communities are ordered along the first Detrended Correspodence Analysis (DCA) axis in a typical hydroseries (*Potametea* → *Lemnetea* → *Phragmition communis* → *Phalaridion arundinaceae*, *Oenanthion aquaticae* and *Sparganio-Glycerion* → *Magnocaricion elatae*). The second DCA axis was most correlated with EIV for nutrients. Among the five directly measured ecological characteristics (temperature, pH and conductivity of water, water depth, and substrate type), conductivity of water (0.44, $P < 0.01$) and substrate type (0.32, $P < 0.05$) were the statistically significant variables explaining the variability along the first DCA axis.

**Key words:** *Charetea fragilis*; *Littorelletea uniflorae*; *Lemnetea*; *Potametea*; *Phragmito-Magnocaricetea*; aquatic and marsh plant communities; ecology; phytosociology

## Introduction

Recent phytosociological research of aquatic and marshland habitats brought significant new information about vegetation types in small (e.g. Hrivnák 2009; Stančić 2010; Lastrucci et al. 2010) and larger geographical regions (e.g. Nobis et al. 2006; Spałek 2006; Hroudová et al. 2009) in Central Europe. Several new vegetation units have been discovered in recent years, just through detailed regional research (Rydlo 2007; Stančić 2009). New information concerning the distribution, floristic variability and ecology of aquatic and marshland plant communities in Slovakia has been presented over the last decade. Phytosociological and ecological data were published mainly from the mountain ranges and/or artificial aquatic habitats (Bartošová et al. 2008; Oťaheľová et al. 2008; Hrivnák 2009; Hrivnák et al. 2009a), but information about these vegetation types from the Orava region was not available. This region has specific climatic, geomorphological and geological conditions which have a considerable influence on the vegetation, including the vegetation of the aquatic and marshland habitats studied. Moreover, there are several older and partially naturalized artificial water bodies (e.g. the Oravská priehrada reservoir, and abandoned fishponds near the village of Párnica), which are potential and appropriate habitats for the vegetation types studied. Therefore, we decided to focus our research directly on the Orava region. The main aims of this study are: 1) to provide a review of aquatic and marsh vegetation of aquatic habitats in the northernmost territory of Slovakia, as well as at the northern boundary of the Danube River catchment basin, 2) to present floristical, ecological, and chorological characteristics of the plant communities detected, 3) to evaluate the influence of ecological variables on the species composition of the vegetation studied, and, 4) to compare the selected ecological variables of the most frequent aquatic and marshland plant communities.

### Study site

The vegetation of aquatic habitats was studied in the Orava region, which lies in the northern part of Central Slovakia (Fig. 1). The study area is situated in the central and upper part of the Orava River catchment basin, which is one of

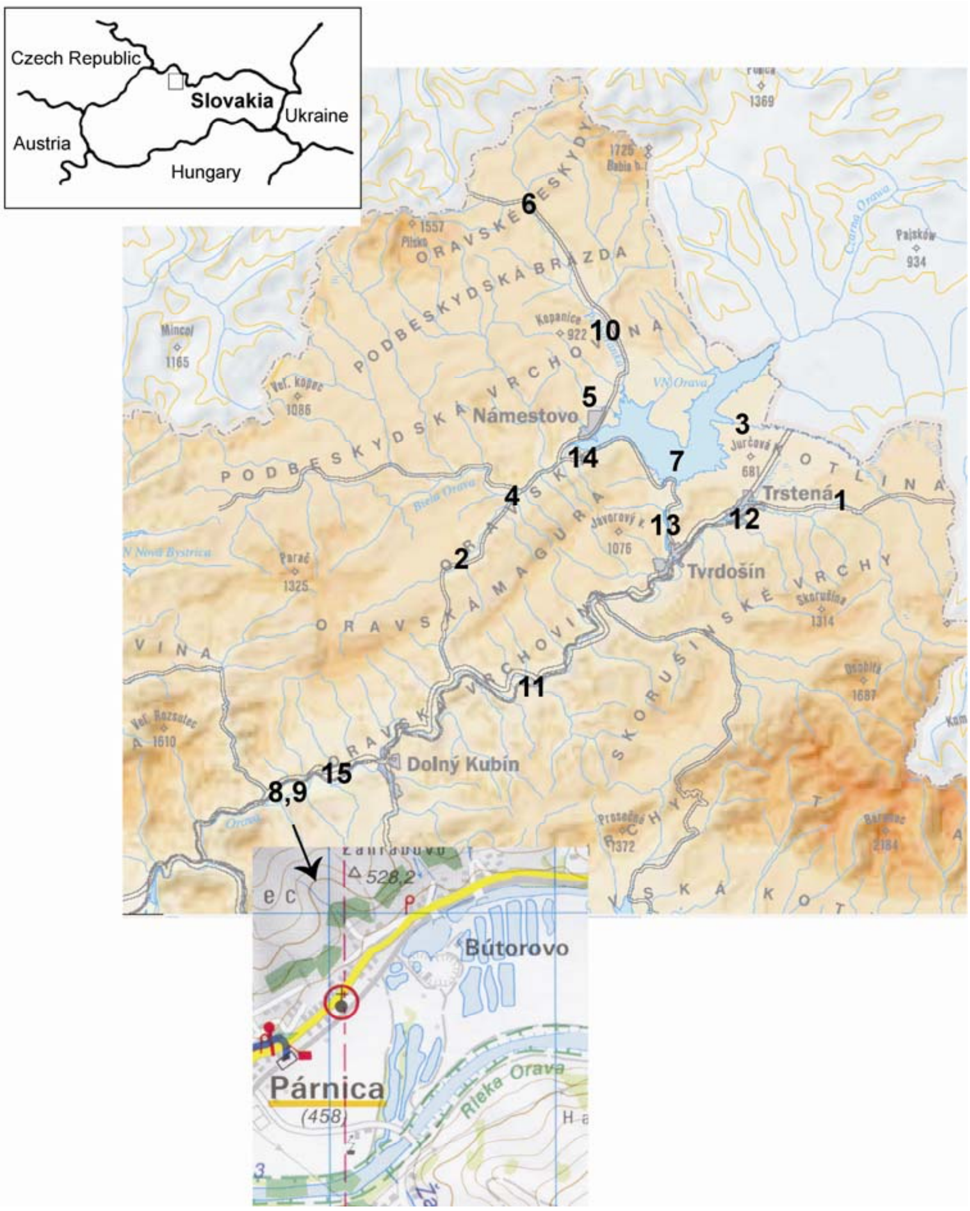


Fig. 1. Study area: The map of orographical units (Miklós 2002), displaying the studied localities in order, according to Table 1, and the map of the localities near the village of Párnica.

the northernmost areas of the Danube River basin, as well as the whole Black Sea drainage basin. It is located near the territorial boundaries of the Atlantic Ocean drainage basin. This area includes the following orographical units: Oravské Beskydy Mts., Podbeskydská brázda Furrow, Podbeskydská vrchovina Upland, Oravská Magura Mts., Oravská vrchovina Upland, Oravská kotlina Basin and Skorušinské vrchy Mts (Fig. 1). The area is part of the Carpathian phytogeographical region (Futák 1984) with a moderately cool climate; the mean July temperature oscillates from 12 °C to 16 °C and the total annual precipitation ranges from 700 to 1200 mm (Miklós 2002). Fifteen localities that represent variable types of aquatic habitats were visited during the research (Table 1 and Fig. 1). The localities are situated in the colline to submontane belts at elevations ranging from 450 m to 725 m. Their area ranges from just a few $m^2$ (gravel ditch near the village of Čimhová) to more than 35 $km^2$ (the Oravská priehrada water reservoir). Within the habitats studied, the water was slightly acidic to alkaline, poor to moderately rich in soluble mineral content, and its temperature range was relatively wide (from 13 °C to almost 25 °C; Table 1).

## Methods

Phytosociological relevés were taken, applying the Zürich-Montpellier approach. Only stands with at least the minimum area recommended for these types of vegetation were recorded (aquatic and annual amphibious vegetation > 5 $m^2$, marshland vegetation > (6) 10 $m^2$; cf. Chytrý & Otýpková 2003). Macrophyte vegetation data were collected in August and September 2009. All the relevés were stored using the TURBOVEG database (Hennekens & Schaminée 2001), and then exported and processed by JUICE software (Tichý 2002). They were further analyzed by TWINSPAN (Hill 1979) applying the dominance principle. CANOCO

Table 1. List of the localities studied and a selection of their characteristics.

| Number of locality | Locality | Altitude (m) | Longitude | Latitude | Approximate area (ha) | Water conductivity (S/cm at 25 °C) | Water reaction (pH) | Water temperature (°C) |
|---|---|---|---|---|---|---|---|---|
| 1. | Čimhová village, Oravica stream, gravel ditches | 650 | 19°42′ | 49°22′ | < 0.01 | 224 | 8.65 | 17.5 |
| 2. | Hruštín, wr NE of village | 680 | 19°22′ | 49°20′ | < 1.00 | 238 | 7.9 | 20.3 |
| 3. | Jelešňa river, over river mouth to Oravská priehrada wr | 605 | 19°36′ | 49°25′ | < 0.01 | 133–287 | 6.9 | 13.0–14.5 |
| 4. | Lokca village, oxbow of Hruštínka stream | 630 | 19°22′ | 49°22′ | < 0.01 | – | – | - |
| 5. | Námestovo, Michalovka wr Michalovka | 630 | 19°28′ | 49°25′ | < 10.00 | 308 | 7.8 | 19.3 |
| 6. | Oravská Polhora village, Píla, mire ditches | 725 | 19°25′ | 49°33′ | < 1.00 | 92 | 6.85 | 15.0 |
| 7. | Oravská priehrada wr | 600 | 19°37′ | 49°26′ | > 10.00 | 188–222 | 6.16–8.10 | 17.5–21.1 |
| 8. | Párnica village, abandoned fishponds | 450 | 19°13′ | 49°12′ | > 10.00 | 182–229 | 8.45–9.26 | 22.7–24.7 |
| 9. | Párnica village, Orava ro and gravel ditches | 450 | 19°12′ | 49°11′ | > 10.00 | 440–444 | 7.95–8.24 | 22.2–23.0 |
| 10. | Rabča village, Modré jazierko lake | 620 | 19°30′ | 49°27′ | < 10.00 | 265 | 8.2 | 15.9 |
| 11. | Sedliacka Dubová village, canal | 510 | 19°25′ | 49°15′ | < 1.00 | – | – | – |
| 12. | Trstená town, fishponds | 610 | 19°36′ | 49°21′ | < 10.00 | 204–250 | 8.70–9.40 | 15.9–21.6 |
| 13. | Tvrdošín town, wr | 575 | 19°32′ | 49°21 | > 10.00 | 194 | 8.17 | 20.3 |
| 14. | Vavrečka village, small lake near Oravská priehrada wr | 605 | 19°28′ | 49°24′ | < 10.00 | 359 | 7.8 | 18.4 |
| 15. | Veličná village, Orava ro | 460 | 19°14′ | 49°12′ | < 1.00 | 657 | 7.4 | 22.3 |

Legend: ro – river oxbow; wr – water reservoir

4.5 for Windows package (ter Braak & Šmilauer 2002) was used for a detrended correspondence analysis (DCA); logarithmic transformation was used and rare species were downweighted. For the ecological interpretation of major gradients of the wetland vegetation studied, the average non-weighted Ellenberg's indicator values of vascular plant species (Ellenberg et al. 1992) as well as selected ecological variables (water conductivity, temperature, pH and depth, as well as substrate type) were plotted onto a DCA ordination diagram as supplementary variables. The connection between the values of the above-mentioned ecological variables and the positions of samples (relevés) along the first two axes were expressed by Pearson correlation coefficients, calculated by using the STATISTICA software (StatSoft 2001). Water conductivity, temperature and pH values were measured for most relevés by the pH-meter/conductometer WTW pH/Cond 340i in the field. Water depth was measured for all relevés, and the substrate type was evaluated according to the following scale: fine organic substrate (1), fine inorganic substrate including sand (2) and/or gravel (3); other types were not detected on the study sites. The position of each relevé was obtained using the GPS eTrex Summit (Garmin, United States; WGS 84 system).

The nomenclature of plants followed Marhold & Hindák (1998). The names of vegetation units are presented with the author's name and the year of description.

## Results and discussion

Survey of plant communities

*Charetea fragilis* Fukarek ex Krausch 1964
  *Charetalia hispidae* Sauer ex Krausch 1964
    *Charion fragilis* Krausch 1964 em. Van Raam et Schaminée in Schaminée et al. 1995
      *Charetum fragilis* Fijałkowski 1960 (Table 2, relevé 1)
*Lemnetea* de Bolós et Masclans 1955
  *Lemnetalia minoris* R. Tx. 1955
    *Lemnion minoris* R. Tx. 1955
      *Lemnetum minoris* Oberd. ex Th. Müller et Görs 1960 (Table 2, relevés 2–6)
  *Lemno-Utricularietalia* Passarge 1978
    *Utricularion vulgaris* Passarge 1964
      *Utricularietum neglectae* Th. Müller et Görs 1960 (Table 2, relevés 7–9)
*Potametea* Klika in Klika et Novák 1941
  *Potametalia* Koch 1926
    *Nymphaeion albae* Oberd. 1957
      *Polygonetum amphibii* von Soó 1927 (Table 2, relevés 10–13)
      *Potametum natantis* von Soó 1927 (Table 2, relevés 14–16)
    *Potamion lucentis* Rivas-Martínez 1973
      *Potametum alpini* Br.-Bl. 1949 (Table 2, relevé 17)
      *Potametum lucentis* Hueck 1931 (Table 2, relevés 18–23)
      *Potametum zizii* Černohous et Husák 1986 (Table 2, relevé 24)
      *Potametum perfoliati* Koch 1926 em. Passarge 1964 (Table 2, relevés 25–27)
      *Myriophylletum verticillati* Soó 1927 (Table 2, relevés 28–29)
      *Myriophylletum spicati* Soó 1927 (Table 2, relevés 30–36)
      *Alisma gramineum* comm. (Table 2, relevé 37)
    *Potamion pusilli* Hejný 1978
      *Potametum pectinati* Carstensen 1955 (Table 2, relevés 38–39)
      *Potametum berchtoldii* Wijsman ex Shipper, Lanjouw et Schaminée 1995 (Table 2, relevés 40–41)
  *Callitricho-Batrachietalia* Passarge 1978
    *Ranunculion fluitantis* Neuhäusl 1959

Table 2. Aquatic plant communities in the Orava region.

| * | Taxon / Relevé number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Locality | 1 | 14 | 15 | 11 | 9 | 7 | 9 | 3 | 8 | 7 | 7 | 7 | 7 | A | 5 | 10 | 10 | 7 | 7 | 7 | 7 | 12 | 12 | 7 | 7 | 7 | 7 | 8 | 11 | 5 | 7 | 2 | 8 | 8 | 9 | 8 | 7 | 12 | 7 | 3 | 6 | 9 | 9 | 9 | 9 | 9 | 9 | 8 | 7 | 7 | 7 | 7 |
| | Relevé area ($m^2$) | 5 | 5 | 16 | 15 | 16 | 14 | 10 | 12 | 16 | 16 | 16 | 16 | 15 | 4 | 15 | 15 | 9 | 12 | 12 | 15 | 16 | 16 | 16 | 15 | 16 | 16 | 18 | 12 | 16 | 15 | 14 | 16 | 16 | 28 | 10 | 6 | 7 | 6 | 12 | 12 | 9 | 16 | 16 | 15 | 13 | 11 | 10 | 18 | 12 | 7 | 16 | 16 |
| | **Diagnostic species of the *Charetea fragilis* asociations** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Chara fragilis* | 5 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| | **Diagnostic species of the *Lemnetea* asociations** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Lemna minor* | . | 5 | 3 | 5 | 5 | 4 | + | 4 | . | . | . | . | r | . | + | . | + | . | . | . | . | . | 1 | . | . | . | . | . | 5 | . | . | . | . | . | . | . | . | . | . | 1 | + | + | + | + | + | . | . | . | . | . | . | . |
| | *Utricularia australis* | . | . | . | . | . | . | 5 | a | 4 | . | . | . | . | + | . | . | . | . | . | . | . | . | . | . | . | . | . | + | . | . | . | . | . | . | + | . | . | . | . | . | . | . | 3 | + | . | . | . | . | . | . | . | . |
| | **Diagnostic taxa of the *Potametea* asociations** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Persicaria amphibia* ** | . | . | . | . | . | . | . | . | . | 4 | 4 | 4 | 5 | . | . | . | . | a | . | . | . | . | . | . | . | . | . | . | . | . | + | . | . | . | . | . | . | . | + | . | . | . | . | . | . | . | . | . | + | . | . | . |
| | *Potamogeton natans* | . | . | . | . | . | . | . | . | . | . | . | . | . | b | 5 | 4 | a | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| | *Potamogeton alpinus* | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 3 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| | *Potamogeton lucens* | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 3 | 4 | 5 | 4 | 5 | 5 | . | . | . | . | . | . | . | . | . | . | . | . | a | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| | *Potamogeton ×angustifolius* | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 4 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| | *Potamogeton perfoliatus* | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | + | . | . | . | 5 | 3 | 4 | . | . | . | . | . | . | 1 | . | . | + | . | . | . | . | . | . | . | . | . | . | . | . | + | . | b |
| | *Myriophyllum verticillatum* | . | . | . | . | . | . | . | . | 3 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 5 | 4 | . | . | . | . | . | . | . | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| | *Myriophyllum spicatum* | . | . | . | . | . | . | . | . | . | . | 1 | + | + | . | + | . | . | . | 1 | + | + | . | . | . | + | + | + | . | . | 5 | 3 | 5 | 5 | 5 | 4 | 3 | + | . | . | . | . | . | . | . | . | r | b | 4 | r | + | 1 | + |
| | *Alisma gramineum* | . | . | . | . | . | . | . | . | . | . | . | . | r | . | . | . | . | . | r | . | . | . | . | . | . | + | . | . | . | . | . | . | . | . | . | . | 3 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| | *Potamogeton pectinatus* | . | . | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | + | . | + | 1 | + | . | + | . | . | . | . | . | . | . | . | . | . | b | 4 | . | . | . | . | . | . | . | . | . | . | . | 1 | + |
| | *Potamogeton berchtoldii* | . | . | . | . | . | + | . | . | r | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | . | . | . | . | . | . | . | 3 | . | . | . | b | 5 | . | . | + | + | . | . | . | . | . | . | . |
| | *Potamogeton nodosus* | . | . | . | . | . | . | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 4 | 3 | 5 | 4 | 5 | 3 | 4 | . | . | . | . |
| | *Potamogeton gramineus* | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | + | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | b | . | . | . | . | . | . | . | . | . | 5 | 5 | 4 | 3 |
| | **Other aquatic species of the *Lemnetea* and *Potametea* classes** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Potamogeton crispus* | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | + | . | . | . | . | . | . | . | . | . | + | 1 | 1 | + | . | . | . | . | . | a | . |
| | *Potamogeton pusillus* | . | . | . | . | . | . | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | + | 1 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | . | . | . | . | 3 | . | . | . | . | . | . | . | . | . |
| | *Elodea canadensis* | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | + | . | . | . | . | . | . | . | + | . | . | . | . | . | . | . | . | . | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| | *Najas marina* | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | + | + | . | . | . | . | . | . | . | 3 | . | . | . | . | . | . | . | . | . | . |
| | *Riccia fluitans* | . | . | . | . | . | + | . | 1 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| | *Callitriche cophocarpa* | . | . | . | . | . | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | r | . | . | . | . | . | . | . | . | . | . | . | . |
| | *Ranunculus circinatus* | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | r | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 3 | . | . | . | . | . | . | . |
| | *Callitriche hamulata* | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| | *Ceratophyllum demersum* | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| | *Zannichellia palustris* | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| | **Other species** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| PM | *Sparganium erectum* | . | . | . | . | . | . | + | . | . | . | . | . | . | . | . | r | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | + | . | + | + | . | . | . | . | . | . | . |
| MA | *Agrostis stolonifera* | . | . | . | . | . | . | . | . | . | a | . | . | . | . | . | . | . | 3 | a | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | + | . | . | . | . | . | . | . | . | . | . | . | . | . |
| | *Eleocharis acicularis* | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | + | . | . | . | . | . | . | . | . | . | a | . | . | . | . | + |
| PM | *Equisetum fluviatile* | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | . | . | . | . | . | . | . | . | . | . | . |
| PM | *Typha latifolia* | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | r | . | . | . | . | . |

Legend: *diagnostic species – MA *Molinio-Arrhenatheretea*, PM *Phragmito-Magnocaricetea*; ***Persicaria amphibia* f. *natans*;
The number of the locality is presented according to Table 1, except A – Klin, Nature reserve Klinské rašelinisko.
Coordinates of the localities of the relevés (1–52 – Number of the relevé, E – Longitude, N – Latitude): 1:19°41′53.20″ E, 49°21′56.50″ N; 2:19°28′28.50″, 49°23′51.40″; 3:19°14′43.30″, 49°12′06.90″; 4:19°25′23.00″, 49°15′41.90″; 5:19°12′16.50″, 49°11′21.30″; 6:19°36′19.40″, 49°24′54.30″; 7:19°12′15.10″, 49°11′22.10″; 8:19°36′20.70″, 49°24′52.50″; 9:19°12′51.70″, 49°11′51.20″; 10:19°35′13.30″, 49°26′29.90″; 11:19°35′52.70″, 49°24′57.80″; 12:19°37′27.70″, 49°26′45.90″; 13:19°30′45.70″, 49°25′17.40″; 14:19°29′37.90″, 49°25′38.30″; 15:19°28′32.40″, 49°25′23.40″; 16:19°29′50.50″, 49°27′33.30″; 17:19°29′49.30″, 49°27′32.60″; 18:19°35′07.60″, 49°26′29.30″; 19:19°31′45.70″, 49°24′51.60″; 20:19°30′54.00″, 49°24′01.30″; 21:19°31′46.80″, 49°24′41.80″; 22:19°36′41.70″, 49°21′20.10″; 23:19°36′39.40″, 49°21′20.00″; 24:19°35′17.20″, 49°26′29.90″; 25:19°31′43.30″, 49°24′49.20″; 26:19°37′36.90″, 49°26′24.60″; 27:19°30′53.40″, 49°24′03.10″; 28:19°12′51.70″, 49°11′51.20″; 29:19°25′18.40″, 49°15′43.70″; 30:19°28′32.40″, 49°25′23.40″; 31:19°35′46.30″, 49°24′54.10″; 32:19°22′05.90″, 49°20′02.20″; 33:19°12′42.60″, 49°11′50.60″; 34:19°12′53.90″, 49°11′52.10″; 35:19°12′23.10″, 49°11′40.50″; 36:19°12′47.60″, 49°11′50.60″; 37:19°31′48.60″, 49°24′48.50″; 38:19°36′42.40″, 49°21′19.30″; 39:19°35′09.80″, 49°26′30.10″; 40:19°36′22.14″, 49°24′51.20″; 41:19°25′13.10″, 49°33′07.70″; 42:19°12′15.30″, 49°11′21.80″; 43:19°12′15.20″, 49°11′22.00″; 44:19°12′15.40″, 49°11′22.00″; 45:19°12′15.30″, 49°11′21.70″; 46:19°12′17.80″, 49°11′49.80″; 47:19°12′16.20″, 49°11′29.80″; 48:19°12′53.60″, 49°11′52.10″; 49:19°35′05.80″, 49°26′29.50″; 50:19°30′40.60″, 49°25′17.20″; 51:19°31′47.00″, 49°24′50.50″; 52:19°36′00.30″, 49°23′36.60″. Full headers of individual relevés are presented in the Slovak national phytosociological database.
Species with occurrence only in one relevé in Table 2: *Alisma plantago-aquatica* 8: 1, *Carex rostrata* 41: +, *Carex vesicaria* 8: +, *Eleocharis palustris* 47: +, *Equisetum palustre* 16: r, *Eriophorum angustifolium* 14: r, *Phalaroides arundinacea* 47: +, *Potentilla palustris* 14: 1, *Rorippa amphibia* 2: +, *Salix viminalis* 2: 1, *Solanum dulcamara* 8: +, *Sparganium natans* 14: 1.

*Potametum nodosi* Passarge 1964 (Table 2, relevés 42–48)

*Ranunculion aquatilis* Passarge 1964

*Potametum graminei* Koch 1926 (Table 2, relevés 49–52)

*Phragmito-Magnocaricetea* Klika in Klika et Novák 1941

*Phragmitetalia* Koch 1926

*Phragmition australis* Koch 1926

*Phragmitetum vulgaris* von Soó 1927 (Table 3, relevé 1)

*Typhetum latifoliae* Lang 1973 (Table 3, relevés 2–5)

*Sparganietum erecti* Roll 1938 (Table 3, relevés 6–12)

*Equisetetum fluviatilis* Steffen 1931 (Table 3, relevés 13–18)

*Magnocaricion elatae* Koch 1926

*Caricenion rostratae* (Balátová-Tuláčková 1963) Oberd. et al. 1967

*Equiseto limosi-Caricetum rostratae* Zumpfe 1929 (Table 3, relevés 19–20)

*Caricetum paniculatae* Wangerin ex von Rochow 1951 (Table 3, relevé 21)

*Caricetum acutiformis* Eggler 1933 (Table 3, relevé 22)

*Carex pseudocyperus* comm. (Table 3, relevé 23)

*Calletum palustris* Osvald 1923 (Table 3, relevé 24)

*Caricenion gracilis* (Neuhäusl 1959) Oberd. et al. 1967

*Caricetum gracilis* Almquist 1929 (Table 3, relevés 25–29)

*Caricetum vesicariae* Chouard 1924 (Table 3, relevés 30–31)

*Phalaridetum arundinaceae* Libbert 1931 (Table 3, relevés 32–34)

*Nasturtio-Glycerietalia* Pignatti 1953

*Phalaridion arundinaceae* Kopecký 1961

*Rorippo-Phalaridetum arundi*naceae Kopecký 1961 (Table 3, relevés 35–37)

*Sparganio-Glycerion* Br.-Bl. et Sissing in Boer 1942

*Leersietum oryzoidis* Eggler 1933 (Table 3, relevé 38)

*Oenanthetalia aquaticae* Hejný in Kopecký et Hejný 1965

*Oenanthion aquaticae* Hejný ex Neuhäusl 1959

*Oenantho aquaticae-Rorippetum amphibiae* Lohmeyer 1950 (Table 3, relevé 39)

*Eleocharitetum palustris* Ubrizsy 1948 (Table 3, relevés 40–42)

*Littorelletea uniflorae* Br.-Bl. et Tüxen ex Westhoff et al. 1946

*Littorelletalia* Koch ex R. Tx. 1937

*Eleocharition acicularis* Pietsch ex Dierßen 1975

*Eleocharis acicularis* comm. (Table 3, relevé 43)

*Ranunculo-Juncetum bulbosi* Oberdorfer 1957 (Table 3, relevé 44)

Phytosociological, ecological and chorological characteristics of plant communities

Sixteen aquatic plant communities of the classes *Charetea fragilis*, *Lemnetea*, and *Potametea*, 16 marsh communities of the class *Phragmito-Magnocaricetea*, and two communities of the oligotrophic water vegetation (*Littorelletea uniflorae*) were found in the aquatic habitats studied.

Stoneworts vegetation was documented only by a single relevé (Table 2, relevé 1); a monodominant stand of *Chara fragilis* grew in the shallow and alkaline water of a small gravel-ditch. *Charetum fragilis* is one of the most frequent stonewort communities, which is common in Western and Central Slovakia. The locality in Orava region is at the northernmost point within the territory of Slovakia (cf. Oťaheľová 2001; Hrivnák et al. 2005).

The vegetation of the class *Lemnetea* was relatively rare in the aquatic habitats studied (Table 2, relevés 2–9). Only two associations, *Lemnetum minoris* and *Utricularietum neglectae* were found in stagnant, 5–20 (40) cm deep water with fine organic sediment on the bottom, and frequently shaded by shrubs and trees. *Utricularietum neglectae* belongs to rare aquatic communities in Slovakia, while *Lemnetum minoris* is frequent over the whole territory of Slovakia (cf. Oťaheľová 1995a; Hrivnák 2002).

The freshwater plant communities of the class *Potametea* were relatively frequent, represented by several vegetation units, and well documented by phytosociological relevés (Table 2, relevés 10–52). The most frequent ones were *Myriophylletum spicati*, *Potametum nodosi*, *Potametum lucentis*, *Polygonetum amphibii*, and *Potametum graminei*. Except for *Potametum nodosi*, all the communities mentioned formed closed (cover 70–100%) or, less frequently, open (40–60%) stands, in medium deep to deep (40–130 cm), and less frequently in shallow (20 cm) or very deep (200 cm) water. *Potametum nodosi* was found only in aquatic habitats near the village of Párnica in stagnant or slowly running, shallow or medium-deep water, with various substrate types (fine organic sediment in deeper and stagnant water, and gravel in shallower and slowly running water). Within these associations, the average water pH value increased in the order *Polygonetum amphibii* → *Potametum graminei* → *Potametum lucentis* → *Potametum nodosi* → *Myriophylletum spicati*, though the first three communities exhibited relatively high variability in the relationship to pH values. Water conductivity was similar for all communities except *Potametum nodosi*, where it was markedly higher (Fig. 2). In general, *Potametum nodosi* is a community typical of waters rich or moderately-rich in nutrients (e.g. Oťaheľová 1995b; Nowak et al. 2007). The above-mentioned communities are relatively frequent in Slovakia, with occurrence mainly in the lowland regions, while distribution data from the mountain regions of Slovakia are rare or missing (e.g. Oťaheľová 1995b; Bartošová et al. 2008; Rydlo 2008; Hrivnák et al. 2009a). *Potametum nodosi* is found in several Cen-

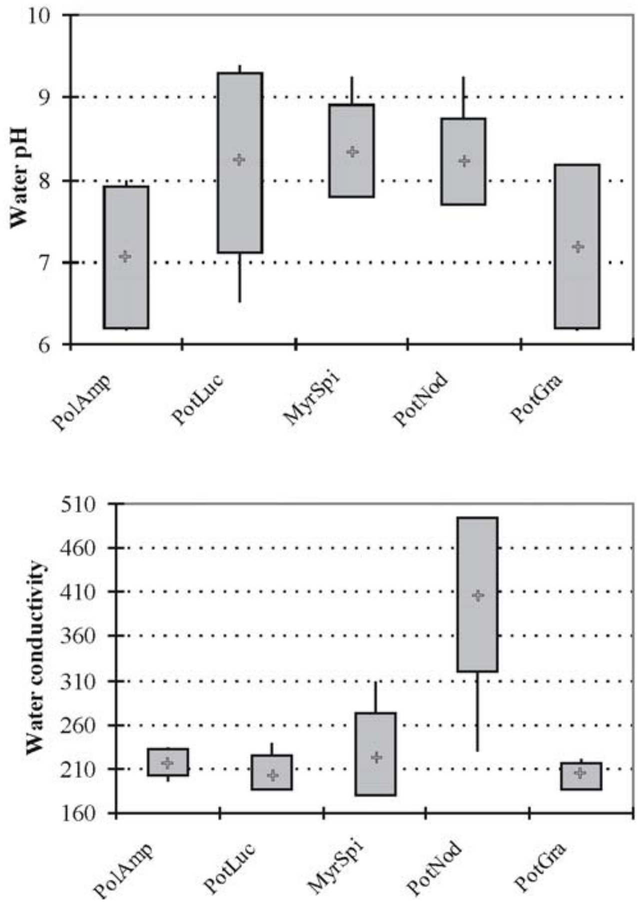


Fig. 2. Measured values of water pH and conductivity in the most frequently occurring *Potametea* plant communities. PotNat – *Polygonetum amphibii* ($n = 4$), PotLuc – *Potametum lucentis* ($n = 5$), MyrSpi – *Myriophylletum spicati* ($n = 6$), PotNod – *Potametum nodosi* ($n = 6$) and PotGra – *Potametum graminei* ($n = 4$). Box – standard deviation, cross – average, vertical bar – minimum and maximum.

tral European countries (cf. Hejný 1995a; Borhidi 1996; Nowak et al. 2007). In Poland, the dominant species of this community, *Potamogeton nodosus*, is relatively rare in the adjacent part of the Polish Carpathians (Zalewska-Gałosz 2008; Zalewska-Gałosz & Oklejewicz 2008), but a community with their dominance is not mentioned (Matuszkiewicz 2008). *Polygonetum amphibii* and *Potametum lucentis* are frequent aquatic communities. Although *Myriophylletum spicati* is also frequently found in Slovakia, data on its distribution and ecology are deficient (Oťaheľová 1995b). *Potametum graminei* is a rare community with its distribution in the lowlands of south-eastern and south-western Slovakia (Oťaheľová 1995b). Our data from the Orava region are the first from the northern part of Slovakia and from higher altitudes. However, the community is known, for instance, in Poland (Matuszkiewicz 2008). In the study area, the occurrence of *Potametum graminei* was limited to several places in the Oravská priehrada water reservoir. In addition, three vegetation units, *Potametum alpini* and *Potametum zizii* associations, and the *Alisma gramineum* community have been found in the Orava region, though their occurrence is rare. The first two communities mentioned are new to the territory of Slovakia. A stand of *Potametum alpini* was found in shallow, relatively cold and alkaline water, shaded by trees, with a fine mixed substrate at the bottom, containing both organic and inorganic matter. Similar ecological characteristics are found in neighbouring countries, the Czech Republic (Šumberová 2011a) and Poland (Nowak et al. 2007; Matuszkiewicz 2008). The documented stand (see Table 2, relevé 17) was relatively poor in species, *Potamogeton alpinus* was a dominant, and *P. natans* a subdominant species; furthermore two species *Calllitriche hamulata*, and *Lemna minor* occurred in low abundance. *Potamogeton alpinus* and *Callitriche hamulata* are amongst species occurring rarely, not only in the region of Orava but within the entire territory of Slovakia (Kaplan 2010; Kochjarová et al. 2010). In the published relevés, other true aquatic species also occurred, e.g. *Callitriche palustris*, *Lemna minor*, *Myriophyllum spicatum*, *Potamogeton natans*, *P. obtusifolius*, *Sparganium emersum* (Černohous & Husák 1986; Nowak et al. 2007). Another community, new in the territory of Slovakia, *Potametum zizii,* was found in the littoral zone of the Oravská priehrada water reservoir. The vegetation of the locality grew in medium-deep water with a slightly acidic/neutral water reaction (pH 6.5) and relatively low conductivity (197 μS/cm). A rare hybrid taxon, *Potamogeton ×angustifolius,* formed nearly monodominant submerged stands, adjacent to localities with *Potametum lucentis*, *Potametum graminei*, and *Polygonetum amphibii.* The community was validly described for the first time in a fishpond near the village of Holice in the north-eastern part of the Czech Republic (Černohous & Husák 1986) and it was also reported in other localities of the country (Černohous & Husák l986; Rydlo 2005; Šumberová 2011b). It is also found in localities in Germany (Rennwald 2000), and India, Kashmir (Zutshi 1975). *Alisma gramineum* community was found, like the other two above-mentioned rare communities, only in the Oravská priehrada water reservoir. The dominant species is relatively common in this reservoir, where open and small stands with several typical aquatic species have developed (Table 2). Other detected plant communities from the class *Potametea* are fairly frequent in the study area. *Potametum natantis* prefered smaller artificial or natural aquatic habitats and formed open and often large stands. Specific species composition was detected in a ditch in the Klinské rašelinisko mire. *Potamogeton natans* formed stands with the occurrence of typical mire species such as *Comarum palustre*, *Eriophorum angustifolium*, and *Sparganium natans.* The species composition of this stand is different from those mentioned for *Potametum natantis*, found over the whole of Europe (Schratt 1993; Oťaheľová 1995b; Rodwell 1995; Popescu & Coldea 1997; Borhidi 2003; Matuszkiewicz 2008; Šumberová 2011c). *Potametum perfoliati* formed open to moderately-closed stands in habitats with medium-deep water in various parts of the Oravská priehrada water reservoir. *Myriophylletum verticillati* is a rare plant community in the region studied, as well as in the territory of Slovakia as a whole, reported only in a few localities (e.g. Hrivnák et al. 2004; Hrivnák et al. 2009b). It grew in shallow to medium-deep water, with fine organic substrate at the bottom. In addition to the typical submersed form, the dominant species often develops a terrestrial form, too. The vegetation with dominance of small linear-leaved pondweeds was represented by *Potametum pectinati* and *Potametum berchtoldii*. *Potametum pectinati* is a community typical of nutrient-rich waters. It is frequent throughout Slovakia, although relatively rare in Orava region. Higher values of water conductivity (250 and 359 μS/cm) and an increased nutrient supply, either from agricultural activities or due to the additional fertilization of fishponds at fish-farms, are typical of both localities of this community in the region studied. There is relatively little information about the *Potametum berchtoldii* community in Slovakia (e.g. Bartošová et al. 2008; Hrivnák et al. 2009a). Until now, *Potamogeton pusillus* has been determined at the aggregate-taxon level in most of the stands where its occurrence was dominant, while *P. berchtoldii* and *P. pusillus* s. s. were determined sporadically in Slovakia.

The typical marsh vegetation contained a relatively high number of vegetation units, but only a few of them were frequent in the studied area (*Sparganietum erecti*, *Equisetetum fluviatilis* and *Caricetum gracilis*). Four associations were found within the *Phragmition australis* alliance (Table 3). Their species composition and ecological characteristics are similar to those from other parts of Slovakia (cf. Oťaheľová et al 2001). Specific species composition was detected in the case of *Sparganietum erecti* from the Jelešňa river alluvium, where a combination of spring (e.g. *Cardamine amara*), typical marsh (e.g. *Carex rostrata*, *Glyceria fluitans* and *Scutellaria galericulata*) and mire species (e.g. *Calla palustris*) was found. This is related to the presence of specific habitat conditions (fen-soils, river floods, springs, high level of groundwater all year round). Tall-sedge vegetation included eight plant communities. Only *Caricetum gracilis* and *Phalaridetum arundinaceae* were relatively frequent, however. The first of the above-mentioned communities formed large and closed monodominant stands in the littoral of large water reservoirs (Oravská priehrada and Tvrdošínska priehrada). *Phalaridetum arundinaceae* was in contact with *Caricetum gracilis* in the upper littoral, and the dominant species *Carex gracilis* and *Phalaroides arundinacea* often occurred in both associations. Other communities of the *Magnocaricion elatae* alliance were less frequent or rare. *Calletum palustris* is the most interesting finding within *Phragmito-Magnocaricetea*. It was found in a terrain depression within an alder forest, growing in shallow water, with deep fen-soil. *Calletum palustris* is sometimes included in a separate alliance *Carici-Rumicion hydrolapathi* Passarge 1964 (Hejný & Husák 1978; Hejný 1995b). However, in several lists of Slovak syntaxa (Mucina & Maglocký 1985; Jarolímek et al. 2008) it was classified as belonging to the *Magnocaricon elatae* alliance. The community was not mentioned in the Slovak survey of wetland vegetation (Oťaheľová et al. 2001), because no relevant phytosociological relevés were documented at that time. Four associations were detected from the other alliances within *Phragmito-Magnocaricetea*. *Rorippo-Phalaridetum arundinaceae* formed stands along stream tributaries or banks of water reservoirs with a strong and direct wave impact. A typical habitat for this community is a river bank (Kopecký 1961; Kopecký & Hejný 1965). *Eleocharitetum palustris* and *Oenantho aquaticae-Rorippetum amphibiae* are communities typical of shallow, relatively nutrient-rich, aquatic habitats with a seasonal water level fluctuation. Shallow water, or the limose ecophase, is optimal for development of their stands (Oťaheľová et al. 2001). *Leersietum oryzoidis* formed small stands on the banks of the Orava river oxbow, near the village of Párnica. Distribution data are known mainly in the southern part of Slovakia (Zaliberová et al. 2000; Oťaheľová et al. 2001), while no occurrence in northern areas has so far been reported.

The vegetation of the *Littorelletea uniflorae* class is represented only by two relevés of various plant communities (Table 3, relevés 43–44). *Eleocharis acicularis* stands were found in the river oxbow bottom near the village of Párnica, in the limose ecophase. Larger stands of this community with the occurrence of several endangered species (e.g. *Limosella aquatica* and *Tillaea aquatica*) occurred on the sandy bottom of the Oravská priehrada water reservoir, after drainage in 1990 (Jarolímek & Zaliberová 1991). *Ranunculo-Juncetum bulbosi* was formed by several *Juncus* species (*J. bulbosus*, *J. articulatus* and *J. bufonius* agg.) and a number of mire species, such as *Agrostis canina* or *Carex echinata*, which formed open stands at the exposed bottom of an excavated mire. *Juncus bulbosus* was found in the mire vegetation in the region studied (Bernátová et al. 2007), but it grew more frequently on exposed and waterlogged soils on stream banks, in wood yards, mire ditches or forest roadsides, with the presence of *Carex demissa*, *Isolepis setacea* and *Juncus articulatus* (D. Dítě, pers. com.). This is the first paper to report the occurrence of *Ranunculo-Juncetum bulbosi* in Slovakia. However, it is known in neighbouring countries Austria, the Czech Republic and Poland (Traxler in Grabherr & Mucina 1993; Šumberová et al. 2011; Matuszkiewicz 2008).

Among Ellenberg's indicator values, "moisture" was the most important ecological characteristic explaining the variability of the species data along the first DCA axis in the studied vegetation of aquatic and marshland habitats (Fig. 3). Plant communities are ordered along the moisture gradient, from aquatic vegetation (*Potametea* and *Lemnetea*), through littoral (*Phragmition communis*) and other marsh vegetation (*Phalaridion arundinaceae*, *Oenanthion aquaticae* and *Sparganio-Glycerion*) to tall-sedge vegetation (*Magnocaricion elatae*). This zonation is typical of the vegetation of aquatic and marshland habitats at regional (e.g. Balátová-Tuláčková 1993; Oťaheľová et al. 2001)

Table 3. Marsh plant communities in the Orava region.

| * | Taxon / Relevé number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Locality | 15 | 8 | 6 | 15 | 9 | 10 | 9 | 9 | 4 | 3 | 9 | 9 | 6 | 7 | 7 | 7 | 5 | 7 | 7 | 6 | 8 | 7 | 8 | 3 | 7 | 7 | 7 | 13 | 7 | 7 | 13 | 7 | 7 | 7 | 7 | 7 | 7 | 9 | 14 | 7 | 7 | 7 | 9 | 6 |
| | Relevé area (m$^2$) | 16 | 16 | 15 | 15 | 20 | 16 | 7 | 13 | 18 | 12 | 6 | 6 | 15 | 16 | 16 | 16 | 14 | 16 | 12 | 15 | 16 | 16 | 8 | 15 | 16 | 15 | 16 | 12 | 16 | 14 | 6 | 16 | 7 | 16 | 15 | 18 | 16 | 13 | 16 | 10 | 4 | 9 | 3 | 9 |
| **Diagnostic species of the *Phragmito-Magnocaricetea* asociations** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Ph | *Phragmites australis* | 5 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| Ph | *Typha latifolia* | b | 4 | 5 | 5 | 3 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | + | . | . | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| Ph | *Sparganium erectum* | . | . | . | . | . | . | 4 | 3 | 4 | 5 | 3 | 3 | 3 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | + | . | . | . | . | . | . |
| Ph | *Equisetum fluviatile* | . | . | 1 | . | . | . | . | . | . | . | . | . | . | 4 | 3 | 5 | 4 | 5 | 3 | + | 1 | a | . | . | 1 | . | a | . | + | . | . | . | + | + | . | . | . | . | . | . | . | . | . | . |
| Mc | *Carex rostrata* | . | . | + | . | . | . | . | . | . | + | . | . | . | . | . | . | . | 1 | 4 | 5 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| Mc | *Carex paniculata* | . | . | . | . | 1 | . | . | . | . | . | . | . | . | . | . | . | + | . | . | . | 5 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| Mc | *Carex acutiformis* | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 5 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| Mc | *Carex pseudocyperus* | . | . | . | . | 1 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 4 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | . | . | . | . | . | . |
| Ci | *Calla palustris* | . | . | . | . | . | . | . | . | . | 1 | . | . | . | . | . | . | . | . | . | . | . | . | . | 4 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| Ci | *Cicuta virosa* | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| Mc | *Carex acuta* | . | . | . | . | . | . | . | . | . | . | . | . | . | + | . | . | . | . | . | . | . | . | . | . | 5 | 5 | 5 | 5 | 5 | . | . | + | + | . | . | . | . | . | . | + | . | . | . | . |
| Mc | *Carex vesicaria* | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 5 | 5 | . | . | . | . | . | . | . | . | . | . | . | . | . |
| Mc, Ph | *Phalaroides arundinacea* | . | 1 | . | . | . | . | . | + | . | . | . | . | . | a | + | . | . | . | . | . | + | + | . | . | . | + | + | 1 | + | . | 1 | 5 | 5 | 5 | 5 | 5 | 5 | + | + | a | + | . | . | . |
| Ph | *Rorippa sylvestris* | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | r | . | . | . | . | r | . | . | + | . |
| Ph | *Persicaria hydropiper* | . | . | . | . | . | . | . | . | . | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | . | . | + | . | . | . | . | a | + | . | . | . | . | . | . | . |
| Gs | *Leersia oryzoides* | . | . | . | . | r | . | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 5 | . | . | . | + | + | . |
| Oe | *Rorippa amphibia* | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 5 | . | . | . | . | . |
| Oe | *Eleocharis palustris* | . | . | . | . | . | . | . | . | . | . | b | b | . | + | . | . | + | . | . | . | . | . | + | . | . | . | . | . | . | . | . | . | . | 1 | . | . | . | . | . | 4 | 3 | 3 | + | . |
| **Diagnostic taxa of the *Littorelletea uniflorae* asociations** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Eleocharis acicularis* | . | . | . | . | + | . | . | . | . | . | r | r | . | . | . | . | . | 4 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | b | + | 4 | . |
| | *Juncus bulbosus* | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 3 |
| | *Juncus bufonius* agg. | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | + |
| **Aquatic species of the *Lemnetea* and *Potametea* classes** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Lemna minor* | . | + | + | 3 | + | + | . | b | 3 | + | + | r | + | . | . | . | + | . | . | + | . | . | . | b | . | . | . | . | . | . | . | . | . | . | . | . | + | . | a | . | . | . | . | . |
| | *Potamogeton berchtoldii* | . | a | . | . | + | . | . | a | . | . | . | . | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| | *Potamogeton nodosus* | . | . | . | . | + | . | b | a | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| | *Myriophyllum verticillatum* | . | b | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | a | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| | *Batrachium circinatum* | . | . | . | . | + | . | . | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| | *Myriophyllum spicatum* | . | . | . | . | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | + | . | . | . |
| | *Potamogeton natans* | . | . | . | . | . | + | . | . | . | . | . | . | . | . | . | . | 1 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| | *Potamogeton perfoliatus* | . | . | . | . | . | . | . | . | . | . | . | . | . | . | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | + | . | . | . |
| | *Potamogeton gramineus* | . | . | . | . | . | . | . | . | . | . | . | . | . | . | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | + | . | . | . |
| **Marsh species of the *Phragmito-Magnocaricetea* class** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Galium palustre* | b | . | . | . | + | . | . | . | . | a | . | . | . | r | . | . | . | . | . | + | 1 | . | . | . | . | . | . | . | . | . | . | . | a | . | . | 1 | + | . | . | + | . | . | . | . |
| | *Lycopus europaeus* | 1 | + | . | . | r | . | . | . | . | + | . | . | . | . | . | . | + | . | . | r | + | . | . | . | . | . | . | + | . | . | . | . | . | . | . | . | . | + | . | . | . | . | . | . |
| | *Alisma plantago-aquatica* | . | . | . | . | + | + | . | . | + | . | . | . | . | . | . | 1 | . | . | . | . | . | . | + | . | . | + | . | . | . | . | . | . | . | . | . | r | . | . | . | . | . | a | r | . |
| | *Lythrum salicaria* | . | . | . | . | + | . | . | . | . | . | . | . | . | . | + | . | . | . | . | . | . | . | . | . | . | . | . | . | + | . | . | . | + | . | . | + | . | + | . | . | . | . | r | . |
| | *Scutellaria galericulata* | . | . | . | . | r | . | . | . | . | + | . | . | . | . | . | . | . | . | . | . | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| | *Glyceria fluitans* | . | . | . | . | . | . | . | . | . | b | . | . | . | . | . | . | . | . | . | . | . | . | . | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| | *Epilobium hirsutum* | . | . | . | . | . | . | . | . | . | . | r | r | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| | *Stachys palustris* | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | + | . | . | . | . | . | . | . |
| | *Symphytum officinale* | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | r | . | . | . | . | . | + | . | . | . | . | . | . | . | . | . | . | . |
| | *Mentha aquatica* | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | + | . | . | . | . | . | . | . | + | . | . | . | . | . | . | . | . |
| **Other taxa** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| MA, PM | *Lysimachia vulgaris* | . | . | . | . | + | . | . | . | . | + | . | . | . | . | . | . | . | . | . | . | + | . | . | + | + | . | . | . | 1 | . | . | . | . | . | . | . | + | + | . | . | . | . | . | . |
| | *Persicaria amphibia* | . | . | . | . | . | . | . | . | . | . | . | . | . | 4 | . | 1 | . | + | . | . | . | . | . | . | . | . | . | r | + | . | . | . | . | . | + | . | . | . | + | . | . | + | . | . |
| | *Salix fragilis* | . | . | . | . | + | . | . | + | . | + | . | . | . | r | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | + | . | . | . | . | . | . | . | . | . |
| MA | *Agrostis stolonifera* | . | . | . | . | . | . | . | + | . | . | + | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | + | . | . | . | . | + | . | . | . | 1 | . | . |
| | *Juncus articulatus* | . | . | . | . | . | . | . | . | . | . | + | 1 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | + | . | + | . | . | 1 | 1 |
| BI | *Bidens frondosa* | . | . | . | . | . | . | . | + | . | . | r | r | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | r | . | . | . | . | . | . | + | . | . | . | . | . | 1 |
| | *Equisetum palustre* | . | . | . | . | r | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | a | . | . | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 3 | . | . | + |
| | *Salix purpurea* | . | . | . | . | . | . | . | . | r | . | . | . | . | . | . | . | . | r | r | . | . | . | . | . | . | . | . | . | . | . | . | . | . | + | . | . | . | . | . | . | r | . | . | . |
| | *Solanum dulcamara* | 1 | . | . | . | . | . | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| | *Lysimachia nummularia* | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | + | . | . | . | . | + | . |
| SC | *Comarum palustre* | . | . | a | . | . | . | . | . | . | . | . | . | 1 | . | . | . | . | . | . | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| MC | *Cardamine amara* | . | . | . | . | r | . | . | . | . | r | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | + | . | . | . | . | . | . | . | . | . | . | . | . |
| | *Ranunculus repens* | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | + | . | . | . | . | . | . | . | a | . | + | . | . | . | . | . | . |
| | *Cardamine pratensis* agg. | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | r | . | . | . | . |
| SC | *Menyanthes trifoliata* | . | . | r | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| BI | *Bidens cernua* | . | . | . | . | r | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | + | . | . |
| | *Rhizomnium punctatum* | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | . | . | 1 | . | . | . | . | . | . | . | . | . | . | . | . | . |
| | *Myosotis palustris* agg. | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | + | . | . | . | + | . | . | . | . |
| | *Ranunculus flammula* | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | + | . | . | . | + |

Legend: *Diagnostic species – BI *Bidentetea tripartitae*, Ci *Cicution virosae*, MA *Molinio-Arrhenatheretea*, Oe *Oenanthion aquaticae*, Mc *Magnocaricion elatae*, Ph *Phalaridion arundinaceae*, Ph *Phragmition communis*, PM *Phragmito-Magnocaricetea*, SC *Scheuchzerio-Caricetea fuscae*, Sg *Sparganio-Glycerion.*
The number of the locality is presented according to Table 1.

Table 3. (continued)

Coordinates of the localities of the relevés (1–44 – Number of the relevé, E – Longitude, N – Latitude): 1:19°14′43.90″ E, 49°12′07.10″ N; 2:19°12′52.50″, 49°11′49.90″; 3:19°25′12.80″, 49°33′07.20″; 4:19°14′42.30", 49°12′08.30″; 5:19°12′23.30″, 49°11′40.30″; 6:19°29′49.90″, 49°27′33.30″; 7:19°12′21.70″, 49°11′51.00″; 8:19°12′15.60″, 49°11′23.30″; 9:19°22′22.60″, 49°21′51.30″; 10:19°36′18.40″, 49°24′53.90″; 11:19°12′16.80″, 49°11′34.30″; 12:19°12′16.80″, 49°11′34.30″; 13:19°25′13.10″, 49°33′07.70″; 14:19°31′49.30″, 49°24′48.20″; 15:19°31′48.60″, 49°24′48.50″; 16:19°36′01.30″, 49°24′54.20″; 17:19°28′32.50″, 49°25′24.30″; 18:19°30′46.20″, 49°25′18.10″; 19:19°30′46.20″, 49°25′17.10″; 20:19°25′12.70″, 49°33′07.00″; 21:19°12′24.20″, 49°11′41.20″; 22:19°34′54.50″, 49°26′29.80″; 23:19°12′53.00″, 49°11′50.40″ 24:19°36′18.20″, 49°24′54.50″; 25:19°31′49.80″, 49°24′47.80″; 26:19°36′07.20″, 49°23′35.00″; 27:19°31′58.70″, 49°25′13.80″; 28:19°32′34.30″, 49°21′35.90″; 29:19°37′37.90″, 49°26′22.70″; 30:19°34′55.20″, 49°26′30.00″; 31:19°32′34.30″, 49°21′35.90″; 32:19°36′08.70″, 49°23′33.70″; 33:19°31′58.70″, 49°25′13.80″; 34:19°30′47.40″, 49°25′18.30″; 35:19°35′58.80″, 49°24′47.60″; 36:19°32′38.30″, 49°21′38.30″; 37:19°34′54.50″, 49°26′29.80″; 38:19°12′16.80″, 49°11′34.30″; 39:19°28′27.40″, 49°23′51.00″; 40:19°30′53.00″, 49°24′02.40″; 41:19°31′48.50″, 49°24′49.30″; 42:19°35′59.40″, 49°24′55.70″; 43:19°12′16.80″, 49°11′34.30″; 44:19°25′09.00″, 49°33′10.00″. Full headers of individual relevés are presented in the Slovak national phytosociological database.

Species with occurrence in only one relevé in Table 3: *Agrostis canina* 44: +, *Amblystegium* sp. 1: a, *Bidens tripartita* 26: +, *Calliergonella cuspidata* 29: 3, *Calystegia sepium* 38: r, *Carex echinata* 44: +, *Carex flava* agg. 44: +, *Carex* sp. 42: +, *Cirsium palustre* 20: +, *Juncus compressus* 44: +, *Juncus effusus* 38: +, *Najas marina* 7:+, *Poa trivialis* 10: +, *Potentilla anserina* 40: 1, *Rumex maritimus* 40: r, *Scirpus sylvaticus* 38: +.

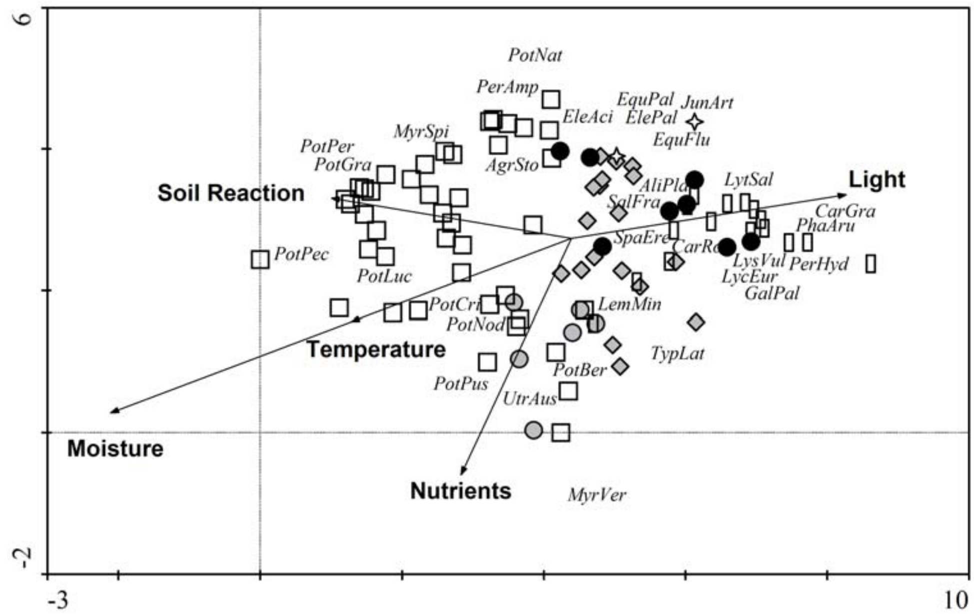


Fig. 3. Ordination diagram (DCA) of species and sample data with supplementary environmental variables (Ellenberg's indicator values). Only species with a weight value higher than 10 % are displayed. Empty squares – *Potametea*, shaded circles – *Lemnetea*, shaded diamonds – *Phragmition communis*, full circles – marsh vegetation of the *Phalaridion arundinaceae*, *Oenanthion aquaticae* and *Sparganio-Glycerion*, stars – *Littorelletea uniflorae*, boxes – *Magnocaricion elatae*. First two axes explain 10.0 and 40.0 % of species variability and species-environment relation, respectively. Weighted correlations between first two axes and environmental variables: Light: 0.5162 and 0.0606, Temperature: −0.4130 and −0.1193, Moisture: −0.8648 and −0.2492, Soil reaction: −0.4511 and 0.0620, Nutrients: −0.2058 and −0.3451. Abbreviations of species: AgrSto – *Agrostis stolonifera*, AliPla – *Alisma plantago-aquatica*, CarGra – *Carex gracilis*, CarRos – *C. rostrata*, EleAci – *Eleocharis acicularis*, ElePal – *E. palustris*, EquFlu – *Equisetum fluviatile*, EquPal – *E. palustre*, GalPal – *Galium palustre*, LemMin – *Lemna minor*, LycEur – *Lycopus europaeus*, LysVul – *Lysimachia vulgaris*, LytSal – *Lythrum salicaria*, MyrSpi – *Myriophyllum spicatum*, MyrVer – *M. verticillatum*, PerAmp – *Persicaria amphibia*, PerHyd – *P. hydropiper*, PhaAru – *Phalaroides arundinacea*, PotBer – *Potamogeton berchtoldii*, PotCri – *P. crispus*, PotGra – *P. gramineus*, PotLuc – *P. lucens*, PotNat – *P. natans*, PotNod – *P. nodosus*, PotPec – *P. pectinatus*, PotPer – *P. perfoliatus*, PotPus – *P. pusillus* s. s., SalFra – *Salix fragilis*, SpaEre – *Sparganium erectum*, TypLat – *Typha latifolia*, UtrAus – *Utricularia australis*.

as well as local (e.g. Hrivnák 2009) levels. Sometimes, the position at the end of the moisture gradient is occupied by the vegetation of periodically flooded and dried-out habitats (e.g. *Oenanthion aquaticae*, *Sparganio-Glycerion* within *Phragmito-Magnocaricetea* or *Bidentetea tripartitae* R. Tx. et al. ex von Rochow 1951, *Isoëto-Nanojuncetea*; Dimopulos et al. 2005; Hrivnák & Csiky 2009). In the Orava region, however, the tall-sedge vegetation was typical for the drier parts of the littoral, with a strongly fluctuating water level. There, it often grew in direct contact with the shrub or forest vegetation (e.g. the Oravská priehrada water reservoir and aquatic habitats near the village of Párnica). True aquatic plants (mainly *Potamogeton* species) are displayed on the left side of the DCA diagram (the wettest habitats), while the typical marsh plants (e.g. *Carex gracilis*, *Galium palustre*, *Persicaria hydropiper* or *Phalarodies arundinaceae*) are displayed at the opposite part of the moisture gradient (amongst the relatively drier habitats). The second DCA axis correlated with the EIV for "nutrients", whereby the gradient from nutrient-poor to nutrient-rich habitats is de-

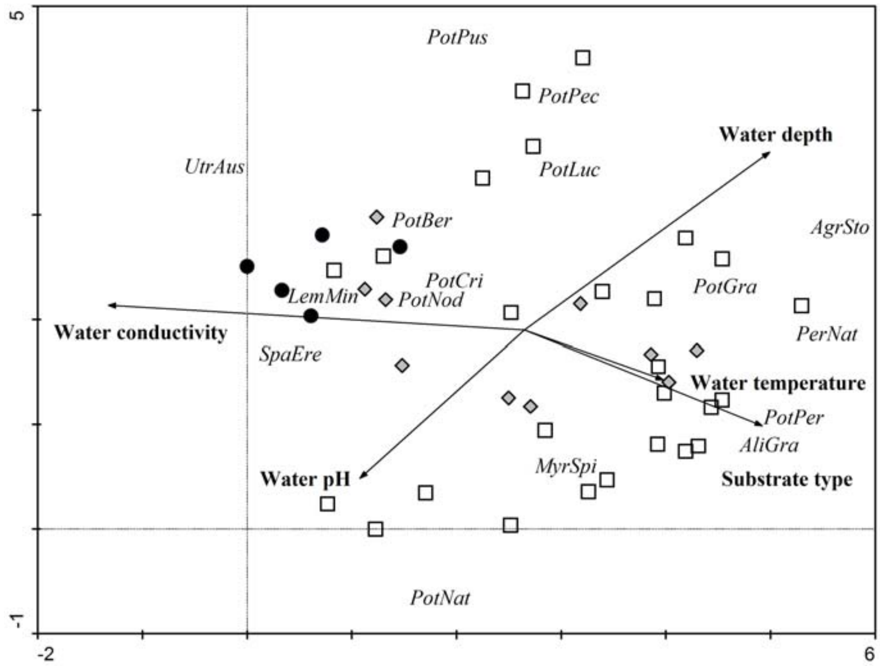


Fig. 4. Ordination diagram (DCA) of species and sample data with supplementary environmental variables measured and observed in the field. Only species with a weight value higher than 10 % are displayed. Full circles – *Lemnetea*, empty squares – *Potametalia*, shaded diamonds – *Callitricho-Batrachietalia*. The first two axes explain 21.5 and 35.9 % of species variability and species-environment relation, respectively. Pearson correlations between first two axes and environmental variables: Substrate type: 0.32* and $-0.15^{ns}$, water depth: $0.27^{ns}$ and $0.21^{ns}$, water pH: $-0.17^{ns}$ and $-0.16^{ns}$, water conductivity: −0.44** and $-0.01^{ns}$, water temperature: $0.29^{ns}$ and $-0.11^{ns}$ (* $P < 0.05$, ** $P < 0.01$, ns – not significant). Species abbreviations are presented in Fig. 3 (AliGra – *Alisma gramineum*).

tectable within all groups of the detected plant communities (Fig. 3). When only the ecological characteristics, gained directly from field measurements, were used in the analysis, water conductivity was the most important ecological factor, and the substrate type the second most important, explaining the variability of the species data within the aquatic plant communities (Fig. 4). The vegetation of the *Lemnetea* class preferred water, which was the richest in soluble mineral substances, having the finest substrate types at the bottom, while the *Potametea* vegetation had a relatively wide range of both ecological characteristics (Fig. 4). *Utricularia australis*, *Lemna minor* and *Sparganium erectum* belong to the species preferring fine organic substrate type and water with the highest values of conductivity, while *Alisma gramineum*, *Potamogeton perfoliatus*, *P. natans* and *Agrostis stolonifera* preferred sand and gravel as a sediment type and water relatively poor in mineral substances (Fig. 4). In general, finer substrate types (silt and clay), with higher organic content, are typical for the first three of the above-mentioned species. The species of the second group, on the other hand, typically exhibits an affinity to a wider range of substrate properties than those observed in the region of Orava (cf. Willby et al. 2000).

The Orava region is very interesting, due to its diversity of aquatic and marshland vegetation. It is important at both national and Central-European levels. Despite large-scale human hydrological changes, this region comprises a valuable system of aquatic and wetland habitats. In this area, three aquatic plant communities (*Potametum alpini, Potametum zizii* and *Ranunculo-Juncetum bulbosi*) have recently been discovered in Slovakia, and some other vegetation units (*Myriophylletum verticillati*, *Potametum nodosi*, *Potametum graminei,* and *Alisma gramineum* community) have their northernmost occurrence there within the territory of the country.


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