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MACROPHYTE VEGETATION OF ARTIFICIAL WATER RESERVOIRS IN THE KRUPINSKÁ PLANINA MTS., INCLUDING THE FIRST RECORD OF *POTAMETUM ACUTIFOLII* FROM SLOVAKIA

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Abstract
Research of macrophyte vegetation of the artificial water reservoirs was carried out during the vegetation season of 2008 in the Krupinská planina Mts. (southern part of central Slovakia). Twenty-one reservoirs were studied and twenty plant communities from the *Lemnetea*, *Potametea* and *Phragmito-Magnocaricetea* classes were found. *Potametum acutifolii* is a new aquatic community for the territory of Slovakia that was found in the reservoir near Hrušov village in intermediately deep, slightly alkaline water with a relatively low content of soluble mineral matters, a high water transparency and a silt-clay sediment on the bottom. Moisture was the main environmental gradient of the studied vegetation explained by Ellenberg's indicator values. Species richness was significantly negatively correlated with water depth. The correlation between the area of reservoirs and the number of detected plant communities was weak and non-significant. Changes of macrophyte vegetation were studied on the case of three reservoirs. Detected changes were caused mainly by human activities or water level fluctuations within the studied period.
Key words: aquatic and marsh vegetation, plant community changes, ecology, DCA.

Izvleček
Raziskave makrofitske vegetacije umetnih vodnih smo izvedli v vegetacijski sezoni leta 2008 v hribovju Krupinská planina (južni del osrednje Slovaške). Raziskali smo enaindvajset vodnih teles in našli dvaindvajset rastlinskih združb iz razredov *Lemnetea*, *Potametea* in *Phragmito-Magnocaricetea*. Asociacija *Potametum acutifolii* je nova vodna rastlinska združba, najdena na ozemlju Slovaške. Našli smo jo v vodnem telesu blizu vasi Hrušov v srednjegloboki, rahlo alkalni vodi z razmeroma nizko vsebnostjo raztopljenih mineralnih snovi, z visoko vodno prepustnostjo in muljasto-glineno usedlino na dnu. Glavni okoljski gradient obravnavane vegetacije, kot kažejo Ellenbergove indikacijske vrednosti, je vlažnost. Število vrste je v negativni odvisnosti z globino vode. Korelacija med površino vodnega telesa in številom najdenih rastlinskih združb je bila nizka in ni bila značilna. Spremembe makrofitske vegetacije smo proučevali v treh vodnih zbiralnikih. Opažene spremembe so posledica predvsem človeških dejavnosti ali nihanja vodnega nivoja v obravnavanem obdobju.
Ključne besede: vodna in močvirna vegetacija, spremembe rastlinske združbe, ekologija, DCA.

1. INTRODUCTION

Anthropogenic aquatic habitats as water reservoirs are unique localities in cultural and human-exploited landscape. Their value increases when natural aquatic habitats are destroyed or strongly changed by human acitivities. In that case, they represent substitute habitats for indigenous aquatic and marsh vegetation. In the past, the information about vegetation of artificial aquatic habitats in the teritorry of Slovakia was relatively scarce (e.g. Oťaheľová & Husák 1992). More intensive research started recently (Hrivnák 1999, Oťaheľová 2005, Jursa & Oťaheľová 2005, Oťaheľová & Oťaheľ 2006). Until this period, research activities of botanists had been concentrated on natural aquatic habitats with stagnant water (e.g. river oxbows or natural flooded terrain depressions), which are situated in the val-

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leys of bigger rivers such as the Danube, Morava or Latorica (e.g. Šomšák 1963, Oťaheľová 1980, Oťaheľová & Husák 1982, Oťaheľová & al. 1994). In general, research of aquatic and marsh vegetation was concentrated into areas with its optimum occurrence, i.e. mainly lowlands and uplands of southern and south-eastern parts of Slovakia. Altitudinally higher and more northern areas have been neglected for a relatively long time. Similarly, research of artificial aquatic habitats started in the last years and data from several Carpathian basins and mountains were published (e.g. Hrivnák 2002a, Hrivnák & al. 2004, Hrivnák & Kochjarová 2008, Oťaheľová & al. 2008). Krupinská planina Mts. is an interesting region of Slovakia where no hydrobotanical research has yet been performed (Fig. 1). I chose this area for the study of macrophyte vegetation of the artificial water reservoirs from following reasons: 1) the study area is situated on the border of two phytogeographical regions, southern part in the Pannonicum and northern part in the Carpaticum regions (cf. Futák 1980), which reflects mainly different climatic characteristics; 2) there are enough appropriate habitats (artificial water reservoirs) for the study to be relatively representative; 3) no complex research of macrophyte vegetation has been done in the study area; 4) there is only limited knowledge on plant communities of artificial water reservoirs from the past, but some of the information available is suitable for a comparison with the results presented in this paper (e.g. Hrivnák 1999; Hrivnák 2002b, 2004). Therefore, the main aim of this work is a complex phytosociological and ecological evaluation of macrophyte vegetation of the artificial water reservoirs in the Krupinská planina Mts., including evaluation within a broader regional context as well as comparison of changes of selected water reservoirs.

2. STUDY AREA

Macrophyte vegetation was studied in the Krupinská planina Mts (Fig. 1). The mountain is situated in the southern part of central Slovakia with altitudinal range from the lowland to the submountain level. It is a typical volcanic mountain range formed mainly of andesites. From the hydrological point of view, the study area belongs to the Ipeľ river catchment area with the following larger rivers and streams: Krupinica, Litava, Vrbovok, Plachtinský potok and Krtíš. A substantial part of

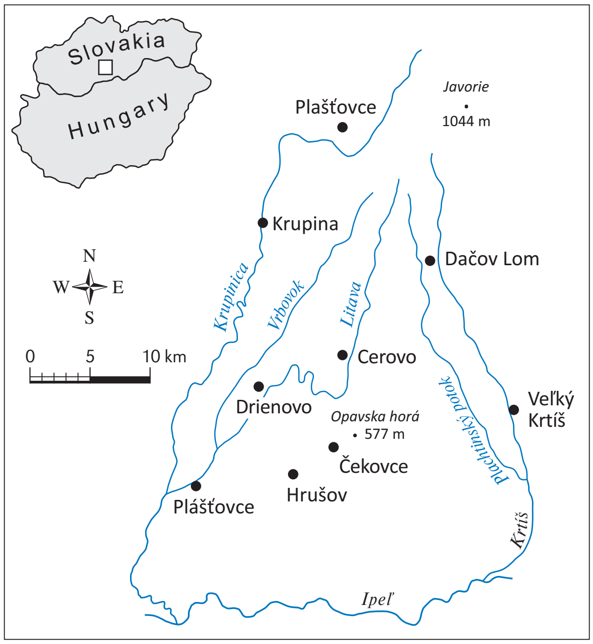

Figure 1: Study sites.
Slika 1: Lokacije preučevanih zbiralnikov.

the area belongs to the warm or moderately warm region with a mean annual air temperature and a precipitation total of 6 to 7 °C and 600 to 700 mm, respectively (Miklós 2002). Twenty-one artificial water reservoirs with various areas, recent uses and statuses were studied and their characteristics are briefly presented in Table 1.

3. METHODS

Phytosociological relevés were taken according to the Zürich-Montpellier approach. Only stands with at least the minimum areas recommended for this type of vegetation were recorded (Chytrý & Otýpková 2003). Macrophyte vegetation data were collected in 2008. Fifty-three phytosociological relevés were collected. All the relevés were stored using the TURBOVEG database (Hennekens & Schaminée 2001) and then exported and processed by the JUICE software (Tichý 2002). Further, they were analysed by TWINSPAN (Hill 1979) with application of the dominance principle. CANOCO 4.5 for Windows package (ter Braak & Šmilauer 2002) was used for a detrended correspodence analysis (DCA); species percentage data with logarithmic transformation were used and rare species were downweighted. For the ecological interpretation of major gradients of the studied wetland vegetation, average non-weighted Ellenberg's indicator values of vascular plant species (Ellenberg & al. 1992) were plotted onto a DCA ordination diagram as supplementary variables. The associations between some selected environmental and species variables were expressed by Spearmann correlation coeficients using the STATISTICA software (StatSoft 2001). Water reaction and conductivity were measured in selected water reservoirs by pH-meter/conductometer WTW pH/Cond 340i. The position and area of the studied sites was obtained using GPS eTrex Summit fy Garmin and GIS (ArcView programme) from digital orthophotomaps with a resolution of 1 m to pixel. Data from older papers (Hrivnák 1999; Hrivnák 2002b, 2004) were used for a comparison of diversity and plant communities changes within selected water reservoirs.

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

4. RESULTS AND DISCUSSION

Checklist of vegetation units

Lemnetea O. de Bolós et Masclans 1955
- *Lemnetalia minoris* R. Tx. 1955
  - *Lemnion minoris* R. Tx. 1955
    - *Lemno minoris-Spirodeletum polyrhizae* Koch 1954 em. Th. Müller et Görs 1960 (Tab. 2, rels 1–3)
- *Hydrocharitetalia* Rübel 1933
  - *Hydrocharition morsus-ranae* Rübel 1933 em. Westhoff et Den Held 1969
    - *Ceratophylletum demersi* Hild 1956 (Tab. 2, rel. 4)

Potametea Klika in Klika et Novák 1941
- *Potametalia* Koch 1926
  - *Nymphaeion albae* Oberd. 1957
    - *Potametum natantis* von Soó 1927 (Tab. 2, rels 7–10)
    - *Polygonetum amphibii* von Soó 1927 (Tab. 2, rels 5–6)
    - *Potametum nodosis* Passarge 1964 (Tab. 2, rel. 13)
  - *Potamion pusilli* Hejný 1978
    - *Potametum pectinati* Carstensen 1955 (Tab. 2, rel. 15)
    - *Potametum acutifolii* Segal 1961 (Tab. 2, rels 11–12)
    - *Potametum trichoidis* Tüxen 1974 (Tab. 2, rel. 14)

Phragmito-Magnocaricetea Klika in Klika et Novák 1941
- *Phragmitetalia* Koch 1926
  - *Phragmition australis* Koch 1926
    - *Equisetetum fluviatilis* Steffen 1931 (Tab. 3, rels 1–2)
    - *Glycerietum aquaticae* Hueck 1931 (Tab. 3, rels 3–4)
    - *Phragmitetum vulgaris* von Soó 1927 (Tab. 3, rel. 5)
    - *Scirpetum lacustris* Chouard 1924 (Tab. 3, rels 11–12)
    - *Sparganietum erecti* Roll 1938 (Tab. 3, rels 6–10)
    - *Typhetum angustifoliae* Pignatti 1953 (Tab. 3, rels 13–18)
    - *Typhetum latifoliae* Lang 1973 (Tab. 3, rels 19–27)
  - *Magnocaricion elatae* Koch 1926
  - *Caricenion gracilis* (Neuhäusl 1959) Oberd. et al. 1967
    - *Caricetum vesicariae* Chouard 1924 (Tab. 3, rels 28–30)
    - *Phalaridetum arundinaceae* Libbert 1931 (Tab. 3, rel. 31)
- *Nasturtio-Glycerietalia* Pignatti 1953
  - *Sparganio-Glycerion* Br.-Bl. et Sissing in Boer 1942
    - *Glycerietum fluitantis* Eggler 1933 (Tab. 3, rels 32–34)
    - *Leersietum oryzoidis* Eggler 1933 (Tab. 3, rels 35–36)
- *Oenanthetalia aquaticae* Hejný in Kopecký et Hejný 1965
  - *Oenanthion aquaticae* Hejný ex Neuhäusl 1959
    - *Eleocharitetum palustris* Ubrizsy 1948 (Tab. 3, rels 37–38)

4.1 Phytosociological and ecological characteristics of plant communities

Duck-weed vegetation (*Lemnetea*) was rare in the studied area (Tab. 2). Two associations were found, *Lemno minoris-Spirodeletum polyrhizae* and *Ceratophylletum demersi*, the former being more frequent. Stands of *Lemno minoris-Spirodeletum polyrhizae* grew in small, shallow, eutrophic and silt-

Figure 2: Plášťovce water reservoir. Stands of *Ceratophylletum demersi*, *Leersietum oryzoidis* and *Typhetum latifoliae* in tributary part of reservoir.
Slika 2: Vodni zbiralnik Plášťovce. Sestoji asociacij *Ceratophylletum demersi*, *Leersietum oryzoidis* in *Typhetum latifoliae* v delu zbiralnika s pritoki.

ed reservoirs near human settlements. A similar characteristic is generally typical for this community in various European countries (Schratt 1993, Oťaheľová 1995a, Coldea 1997), although its ecological amplitude is markedly broader (Tomaszewicz 1979, Šumberová 2007). In Slovakia, the occurrence of this community is known mainly from lowlands and basins in the southern part of the country (Oťaheľová 1980, 1995a; Oťaheľová & al. 1985, 1994; Zlinská & Kubalová 2001, Hrivnák 2002c). *Ceratophyllum demersum* overgrew the water reservoir Plášťovce (Fig. 2), where the mentioned dominant species created large, dense, submerged and species-poor stands. Association *Ceratophylletum demersi* frequently occurs in Slovakia (Oťaheľová 1995a). Hrivnák (2002c) reported about the occurrence of *Lemnetum minoris* in

Figure 3: Stands of the *Potametum natantis* association in the water reservoir near Hrušovo village.
Slika 3: Sestoji asociacije *Potametum natantis* v vodnem zbiralniku v bližini vasi Hrušovo.

Figure 4: Stands of *Potametum nodosi* and *Typhetum angustifoliae* associations in the littoral of the Kosihovská Bukovina water reservoir.
Slika 4: Sestoji asociacij *Potametum nodosi* in *Typhetum angustifoliae* v obrežnem pasu vodnega zbiralnika Kosihovská Bukovina.

Figure 5: Stands of *Polygonetum amphibii* in the Veľký Šiaš water reservoir.
Slika 5: Sestoji asociacije *Polygonetum amphibii* v vodnem rezervoarju Veľký Šiaš.

a water reservoir near the Hrušov village, which was not confirmed within recent research.

Regarding the diversity of the detected plant communities and number of relevés, the communities of the *Potametea* class were relatively better represented (Tab. 2). Stands with the dominance of species of the genus *Potamogeton* were mainly found. Among the broad-leaved species of this genus, *P. natans* was more frequent than *P. nodosus*. *Potametum natantis* (Fig. 3) created closed or moderately open stands in deeper waters. Dominant species of this community (*P. natans*) often grew also in other aquatic and marsh plant communities. On the territory of Slovakia, *Potametum natantis* is relatively frequent and occurs from the lowland up to the montane level (cf. Oťaheľová 1995b; Hrivnák 2002b; Hrivnák & al. 2004, 2009). *Potametum nodosi* grew in the littoral of the water reservoir Kosihovská Bukovina (Fig. 4). Data about this community from Slovakia indicated its occurrence mainly in running waters (Oťaheľová 1995b). The community is rare in stagnant waters (e.g. Oťaheľová 2005), although the dominant species *P. nodosus* has an optimum of occurrence from stagnant to moderately flowing waters (Willby & al. 2000). The last detected community from the *Nymphaeion albae* alliance is *Polygonetum amphibii* (Fig. 5). The association formed open and smaller stands in shallow to moderately deep waters. Among vegetation of the linear-leaved submerged species of the genus *Potamogeton*, *Potametum pectinati*, *P. trichoidis* and *P. acutifolii* associations were found, but their occurrence was relatively rare. *Potametum pectinati* formed larger stands in the water reservoir near Čekovce village, *Potametum trichoidis* occurred fragmentarily in the water reservoir Kozí Vrbovok. The former association occurs relatively often in Slovakia (cf. Oťaheľová 1995b). On the other hand, reports about the latter association are very rare (e.g. Háberová & Karasová

1991, Hrivnák 2002b, Kubalová 2009). *Potametum acutifolii* is a new community for the territory of Slovakia (cf. Oťaheľová 1995b, Jarolímek & al. 2008). Stands of this community were found in the water reservoir near Hrušov village where it formed mosaic stands with *Potametum natantis*. In the *Potametum natantis* stand, *Potamogeton acutifolius* was found in the past (cf. Hrivnák 2002b). The dominant species *P. acutifolius* occurred in almost all plant communities within the reservoir (cf. Tab. 2 a 3). In addition to the mentioned dominant species, floating hydrophytes (*Potamogeton natans* and *Lemna minor*) in deeper water and helophytes in shallower water were detected in the stands of *Potametum acutifolii* (Tab. 2, rel. 11). The water was 70–100 cm deep, slightly alkaline with a relatively low content of soluble mineral matters (cf. Tab. 1) and with a high water transparency (95 cm measured by Secchi disk). The bottom was formed of fine material (silt-clay sediment). Low concentrations of ammonia (0.126 mg/l) and nitrites (0.154 mg/l), and slightly higher values of nitrates (2.189mg/l) and phosphates (1.328 mg/l) in water were detected. In general, this community grows in small ponds, in shallow and eutrophic, neutral or alkaline water with various sediments on the bottom (Tomaszewicz 1979; Rydlo 2005, 2006; Nowak & al. 2007). Stands are species-poor and in addition to dominant species *P. acutifolius*, various aquatic plants grow in stands of this community (Tomaszewicz 1979, Nowak & al. 2007, Šumberová & Hrivnák 2010). These facts are similar to those identified in the Krupinská planina Mts. Among Central European countries, the community rarely occurs in Poland (Matuszkiewicz 2001, Nowak & al. 2007), the Czech Republic (Šumberová & Hrivnák 2010) and Germany (Pott 1992). It is interesting that in the Czech Republic *Potamogeton acutifolius* is quite abundant (Kaplan 2001), but stands with its dominance are rare (Šumberová & Hrivnák 2010).

The most diverse groups of the studied vegetation are the marsh communities, where 12 associations were detected. More than a half of them belong to typical littoral marsh communities of the *Phragmition communis* alliance. The most frequent are *Typhetum latifoliae*, *T. angustifoliae* and *Sparganietum erecti*. All are frequent not only in the studied area, but within the whole territory of Slovakia (Oťaheľová & al. 2001). Species composition reflects the actual ecophase (sensu Hejný 1960): in addition to dominant species, true aquatic species (*Lemna minor*, *Potamogeton* spec. div.) grow in

Figure 6: Water reservoir near Duchenec village with large stands of *Equisetum limosi* and *Typhetum latifoliae* in the littoral after strong rainfall.

Slika 6: Vodni zbiralnik pri vasi Duchenec z obsežnimi sestoji asociacij *Equisetum limosi* in *Typhetum latifoliae* v obrežnem pasu po obilnem deževju.

the littoral ecophase, the number of typical marsh species increases with a decrease of water level and species of eutrophic sediments such as *Bidens* spec. div., *Persicaria hydropiper* or *Leersia oryzoides* grow in the limose ecophase. Less frequent are the following 4 communities: *Glycerietum aquaticae*, *Phragmitetum vulgaris*, *Scirpetum lacustris* and *Equisetetum limosi*. *Equisetetum limosi* is interesting for its occurrence in water reservoirs near Duchenec (Fig. 6) and Riečky villages. This association has a boreal-subatlantic distribution (Balátová-Tuláčková & al. 1993) and in Slovakia it occurs from the upland to the montane levels and very rarely also in lowlands (cf. Oťaheľová & al. 2001). Accessible data about this association in Slovakia are relatively rare and data from phytogeographical region Ipeľsko-rimavská brázda are absent at present. The *Magnocaricion elatae* alliance is represented only by two associations, *Caricetum vesicariae* and *Phalaridetum arundinaceae*. Both of them are rare in the study area and the occurrence of the former one is fragmentary. *Glycerietum fluitantis* and *Leersietum oryzoidis* grew on silted and deep sediment within inflow parts of reservoirs. The water was shallow or sometimes only the sediment was waterlogged. Similar ecological characteristics were typical also for *Eleocharitetum palustris*, stands of which were found in the water reservoir of Kosihovská Bukovina from shallow to moderately deep water. The community survives well within disturbed habitats, too. Great water level fluctuation is typical for all three communities. Similar characteristics were reported from several European countries (e.g. Balátová-Tuláčková & al. 1993, Coldea 1997, Oťaheľová & al. 2001, Stančič 2007).

Based on the Ellenbergs indicator values, I detected that the main environmental gradient is clearly the factor "Moisture" (Fig. 7). This factor correlates most closely with the first DCA axes

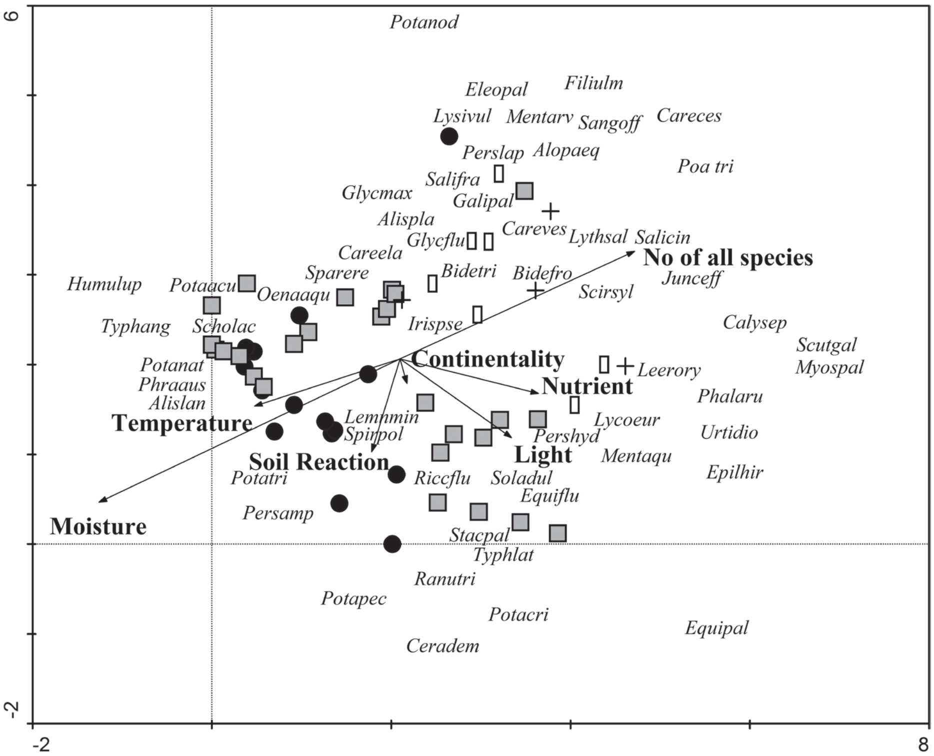

Figure 7: Ordination diagram of both species and sample data with supplementary environmental variables (Ellenberg indicator values) and number of species. Full circles – aquatic plant communities of the *Lemnetea* and *Potametea* classes, shaded squares – reed vegetation of the *Phragmition communis* alliance, empty rectangles – marsh vegetation of the *Oenanthion aquaticae* and *Glycerio-Sparganion* alliances, crosses – tall-sedges vegetation of the *Magnocaricion* alliance. The first two axes explain 15.3 and 32.0 % of species variability and species-environment relation, respectively. Weighted correlations between first two axes and environmental variables: Light: 0.2907 and –0.1900, Temperature: –0.3766 and –0.1107, Continentality: 0.0184 and –0.0585, Moisture: –0.7794 and –0.3385, Soil reaction: –0.0721 and –0.2217, Nutrients: 0.3599 and –0.0848.

Slika 7: Ordinacijski diagram vrst in popisov z dodatnimi okoljskimi spremenljivkami (Ellenbergove indikacijske vrednosti) in število vrst. Polni krogi – vodne rastlinske združbe razredov *Lemnetea* in *Potametea*, zasenčeni kvadrati – trstje, ki ga uvrščamo v zvezo *Phragmition communis*, prazni pravokotniki – močvirna vegetacija zvez *Oenanthion aquaticae* in *Glycerio-Sparganion*, križi – visoko šašje, ki ga uvrščamo v zvezo *Magnocaricion*. Prvi dve osi pojasnita 15,3 in 32,0 % vrstne variabilnosti oziroma odnosa rastlinske vrste – okolje. Tehtana korelacija med prvima dvema osema in okoljskimi spremenljivakami: svetloba: 0,2907 in –0,1900, toplota: –0,3766 in –0,1107, kontinentalnost: 0,0184 in –0,0585, vlažnost: –0,7794 in –0,3385, reakcija tal: –0,0721 in –0,2217, hranila: 0,3599 in –0,0848.

Abbreviations of species (Okrajšave vrst): Alislan – *Alisma lanceolatum*, Alispla – *Alisma plantago-aquatica*, Alopaeq – *Alopecurus aequalis*, Ranutri – *Batrachium trichophyllum*, Bidefro – *Bidens frondosa*, Bidetri – *Bidens tripartitus*, Calysep – *Calystegia sepium*, Careces – *Carex cespitosa*, Careela – *Carex elata*, Careves – *Carex vesicaria*, Ceradem – *Ceratophyllum demerum*, Eleopal – *Eleocharis palustris*, Epilhir – *Epilobium hirsutum*, Equiflu – *Equisetum fluviatile*, Equipal – *Equisetum palustre*, Filiulm – *Filipendula ulmaria*, Galipal – *Galium palustre*, Glycflu – *Glyceria fluitans*, Glycmax – *Glyceria maxima*, Humulup – *Humulus lupulus*, Irispse – *Iris pseudacorus*, Junceff – *Juncus effusus*, Leerory – *Leersia oryzoides*, Lemnmin – *Lemna minor*, Lycoeur – *Lycopus europaeus*, Lysyvul – *Lysimachia vulgaris*, Lythsal – *Lythrum salicaria*, Mentarv – *Mentha arvenis*, Mentaqu – *Mentha aquatica*, Myospal – *Myosotis scorpioides* agg., Persamp – *Persicaria amphibia*, Pershyd – *Persicaria hydropiper*, Perslap – *Persicaria lapathifolia*, Phalaru – *Phalaroides arundinacea*, Oenaaqu – *Phellandrium aquaticum*, Phraaus – *Phragmites australis*, Poa tri – *Poa trivialis*, Potaacu – *Potamogeton acutifolius*, Potacri – *Potamogeton crispus*, Potanat – *Potamogeton natans*, Potanod – *Potamogeton nodosus*, Potapec – *Potamogeton pectinatus*, Potatri – *Potamogeton trichoides*, Riccflu – *Riccia fluitans*, Sangoff – *Sanguisorba officinalis*, Salicin – *Salix cinerea*, Salifra – *Salix fragilis*, Scholac – *Schoenoplectus lacustris*, Scirsyl – *Scirpus sylvaticus*, Scutgal – *Scutellaria galericulata*, Soladul – *Solanum dulcamara*, Sparere – *Sparganium erectum*, Spirpol – *Spirodella polyrhiza*, Stacpal – *Stachys palustris*, Typhang – *Typha angustifolia*, Typhlat – *Typha latifolia*, Urtidio – *Urtica dioica*.

Figure 8: Water reservoir near Hrušov village with the most various macrophyte vegetation and with occurrence of the *Potametum acutiformis* association.
Slika 8: Vodni zbiralnik pri vasi Hrušov z najbolj raznoliko makrofitsko vegetacijo in spojavljanjem sestojev asociacije *Potametum acutiformis.*

(–0.78). Along the moisture gradient, individual communities were arranged more or less according to the natural hydrosere of habitats with stagnant water. From the left to the right side of the DCA ordination graph, aquatic communities of the *Potametea* class are the first displayed, followed by pleustophyte vegetation of the *Lemnetea* class and littoral communities of the *Phragmition communis* alliance and finished by marsh vegetation of shallow waters of the upper littoral of the *Magnocaricion elatae*, *Sparganio-Glycerion* and *Oenanthion aquaticae* alliances. True aquatic plants, such as species of the *Potamogeton* genera, *Persicaria amphibia* f. *natans* or some helophytes such as *Phragmites australis*, *Schoenoplectus lacustris* or *Typha angustifolia* (left side of Fig. 7) are typical for permanent and deeper waters. Wet meadow species (e.g. *Poa trivialis*, *Myosotis scorpioides* agg. or *Juncus effusus*), some nitrophilous, liana species or species of exposed substrates (e.g. *Urtica dioica*, *Calystegia sepium* and *Alopecurus aequalis*) are displayed on the other side of the moisture gradient (the right side of Fig. 7).

Species richness increases with decreasing water depth. The correlation between the number of species and water depth in individual relevés is statistically significant ($P < 0.001$), although the correlation coefficient is relatively low (Spearman's $r = -0.506$). The same is indicated by Fig. 7, where a negative correlation between moisture and the number of species ($r = -0.555$, $P < 0.001$) is obvious. It is caused by the presence of true aquatic plants as well as marsh and wet meadow species in shallower waters, representing appropriate conditions for all species groups. Interaction between the size of individual reservoirs and number of detected plant communities is weak and non-significant ($r = 0.436$, $P = 0.1$). Reservoirs with relatively small size can be rich in macrophyte vegetation (Hrušov; Fig. 8), in contrast to large reservoirs (Kozí Vrbovok; Tab. 1). Diversity of plant communities is probably influenced by the heterogeneity of environmental conditions, mainly in the littoral of reservoirs (e.g. type of substrate, reservoir profile, morphometrical characteristics).

4.2 Diversity of vegetation in relation to other Slovak regions

Undoubtedly, Krupinská planina Mts. belongs to the areas with varying macrophyte vegetation of artificial water reservoirs. In general, the plant community diversity of reservoirs in the Pannonicum region is higher than within the Carpaticum. There are more suitable climatic conditions for development of macrophyte vegetation in the Pannonicum. For example, the following mean numbers of plant communities per artificial water reservoir were detected in individual Slovak regions: Pannonicum: Cerová vrchovina Mts – almost 7 communities for reservoir (4 reservoirs were studied; Hrivnák & Csiky 2009), Lučenská kotlina basin – more than 3 (10 reservoirs; Hrivnák 1999), Ipeľská kotlina basin – more than 6 (4 reservoirs; Oťaheľová & al. 1998, Hrivnák 1999), Borská nížina lowland – almost 3 (10 reservoirs; Oťaheľová 2005); Carpaticum: Zvolenská kotlina basin – more than 2 (5 reservoirs; Hrivnák 2002a), Nízke Tatry Mts – almost 2 (14 reservoirs; Hrivnák et al. 2009), Hornonitrianska kotlina basin – almost 3 (13 reservoirs; Dúbravková & al. 2009), Veľká Fatra Mts and Turčianska kotlina basin – almost 2 (11 reservoirs; Hrivnák & Kochjarová 2008). In the Krupinská planina Mts, more than 3 plant communities per reservoir were detected in 15 water reservoirs. The intermediate position of vegetation diversity in this area fully corresponds with the phytogeographical position of the studied region, which includes both Pannonicum and Carpaticum.

4.3 Comparison of macrophyte community changes

Three artificial water reservoirs were chosen for a comparison of changes of macrophyte vegetation: Drienovo (in village; No. 4 in Table 1), Hrušov (6) and Cerovo, Veľký Šiaš (13). For these reservoirs, relatively the most detailed information about the studied vegetation types was available (Table 4). The most important changes were detected in the case of the first-mentioned reservoir (Drienovo). Three plant communities were found at this location in the past, but no community was detected during the recent research; only their fragments affected by strong human impact grew in the littoral of the reservoir (Fig. 9). The locality is situ-

Figure 9: Water reservoirs in Drienovo village.

Slika 9: Vodni rezervoar v vasi Drienovo.

ated on the margin of a village and the reservoir is used for many human activities. Vegetation in the littoral and on the banks is frequently mown during the vegetation period. All these activities inhibit development of littoral vegetation. Heavily eutrophic water is often overgrown by cyanophytes, which inhibits the development of aquatic vegetation as well. Within the second reservoir under study (Hrušov), no negative changes were determined. Only *Eleocharitetum palustris* was missing at present (mentioned in the 1990's; cf. Hrivnák 1999), but it may re-appear if the water level decreases. Individuals of *Eleocharis palustris* were frequent in the littoral of the reservoir, but they did not form larger stands. On the other hand, 6 new communities were found in the reservoir, which were not mentioned in the past. At the last locality (Veľký Šiaš), changes result from the difference in water level during studies in the past and in 2008. The occurrence of *Typhetum angustifoliae* and *Potametum natantis* was detected in the past as well as during the recent research, always during the period of more or less stable higher water level (cf. Hrivnák 2002b, 2004). The next two communities, *Polygonetum amphibii* and *Lemnetum minoris* were found in only one surveyed season. Both communities have a seasonal character, very often they grow fragmentarily and in dependence on various environmental conditions (Oťaheľová 1995a, b). Stands of *Oenantho aquaticae-Rorippetum amphibiae* and *Juncus bufonius* comm. grew on the exposed bottom of the reservoir (cf. Hrivnák 1999). Water level increasing above the usual value was observed during recent research in 2008. Changes recorded in the three model reservoirs show that macrophyte vegetation of stagnant waters is very dynamic and affected by many environmental factors and human influence. Water level fluctuations as well as other disturbances belong to the most important factors affecting aquatic and marsh plants and their vegetation (Lacoul & Freedman 2006).

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Table 1: Short geographical, environmental and vegetation characteristics of the studied water reservoirs.
Tabela 1: Kratka zemljepisna, okoljska in vegetacijska oznaka preučevanih vodnih teles.

N.	Town/Village	Name/Position	Longitude	Latitude	Alt.	Area (ha)	pH	Cond.	Status	Recent use	Pc
1	Plášťovce	W from village	18º 57´ 11.0˝	48º 09´ 42.5˝	175	2.635	9.5	231	water-filled	F, Fc, I, R	3
2	Devičie	S margin of village	19º 01´ 31.2˝	48º 18´ 13.9˝	251	.	.	.	drained	0	1
3	Drienovo	Antalov Laz	19º 02´ 25.6˝	48º 13´ 11.2˝	339	.	.	.	drained	W	2
4	Drienovo	in village	19º 03´ 42.8˝	48º 13´ 57.0˝	372	0.627	.	.	water-filled	R	0
5	Čabradský Vrbovok	SW from village	19º 04´ 14.0˝	48º 15´ 11.3˝	309	.	.	.	drained	0	0
6	Hrušov	N from village	19º 05´ 03.2˝	48º 10´ 45.3˝	400	0.389	7.6	148	water-filled	F, Fc, I, R	9
7	Horný Badín	Lazy 2	19º 05´ 20.1˝	48º 17´ 22.7˝	340	0.050	.	.	water-filled	W	1
8	Horný Badín	Lazy 1	19º 05´ 21.1˝	48º 17´ 25.1˝	340	0.041	7.5	197	water-filled	W	2
9	Kozí Vrbovok	SW from village	19º 05´ 55.9˝	48º 17´ 11.7˝	325	14.254	8.1	233	water-filled	F, Fc, I	2
10	Čekovce	S from village	19º 07´ 07.2˝	48º 20´ 48.5˝	389	1.358	.	.	water-filled	F, Fc, I	3
11	Cerovo	Pod blatami	19º 08´ 16.2˝	48º 15´ 12.5˝	391	.	.	.	drained	rec	0
12	Cerovo	Pri badluckej ceste	19º 08´ 45.7˝	48º 15´ 51.5˝	414	0.876	.	.	water-filled	Ff, I	3
13	Cerovo	Veľký Šiaš	19º 09´ 02.7˝	48º 16´ 07.3˝	420	1.589	.	.	water-filled	Ff, I	4
14	Cerovo	S from village	19º 09´ 05.4˝	48º 14´ 45.5˝	415	.	.	.	drained	W	1
15	Pliešovce	Bzovská Lehôtka	19º 09´ 07.1˝	48º 24´ 35.4˝	421	6.295	9.1	150	water-filled	F, Fc, I, R	4
16	Cerovo	in village	19º 09´ 27.0˝	48º 15´ 27.5˝	448	0.177	.	.	water-filled	I	0
17	Duchenec	NNW from village	19º 11´ 29.3˝	48º 15´ 33.2˝	492	0.188	8.2	.	water-filled	Fc, I	3
18	Opavské Lazy	Kosihovská Bukovina	19º 11´ 48.4˝	48º 13´ 01.7˝	486	2.630	9.7	121	water-filled	F, Fc, I	6
19	Modrý Kameň, Riečky	Kamenný vrch	19º 17´ 24.3˝	48º 18´ 01.6˝	442	2.995	.	.	water-filled	F, Fc, I	5
20	Veľký Lom	N from village	19º 22´ 11.2˝	48º 20´ 38.9˝	437	0.135	.	.	water-filled	W	3
21	Veľký Lom	S margin of village	19º 22´ 26.5˝	48º 19´ 55.5˝	402	.			drained	0	1

Legend: N – number; Long. – Longitude (central part), Lat. – Latitude (central part), Alt. – Altitude, pH – Water pH, Cond. – Water conductivity (µS/cm; 25 ºC); Recent use: F – fishing, Fc – flood control, I – irrigation of farm land, R – recreation, rec – reconstruction, W – without any utilization, 0 – long-term drained; Pc – number of plant communities.
Legenda: N – število; Long. – zemljepisna dolžina (osrednji del), Lat. – zemljepisna širina (osrednji del), Alt. – nadmorska višina, pH – pH vode, Cond. – prevodnost vode (µS/cm; 25 ºC); sedanja raba: F – ribolov, Fc – uravnavanje poplav, I – namakanje kmetijskih površin, R – rekreacija, rec – obnova, W – brez posebnega namena, 0 – dolgotrajno osušeno; Pc – število rastlinskih združb.

Table 2: Aquatic vegetation of the studied water reservoirs.
Tabela 2: Vodna vegetacija preučevanih vodnih zbiralnikov.

*	Relevé number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Water reservoir	20	8	7	1	13	10	20	17	13	6	6	6	18	9	10
	Cover (%)	98	100	95	100	55	90	80	50	95	95	100	100	75	95	80
	Relevé area (m^2)	20	16	16	16	6	9	20	16	12	16	14	14	12	12	16
	Depth of water (cm)	40	10	10	100	55	90	100	150	80	105	80	100	80	45	115
	Sediment type	F	F	F	.	F	.	F	.	.	F	F	F	F	S/F	.
Dominant species of associations																
Le	*Lemna minor*	**5**	**3**	**5**	+	.	m	a	.	.	+	1	1	.	a	+
Le	*Spirodela polyrhiza*	**+**	**4**	**b**	.	.	.	.	.	.	.	.	.	.	.	.
Le	*Ceratophyllum demersum*	.	.	.	**5**	.	.	.	.	.	.	.	.	.	.	.
Po	*Persicaria amphibia* f. *natans*	.	.	.	.	**4**	**4**	.	.	.	.	.	.	.	.	.
Po	*Potamogeton natans*	.	.	.	.	+	.	**4**	**3**	**5**	**5**	3	3	.	.	.
Po	*Potamogeton acutifolius*	.	.	.	.	.	.	.	.	.	1	**4**	**5**	.	.	.
Po	*Potamogeton nodosus*	.	.	.	.	.	.	.	.	.	.	.	.	**4**	.	.
Po	*Potamogeton trichoides*	.	.	.	.	.	.	.	.	.	.	.	.	.	**5**	1
Po	*Potamogeton pectinatus*	.	.	.	.	.	1	.	.	.	.	.	.	.	.	**4**
Other species																
Pm	*Glyceria fluitans*	+	.	.	.	.	.	.	.	.	.	+	.	r	.	.
Pm	*Phellandrium aquaticum*	.	.	.	.	r	.	.	.	.	.	a	.	.	+	.
Pm	*Alisma plantago-aquatica*	r	.	.	.	.	.	.	.	.	.	.	.	1	.	.
Pm	*Eleocharis palustris*	.	.	.	.	.	.	.	.	.	.	+	.	1	.	.

Legend: * Le – *Lemnetea*, Po – *Potametea*, Pm – *Phragmito-Magnocaricetea*; full headers with higher accuracy location of individual relevés are presented in the Slovak national phytosociological database (http://ibot.sav.sk/cdf/index.html).
Sediment type: F – anorganic or organic fine sediment, S – stone or artificial block sediment.
Species only in one relevé (Vrste samo v enem popisu): *Alisma lanceolatum* (7: +), *Batrachium trichophyllum* (14: r), *Carex vesicaria* (11: 1), *Equisetum fluviatile* (8: 1), *Lycopus europaeus* (6: +), *Salix fragilis* (1: r), *Sparganium erectum* (9: +), *Typha latifolia* (6: +).

Legenda: * Le – *Lemnetea*, Po – *Potametea*, Pm – *Phragmito-Magnocaricetea*; celotna glava popisov z večjo natančnostjo lokacije je shranjena v Slovaški nacionalni fitocenološki podatkovni bazi (http://ibot.sav.sk/cdf/index.html).
Tip sedimenta: F – anorganski ali organski fini sediment, S – kamenje ali umetni kamniti sediment.

Table 3: →

Full headers with higher accuracy location of individual relevés are presented in the Slovak national phytosociological database (http://ibot.sav.sk/cdf/index.html).
Celotna glava popisov z večjo natančnostjo lokacije je shranjena v Slovaški nacionalni fitocenološki podatkovni bazi (http://ibot.sav.sk/cdf/index.html).

Table 3: Marsh vegetation of the studied water reservoirs.
Table 3: Močvirna vegetacija preučevanih vodnih zbiralnikov.

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
Water reservoir	19	17	6	15	6	18	12	10	6	3	13	6	18	13	12	9	6	15	21	19	18	17	6	14	1	7	15	19	6	15	19	19	18	3	1	2	20	18
Cover (%)	100	80	100	100	100	70	90	90	80	90	75	80	85	80	90	90	95	80	80	95	85	80	90	90	95	100	95	95	85	100	95	70	60	100	100	100	90	80
Relevé area (m^2)	20	16	16	16	15	16	10	16	16	15	11	12	18	16	16	16	16	15	20	13	15	16	16	16	16	16	16	15	16	12	20	10	15	16	15	16	20	8
Depth of water (cm)	40	105	80	12	90	75	40	45	80	1	40	70	100	80	90	105	95	70	1	25	5	80	25	0	55	10	30	0	80	3	3	30	5	2	1	1	0	90
Sediment type	F	F	F	.	F	F	F	F	F	F	S/F	S	F	S/F	.	F	F	F	F	F	F	F	F	F	F	F	F	F	F	.	F	F	F	.	F	.	F	.
Dominant species of associations																																						
Equisetum fluviatile	**5**	**5**	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	3	.	.	.	.	.	.	.	.	+	a	.	.	.	.	.	.
Glyceria maxima	.	.	**5**	**4**	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	1	.	.	+	.	.	.	.	.	.	.	.
Phragmites australis	.	.	.	.	**4**	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sparganium erectum	.	.	.	.	.	**4**	**5**	**5**	**4**	**5**	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	.	.	.	.	.
Schoenoplectus lacustris	.	.	.	.	.	.	.	.	.	.	**4**	**4**	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Typha angustifolia	.	.	.	.	.	.	.	.	.	.	r	1	**5**	**4**	**5**	**4**	**4**	**5**	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Typha latifolia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**4**	**4**	**4**	**4**	**5**	**5**	**4**	**4**	**5**	+	.	.	.	.	.	.	+	1	.	.
Carex vesicaria	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**5**	**4**	**5**	.	.	.	.	.	.	.	.
Phalaris arundinacea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+	.	.	.	.	.	.	.	**5**	.	.	.	.	a	.	.
Glyceria fluitans	.	.	.	.	.	a	+	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	+	b	.	1	.	.	.	.	.	**3**	**4**	**5**	.	.	.	+
Leersia oryzoides	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**5**	**5**	.	1
Eleocharis palustris	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	**5**	**4**
Aquatic plants *(Lemnetea* and *Potametea* classes)																																						
Lemna minor	+	.	a	.	a	+	3	+	1	.	+	1	.	+	+	3	1	.	.	4	1	.	3	.	3	a	3	.	a	.	.	1	+	.	1	.	.	+
Potamogeton natans	.	.	.	.	5	.	.	.	3	.	1	1	.	+	.	.	3	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Potamogeton acutifolius	.	.	1	.	1	.	.	.	.	.	.	+	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.
Spirodela polyrhiza	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	a	.	.	.	.	.	.	.	.	.	.	.	.
Potamogeton nodosus	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Phragmito-Magnocaricetea																																						
Lythrum salicaria	+	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	+	1	.	1	r	.	.	a	r	.
Alisma plantago-aquatica	.	.	.	.	.	.	r	.	.	.	.	.	+	.	.	.	.	.	.	+	.	.	r	.	.	.	.	.	.	.	.	+	.	r	.	r	+	+
Lycopus europaeus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	+	.	.	.	.	.	.	a	+	.	.	1	r	.	+
Oenanthe aquatica	.	.	+	.	.	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.
Iris pseudacorus	+	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	+	.	.	.	.	.	.
Galium palustre	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.
Lysimachia vulgaris	.	.	.	a	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.
Epilobium hirsutum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.
Mentha aquatica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.
Bidentetea tripartiti																																						
Bidens frondosa	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+	.	.	.	.	.	.	.	+	.	.	+	.	.	+	.
Bidens tripartitus	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.
Persicaria hydropiper	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	a	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Molinio-Arrhenatheretea																																						
Scirpus sylvaticus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	a	.	+	1	+	.	.	.	.	.	.
Filipendula ulmaria	.	.	.	b	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.
Sanguisorba officinalis	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.
Other species																																						
Juncus effusus	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	.	.	.	.	1	+	.	.
Poa trivialis	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.
Persicaria amphibia	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Solanum dulcamara	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	a	.	.	.	.	.	.	.	.	.	.	.	.
Urtica dioica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	r	.	.	.	.	.	.	.

Species in one relevé only (Vrste samo v enem popisu): *Alopecurus aequalis* (34: a), *Batrachium trichophyllum* (21: 1), *Calystegia sepium* (36: +), *Carex cespitosa* (30: +), *Carex elata* (29: 1), *Ceratophyllum demersum* (25: 3), *Equisetum palustre* (19: a), *Humulus lupulus* (18: +), *Mentha arvensis* (38: +), *Myosotis scorpioides* agg. (31: +), *Persicaria lapathifolia* (34: +), *Potamogeton crispus* (21: +), *Riccia fluitans* (27: b), *Salix cinerea* (28: +), *Salix fragilis* (37: r), *Scutellaria galericulata* (31: +), *Stachys palustris* (1: r).

Table 4: Comparison of plant communities changes within the three selected artificial water reservoirs.
Table 4: Primerjava spremembe rastlinskih združb v treh izbranih umetnih vodnih zbiralnikih.

Number of locality/plant community	**4**		**6**		**13**	
Name of locality	**Drienovo**		**Hrušov**		**Cerovo**	
Published paper	*	**	*	**	*	**
Acoretum calami	■					
Caricetum vesicariae				■		
Eleocharitetum palustris			■			
Glycerietum aquaticae				■		
Juncus bufonius comm.					■	
Lemnetum minoris					■	
Oenantho aquaticae-Rorippetum amphibiae					■	
Phragmitetum vulgaris				■		
Polygonetum amphibii						■
Potametum acutifolii				■		
Potametum natantis			■	■	■	■
Scirpetum lacustris				■		■
Sparganietum erecti			■	■		
Typhetum angustifoliae	■		■	■	■	■
Typhetum latifoliae	■			■		

*Earlier papers – Hrivnák (1999; 2002a, b; 2004), **this paper.
*Starejše objave – Hrivnák (1999; 2002a, b; 2004), ** v tem delu.