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DIVERSITY OF VASCULAR HYDROPHYTES IN THE ZASAVICA RIVER (SERBIA) – CHANGES AFTER THIRTEEN YEARS

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Abstract - Zasavica is a 33.1 km-long, slow-flowing river on the southern edge of the Pannonian plain. It has been a protected natural asset since 1997, and has great value as a natural aquatic habitat. In the period between 1998 and 2010, intensive studies of the aquatic vegetation were carried out. The comparisons of results gained at the beginning of that period with those from the end, show significant differences in species composition, spatial distribution, and diversity analyzed through species richness, Shannon's diversity index, and evenness.

Key words: Macrophytes, Shannon's diversity index, evenness, species richness, temporal changes

INTRODUCTION

Vascular aquatic plants include different adaptive types that inhabit different water bodies. Their basic structural and physiological characteristics are in accordance with the ecological conditions and resources of the aquatic environment in which they develop and live. According to their ecomorphology and position in the water body, aquatic plants are divided into the following groups: submerged plants, floating plants and emergent plants, where the first two ecomorphological types are known under the term hydrophytes (*sensu stricto*), while the emergent plants are called helophytes. In contemporary literature, ecologists often use the term "aquatic macrophytes", which has no precise taxonomic meaning. Essentially, it refers to larger aquatic plants, and distinguishes them from microscopic planktonic and benthic plants, and therefore includes aquatic mosses, liverworts and larger algae as well as vascular plants. This study deals with the submerged and floating vascular hydrophytes that belong to the divisions of Polypodiophyta and Magnoliophyta. Hydrophytes are an important component of aquatic ecosystems and can be used to facilitate the monitoring of the ecological status. In addition to their important ecological role, the use of hydrophytes as indicators of ecological quality in running waters is based on the fact that certain species and species groups are indicators for specific running water types and are adversely affected by anthropogenic impact. Sometimes the lack of hydrophytes is also characteristic for certain types of habitats in running waters (Sculthorpe, 1967; Hutchinson, 1975; Cook, 1990; Janauer and Dokulil, 2006).

Hydrophytes, or aquatic macrophytes, are becoming a matter of particular concern from the scientific and economic aspect in relation to the current requirement of the Water Framework Directive to use aquatic macrophytes as biological elements for the assessment of the ecological status of water bodies (WFD, Directive 2000/60/EC).

The Special Nature Reserve Zasavica lies in the area of southern Vojvodina and northern Mačva, in the northwest of Serbia on the territory of municipalities Crna Bara, Banovo Polje, Ravnje, Radenković, Zasavica, Salaš Noćajski, Noćaj, and Mačvanska Mitrovica (44°52'24"/44°58'04" N, 19°24'07"/19°36'31"E, central point at 44°56'12"N 19°29'09"E, altitude between 77.5 and 80.6 m above sea level). The center of the Reserve has the 33.1 km-long river, Zasavica, that meanders between settlements and runs into the Sava River near Mačvanska Mitrovica. Due to the untouched nature, rich and diverse wildlife, Zasavica became a protected natural asset in 1997 (Branković, 1997).

The first information on the aquatic vegetation of Zasavica dates back to the beginning of 20th century (Jurišić, 1911), but more detailed surveys were undertaken after 1997 (Vukov et al., 2000; 2001; 2010; Igić et al., 2001; Perić and Stanković, 2007; Stanković, 2007)

The aim of this study was to detect changes in the composition of hydrophytic species, its abundance and diversity that has come about in the thirteen year-long period. The fact that the study site (the river Zasavica) is a protected natural asset accentuates the importance of this study, in order to determinate the effect of its management on its natural features.

MATERIALS AND METHODS

Field research was carried out in July 1998 and July 2010. The main channel of the river was divided into continuous survey units of different length, depending on the characteristics of hydromorphological features, aquatic and semi-aquatic vegetation, and land use in the adjacent areas along the banks. In each survey unit, submerged and/or floating aquatic vascular plant species were recorded, and for each recorded species the Plant Mass Estimate (PME) was assessed according to an ordinal, five-level descriptive scale: 1-rare, 2-occasional, 3-frequent, 4-abundant, 5-very abundant (Kohler et al., 1971; 1978; 1995; Pall & Janauer, 1995; Janauer, 2003; European Standard EN 14184, 2003, relating to WFD). For further analyses, the ordinal PME data were transformed into "plant quantities" expressed by relative values (abundance here onwards) using the function $y=x^3$ (where y=abundance, x=PME; Janauer and Heindl, 1998). The results obtained in 1998 (Vukov, 2000) were used to group the surveyed units into water bodies according to similarities in species composition, abundance and distribution. In this manner, 17 water bodies were defined (Table 1).

Based on the abundance of the obtained data in 1998 and 2010, the following numerical derivates were calculated for each water body (Janauer, 2003; www.midcc.at): relative plant mass (RPM%); mean mass indices (MMT – mean mass index calculated for the total length of the river; MMO – mean mass index calculated for the lengths of survey units where certain species were recorded), dispersal or distribution ratio (d – the ratio between MMT^3 and MMO^3, ranging between 0 and 1). The diversity of aquatic vascular plant species in each water body was analyzed through species richness (S), Shannon's diversity index (H'), and Pielou's evenness index (J'). The results gained for defined water bodies in 1998 and 2010 are presented graphically, and compared using the Student's t test and F test (STATISTICA 10).

The nomenclature of the analyzed hydrophytes follows 2011 Species 2000 and ITIS Annual Checklist (Bisby et al., 2011).

RESULTS

In 1998, 29 species made up the submerged and floating vegetation in Zasavica River. Thirteen years later, in 2010, that number decreased drastically, and was 19 (Table 2). Seven species recorded in 1998 belonged to the category of strictly protected plant species (SP), while four belonged to the group of protected plant species (P), according to the Declaration of strictly protected and protected wild plant, animal and fungi species (Službeni glasnik RS, No. 5/2010). In 2010, four of the strictly protected and two of the protected species were not recorded in the main channel of the Zasavica.

The abundance and the distribution pattern of *Stratiotes aloides* and *Ceratophyllum demersum*

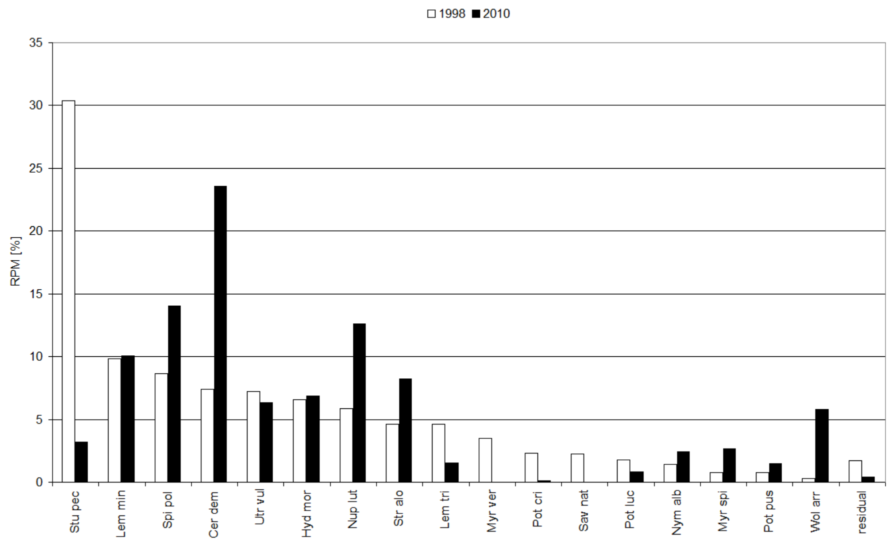

Fig. 1. The RPM (%) values for 1998 and 2010

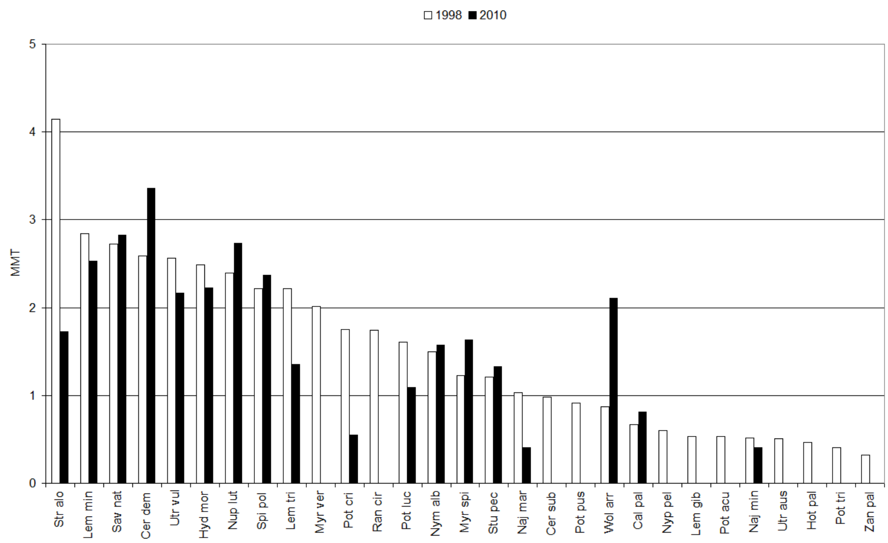

Fig. 2. The MMT values for 1998 and 2010

changed the most drastically in the period between 1998 and 2010.

Stratiotes aloides dominated in the aquatic vegetation in 1998, with RPM 30.35% (Fig. 1), it was also the most abundant hydrophyte in the entire surveyed length of the river (Fig. 2; MMT=4.14) and in the length of the sections where it occurred (Fig. 3; MMO=4.36). According to its distribution ratio, it was nearly ubiquitous, present in 86% of the surveyed sections (Fig. 4, d=0.86).

In 2010, the participation of *S. aloides* in the aquatic vegetation of Zasavica significantly decreased; its RPM value was almost ten times lower (RPM=3.19%). Its abundance, according to Kohler's five-level scale, also decreased with regard to the whole surveyed length and the sections of the river

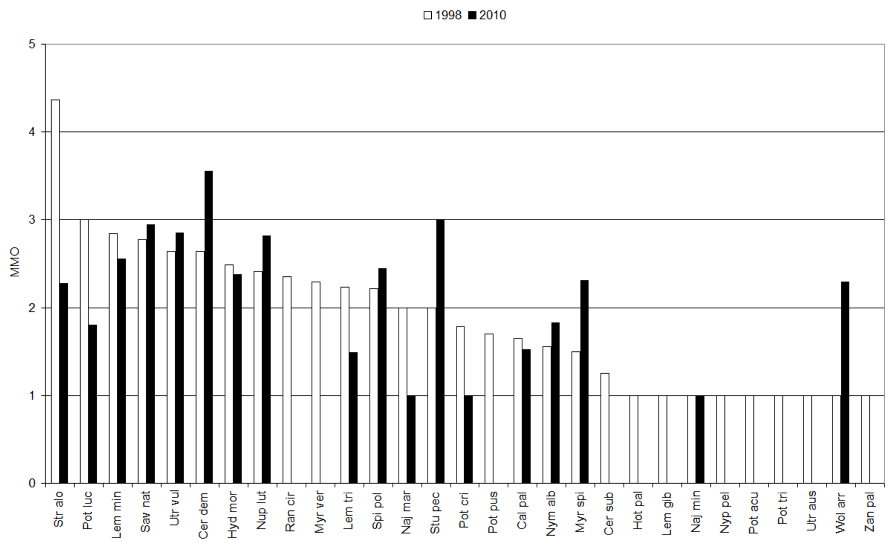

Fig. 3. The MMO values for 1998 and 2010

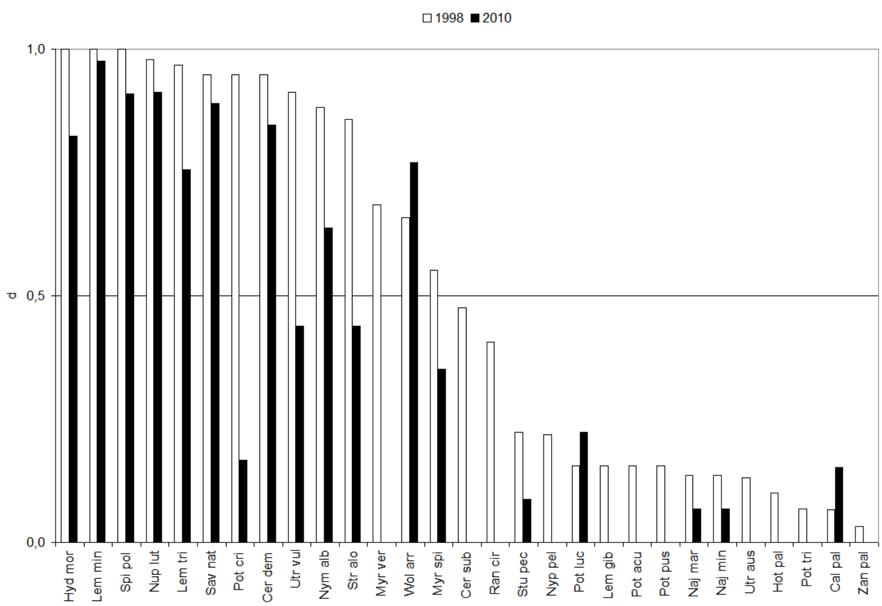

Fig. 4. The d values for 1998 and 2010

where it was recorded (MMT=1.73; MMO=2.27), so the occurrence of this once abundant species became occasional. Its distribution range in the Zasavica was reduced to 44% of the surveyed length (d=0.44).

In 1998, *Ceratophyllum demersum* participated in the aquatic vegetation of Zasavica River by 7.43% (Fig. 1). Its abundance was between occasional and frequent along the total length of the river (Fig. 2; MMT=2.59), and in the sections where it was recorded (Fig. 3; MMO=2.64), but its distribution was homogenous (Fig. 4; d=0.95).

Thirteen years later, *C. demersum* was the most dominant hydrophyte in Zasavica, with an increased RPM value of 23.57%. Its abundance became fre-

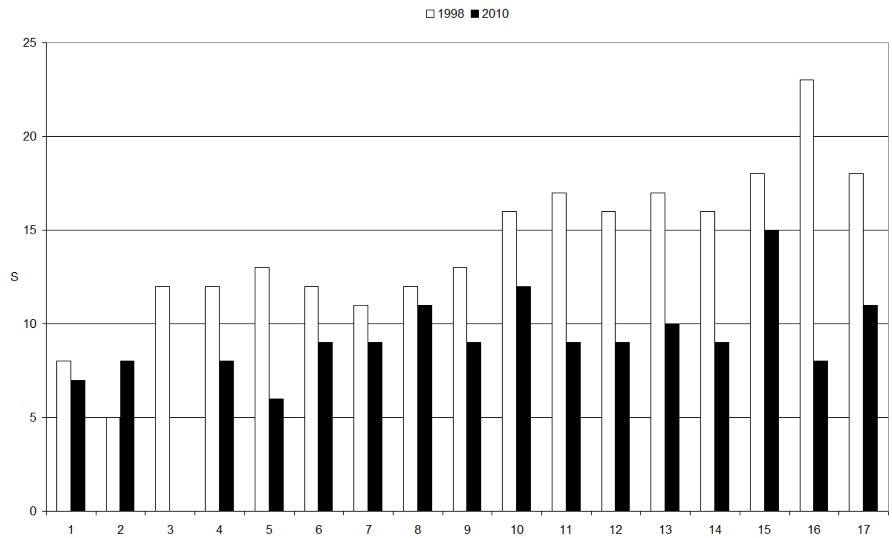

Fig. 5. Species richness in water-bodies of Zasavica

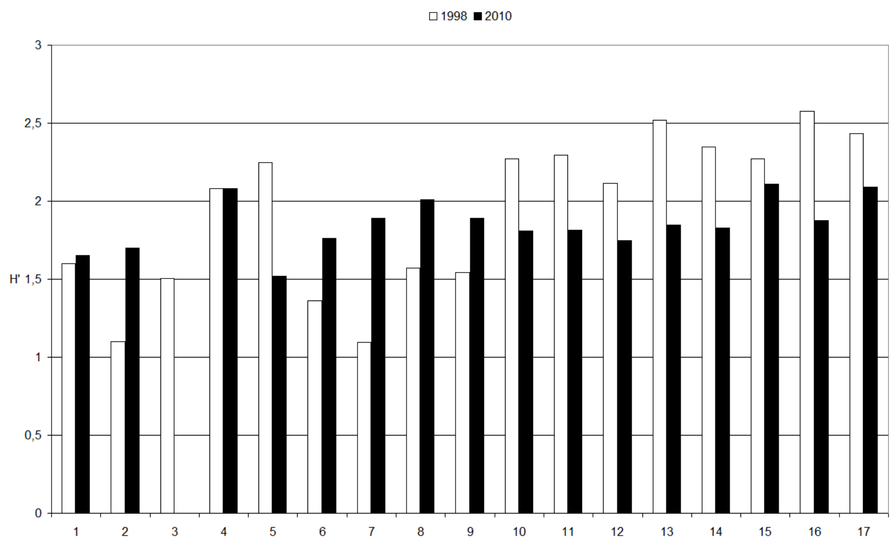

Fig. 6. Shannon's diversity index in water-bodies of Zasavica

quent to abundant in the total surveyed river length (MMT=3.36), and in the sections where it grows (MMO=3.56), although its distribution range was slightly reduced (d=0.85).

The RPM values of the majority of other species recorded in the Zasavica in both 1998 and 2010 have increased. Exceptions are *Lemna minor* and *Najas minor* with a relatively unchanged share in the aquatic vegetation, and *Utricularia vulgaris, Lemna trisulca, Potamogeton crispus, Potamogeton lucens* and *Najas marina* with a decreased RPM.

In general, values of the Mean Mass Indices calculated for the total length of the surveyed river (MMT) tended to decrease, since the mean MMT

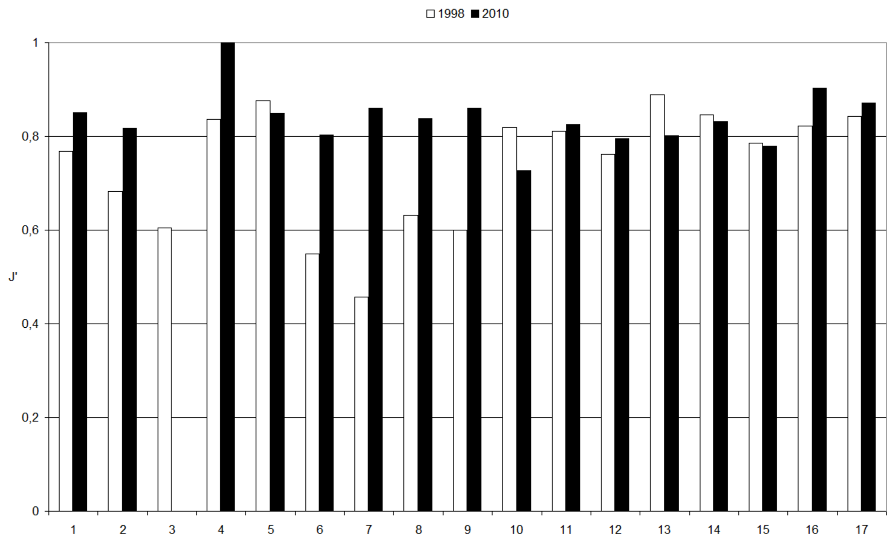

Fig. 7. Pielou's evenness index in water-bodies of Zasavica

value in 1998 was 1.50, and in 2010, 1.08 (Fig. 8), although the recorded difference is not statistically significant (p=0.41; F-ratio Variances=1.28; p_{Var}=0.67).

Although species such as *Salvinia natans, Ceratophyllum demersum, Nuphar lutea, Spirodela polyrrhiza, Nymphaea alba, Myriophyllum spicatum, Stuckenia pectinata* and *Wolffia arrhiza*, have Kohler's abundance values, regarding the total length of the Zasavica, higher in 2010 than in 1998 (Fig. 2), many of hydrophytes found in the Zasavica in 1998 were not recorded in 2010, so the mean MMT is slightly lower in 2010.

Similar to the MMT, the mean MMO was lower in 2010 than in 1998 (Fig. 8). In 1998 it was 1.89 and in 2010, 1.35. The recorded difference is on the verge of statistical significance (p=0.05; F-ratio Variances=2.16; p_{Var}=0.046).

The same assembly of species that showed increased MMT values had higher MMO values in 2010, with the addition of *Utricularia vulgaris* (Fig. 3). Its lower MMT in 2010 shows that it has retreated from the water bodies where it occurred in 1998, but its higher MMO in 2010 shows that in the parts of Zasavica where it still grows, it is more abundant than in 1998.

The dispersal ratio (d) which indicates the distribution of species along the surveyed river has slightly increased; in 1998 its mean value was 0.51, and in 2010 it was 0.53 (Fig. 8). This change is not statistically significant (p=0.91; F-ratio Variances = 1.26; p_{Var}=0.62). Most of the plant species have retreated from the localities they inhabited in 1998, which is shown by the lower values of their dispersal ratio (Fig. 4). On the other hand, species like *Wolffia arrhiza, Potamogeton lucens* and *Callitriche palustris* were found in water bodies in 2010 where they have not been recorded in 1998, so their distribution in the Zasavica has become wider, and this is shown in the increase of their distribution ratio values.

The values of species richness in the defined water bodies along the Zasavica River tend to be lower in 2010, than in 1998. The exception is the 650 m-long water body 2 (Jovača 2; Table 1), with five species recorded in 1998, and eight in 2010. In water body 3 (Prekopac), 12 species were recorded in 1998, while in 2010 the water body was completely overgrown with reeds and without any submerged or floating

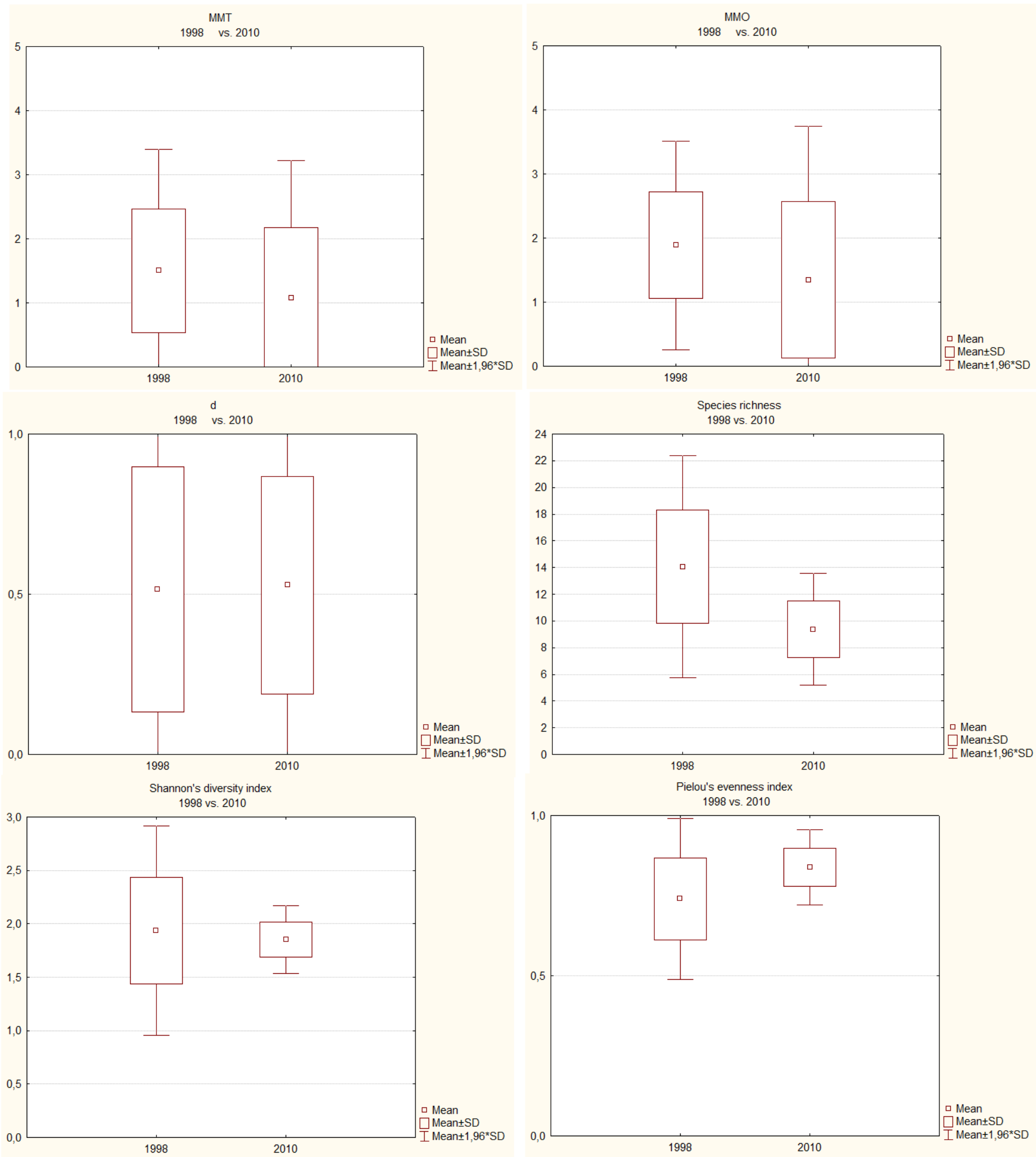

Fig. 8. Comparison of the MMT, MMO, d, S, H', and J' mean values

plants. Water body 16 (Lug) had the highest number of hydrophytes in 1998 – 23, while in 2010 the species richness declined and was 9 (Fig. 5). This water body is also the one with the largest decline in the number of recorded species in thirteen year-long period. The trend of increasing species richness in the downstream direction from water body 1 to 17 that could be observed in 1998, in 2010 is no longer visible.

Water body 16 ("Lug") had the highest value of the diversity index in 1998, 2.58 (Fig. 6), and water bodies 2 and 7 had the lowest – 1.1. In 2010, the highest diversity index was recorded in section 15 (2.11), and the lowest was in water body 5 (1.52). The 1010 m-long water body 5 (Trebljevine 1) is characterized by the biggest decline in diversity index value, since in 1998 it was 2.25, and in 2010, as previously

Table 1.: The list of defined water bodies in Zasavica River

name of water-body	abbreviation	length [m]
Jovača	1	920
Jovača1	2	650
Prekopac	3	750
Trebljevine	4	1030
Trebljevine1	5	1010
Poljansko	6	2030
Poljansko1	7	1900
Batve	8	2500
Batve1	9	2560
Vrbovac	10	2100
Vrbovac1	11	2000
Valjevac	12	2000
Valjevac1	13	2000
Valjevac2	14	2250
Sadžak	15	2070
Lug	16	2070
Modran	17	2650
total		30490

mentioned, 1.52. The localities with increased values of Shannon's diversity index are 2, 6, 7, 8, and 9; the water bodies with decreased diversity are: 5, 10, 11, 12, 13, 14, 15, 16, and 17; sections with nearly unchanged diversity index are 1 and 4. It is interesting to observe that the increase in the diversity index happened in the water bodies characterized by relatively low values in 1998 (1.6 and lower), while the decline in diversity is noticed in the sections with relatively high values recorded in 1998 (between 2.11 and 2.58), so the plant species diversity became more uniform in 2010.

The species evenness values were higher in 2010 than in 1998 in all surveyed water bodies, except 5, 10, 13, 14, and 15, where in the last two the decrease was minimal (Fig. 7). In 1998, the highest evenness value was recorded in section 13 (Valjevac 1) – 0.89, and the lowest in water body 7 (Poljansko 1) – 0.46. Thirteen years later, the highest value was calculated for water body 4 (Trebljevine), where the maximal species evenness occurred, while the lowest value was 0.73, recorded in section 10 (Vrbovac).

The average number of species, or species richness, recorded in each surveyed water body has declined. In 1998, the mean value was 14.06, while in 2010 it was 9.37 (Fig. 8). The observed difference is statistically significant (p=0.0004; F-ratio Variances=3.97; p_{Var}=0.01). In addition, the recorded species number in the water bodies of the Zasavica was more variable in 1998 than in 2010.

In 1998, the average Shannon's Diversity index was 1.94, while in 2010 it was 1.85 (Fig. 8). This difference is not statistically significant, according to the t-test (p=0.25; F-ratio Variances=9.42; pVar=0.00008). More significant is the difference in the deviation of the recorded values from the mean, which was much wider in 1998.

The average value of species evenness was 0.74 in 1998 and 0.84 in 2010 (Fig. 8). The increase in the value is statistically significant (p=0.009; F-ratio Variances=4.60; p_{Var}=0.005). Deviation from the mean value was wider in 1998, while the values of species evenness were much narrowly grouped around the mean in 2010.

DISCUSSION

The temporal changes in aquatic vegetation as indicators of habitat changes have been studied by numerous authors, concluding that the indicative potential of aquatic plants rests on the knowledge of the species tolerance within an ecoregional context (Hutchinson, 1975; Lacoul & Freedman, 2006).

The most notable change in the assemblage of submerged and floating aquatic plant species in the Zasavica River over the course of thirteen years was in the composition of species. At the end of this period, in 2010, no new species were found in the main channel, and eleven species that had inhabited main channel of the river in 1998, were not recorded in 2010. So the overall species richness in the Zasavica decreased. The lower number of hydrophyte species was not expected, since the studied area is protected by law, and is a slow-flowing lowland river, highly susceptible to natural succession (Topuzović et al., 2009; Oťaheľová et al., 2007; Hrivnák et al., 2009). Among the "missing" plants

Table 2. Species List

Species	Abbreviation	1998	2010	National legislative
Callitriche palustris L.	Cal pal	+	+	SP
Ceratophyllum demersum L.	Cer dem	+	+	
Ceratophyllum submersum L.	Cer sub	+		
Hottonia palustris L.	Hot pal	+		SP
Hydrocharis morsus-ranae L.	Hyd mor	+	+	
Lemna gibba L.	Lem gib	+		
Lemna minor L.	Lem min	+	+	
Lemna trisulca L.	Lem tri	+	+	
Myriophyllum spicatum L.	Myr spi	+	+	
Myriophyllum verticillatum L.	Myr ver	+		
Najas marina L.	Naj mar	+	+	
Najas minor All.	Naj min	+	+	
Nuphar lutea (L.) Sibth. & Sm.	Nup lut	+	+	SP
Nymphaea alba L.	Nym alb	+	+	SP
Nymphoides peltata (S. G. Gmelin) O. Kuntze	Nyp pel	+		
Potamogeton acutifolius Link.	Pot acu	+		SP
Potamogeton crispus L.	Pot cri	+	+	
Potamogeton lucens L.	Pot luc	+	+	
Potamogeton pusillus L.	Pot pus	+		SP
Potamogeton trichoides Cham. et Schlecht.	Pot tri	+		SP
Ranunculus circinatus Sibth.	Ran cir	+		
Salvinia natans (L.) All.	Sav nat	+	+	
Spirodela polyrrhiza (L.) Schleiden	Spi pol	+	+	
Stratiotes aloides L.	Str alo	+	+	P
Stuckenia pectinata (L.) Böerner	Stu pec	+	+	
Utricularia australis R. Br.	Utr aus	+		P
Utricularia vulgaris L. 1753	Utr vul	+	+	P
Wolffia arrhiza (L.) Wimm.	Wol arr	+	+	
Zannichellia palustris L.	Zan pal	+		P
	Total number of species	29	18	

are four strictly protected, and two protected species. Since the study site was the central part of the Special Reserve, protected because of its naturalness and numerous rare and protected species, this possible loss of protected aquatic plant species could be an indicator of the inadequate management of this protected natural asset. In this study, only the results of surveys done in 1998 and 2010 were analyzed. In the period between there were records of aquatic plant species that are notable. The most significant is the finding of *Aldrovanda vesiculosa* in 2006 (Stanković, 2007), but in the survey in 2010 it was not found, as along with *Elodea canadensis* (Perić and Stanković, 2007).

The next indicative change in the hydrophytic vegetation of the Zasavica concerns the change in the order of dominance. In 1998, the most dominant aquatic vascular plant in the Zasavica was *Stratiotes aloides*, making up over a third of the relative plant mass, with a ubiquitous distribution along the river and being the most abundant in the assembly of hydrophytes. In 2010, its relative plant mass was over ten times lower, it became occasional instead of abundant, and it retreated from almost half of the localities it had inhabited before. In 2010, a new dominant species emerged, *Ceratophyllum demersum*, which is now abundant and present in almost all the surveyed water bodies. The fact that after thirteen years the most dominant species in a slow-flowing lowland river has become a submerged species instead of the floating one, is a bit unusual in regard to the stages of succession in freshwater ecosystems (Krivtsov et al., 2000). It is to be expected that after a certain period of time, the flotant vegetation would become more developed. The only part of the Zasavica where processes of natural succession took the expected course was Prekopac, which is now in the phase of emergent, or helophyte, vegetation. It seems that in the rest of the Zasavica River, the succession "took a step backwards", allowing the successful development of submerged plant assemblages.

The observed diversity loss is substantiated by the lower species richness and diversity index values, both as a general trend and in the individual water bodies. The most drastic change in species richness occurred in the water body Lug. The most significant drop of diversity index value was observed in abovementioned water-body, and in Trebljevine 1. In addition, regarding the changes in diversity index, it is worth mentioning that the values of this parameter became more uniform in the surveyed parts of the Zasavica, and that its values dropped most significantly in water bodies that were earlier characterized by high diversity. Unlike species richness and diversity index, the values of the evenness index were higher in 2010, both in general and in the separate water bodies. Although the number of recorded species and their diversity have decreased, the abundance of hydrophytes that are growing in the Zasavica have become more evenly distributed between occurring aquatic plant species, and the recorded values of species evenness became less variable along the river (Magurran, 2004).

The increased evenness indicates an evenly distributed abundance among the hydrophytes that were recorded at the end of the thirteen year-long period, and this again illustrates the established stability that happened after the disturbance that caused the diversity loss. It is important to reveal the origin of the disturbance that caused such drastic changes. The possible explanation probably lies in hydrological factors that have changed over the years (Janauer et al., 2010; Hrivnák et al., 2006; 2010; Oťaheľová, 2011). There are some indications that the water level of the Zasavica has become significantly higher, as along with the flow rate. Unfortunately, since there is no available published documentation that such hydrological measures were undertaken, this explanation is just speculation, based on the changes in the aquatic vegetation.

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