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Diversity of aquatic macrophytes in relation to environmental factors in the Slatina river (Slovakia)

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Abstract: Distribution and plant mass of aquatic macrophytes, and their relation to environmental conditions was studied in the submontane-colline Slatina river in 2004. Diversity of macrophytes was low, only 8 vascular plants, 3 mosses and group Algae filamentosae were found. *Myriophyllum spicatum* is dominant species, *Fontinalis antipyretica*, *Rhynchostegium riparioides* and Algae filamentosae are frequent. Interactions between flow class, bed material, depth of water and the first three mentioned macrophytes, as well as *Jungermannia leiantha* were detected. *Sparganium erectum* prefers more antrophogenic conditions and *Myriophyllum spicatum* prefers the light. According to cluster analysis, three distinct and ecologically well separated parts of the river were identified. Based on Reference index, poor ecological status for the studied part of the Slatina river was estimated.

Key words: aquatic vegetation, ecological status, running water

Introduction

Aquatic macrophytes are generally used for environmental monitoring and water quality assessment. There are several countries, where indices for this purpose were established (Kohler, 1982; Tremp & Kohler, 1995; Demars & Harper, 1998; Haury et al., 2002; Schneider & Melzer, 2003; Schamburg et al., 2004a,b; Toso et al., 2005). The whole process was accelerated by European Water Framework Directive (Council of the European Communities, 2000). Studies of relationship between macrophytes and environmental conditions were the base for created indices and ecological groups of aquatic macrophytes. To the main environmental conditions influencing both the distribution and mass of macrophytes belong the following: water level fluctuation, depth of water and current velocity (e.g. Madsen et al., 2001; Riis & Hawes, 2002; Hrivnák, 2005; van Geest et al., 2005), nutriens level (e.g. Solińska-Górnicka & Simonides, 2001; Schneider & Melzer, 2004), antrophic disturbances and management (e.g. Bornette & Amoros, 1996; Husák & Vořechovská, 1996; Oťaheľová & Valachovič, 2002; Bernez et al., 2004; Oťaheľová & Banásová, 2005), bed material (e.g. Baatrup-Pedersen & Riis, 1999), as well as spatial structure, light regime, competition or effect of animals (e.g. Dennison & Orth, 1993; Khedr & El-Demerdash, 1997; Cristofor et al., 2003; Demars & Harper, 2005; Hervé et al., 2005).

In the last decade, mapping of macrophytes and studies of interaction between macrophytes and environment in running waters were very intensive in Danube countries e. g. Germany (Veit & Kohler, 2003), Austria (Janauer & Wychera, 2000), Hungary (Pall et al., 1996), Serbia and Montenegro (Vukov et al., 2003) and Romania (Sarbu, 2003). In the territory of Slovakia, only few data have been published (Hrivnák et al., 2003, 2004; Oťaheľová & Valachovič, 2003, 2005). The aims of this paper are: i) to characterise the diversity of macrophytes and environmental conditions on the selected part of Slatina river, ii) to find the relationship between environmental conditions and macrophyte patterns, iii) to test the method for assessment of the ecological status of running waters based on their aquatic macrophyte vegetation.

For this purpose, part of Slatina river was chosen flowing across different biotopes, from natural and seminatural forests, mowed mesophilous and wet meadows, pastures to a typical urban country (villages, intensive agricultural land, permanent crops, railways or roads).

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Table 1. Selected environmetal variables of the SPR.

Environmental variables		Mean	SD	Max	Min
Depth of water_D		35.729	23.144	110.00	10.00
Width of river_W		9.981	2.063	17.00	7.00
Woody species on banks %_T		74.844	21.463	100.00	10.00
pH		7.356	0.208	7.87	7.15
Conductivity (μS/cm)_C		259.545	11.085	271.00	230.00
Bed material _BM		1	2	3	4
	%	22.84	43.50	29.57	4.09
Flow class_FC		1	2	3	4
	%		70.22	28.85	0.92
Land use type_left_LTl		1	2	3	.
	%	9.71	79.38	10.91	
Land use type_right_LTr		1	2	3	.
	%	22.01	61.81	16.18	
Regulated/No regulated_R		yes		no	.
		12.54		87.46	

Legend: BM, LTl, LTr, R – in % length of the studied part of river; BM – rock 1, gravel 2, sand 3, fine substrate 4; FC – stagnant 1, low flow 2, medium flow 3, high flow 4; LT – artificial surfaces 1, meadows and pastures 2, forests and shrubs 3; SD – standard deviation

Material and methods

Study site

Slatina is a 55 km long submontane-colline river. It rises in the Veporské vrchy Mts (Central Slovakia) at the altitude of ca 930 m in the Cristalline region and flows through the Cristalline region of the Sihlianska planina plateau and Detvianska kotlina basin, further through the Neogene and Quartenary deposits of the Zvolenská kotlina basin and the neovolcanites of the northern slopes of the Javorie Mts. The Slatina river empties into Hron river near Zvolen (280 m a.s.l., $Q = 7.95$ m^3 s^{-1}) and belongs to the Danube river catchment area. The catchment area of Slatina has 792 km^2 and average precipitation in this territory reaches 788 mm per year (Zítek, 1970). It has average overflow $Q = 3.73$ m^3 s^{-1} in Zvolenská Slatina (330 m a.s.l., 808 mm average annual precipitation) and very fluctuating water regime (max. overflow $Q_{\max} = 78.0$ m^3 s^{-1}; Zítek, 1970). The catchment area of the Slatina river belongs to the middle-mountain and upland areas, and it is characterised by snow-rain combined runoff regime, with high water bearing in spring (March–April) and minimum in autumn (September) (Šimo & Zaťko, 2002). According to data of Slovak Hydrometeorological Institute, Slatina river was assigned to III–V water quality (V means the worst quality) in 2002–2003.

The studied part of the river (next only SPR) is situated in the lower part of the catchment area, between villages Vígľaš and Slatinka in the Zvolenská kotlina basin (Fig. 1). The total length of the SPR was more than 9.5 km and altitude ranged from 345 m at the upstream to 320 m at the downstream. The basic data of selected environmental variables are presented in Table 1. The SPR flows across three villages and settlements, but mostly it flows across the meadows, pastures and forests. Tree and shrub vegetation on the banks is formed mainly by *Alnus glutinosa*, *Padus racemosa*, *Salix fragilis;* sometimes *Corylus avelana*, *Euonymus europaeus*, *Salix viminalis* and *Ulmus leavis* occur.

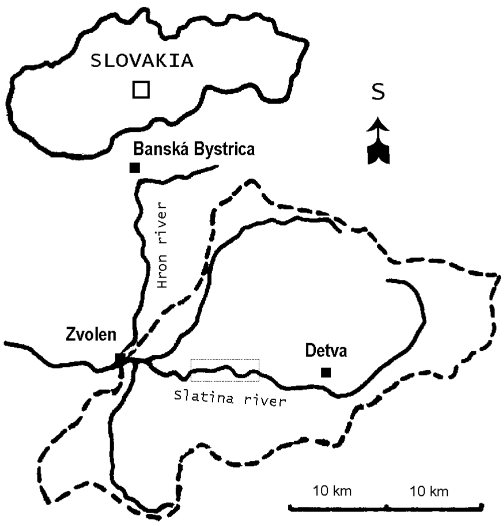

Fig. 1. Map of the studied area (dashed line – catchment area of the Slatina river).

Sampling methods

Field research was carried out in September 2004. The methodology followed a standard approach published by Kohler (1978), Kohler & Janauer (1995) and Janauer (2003). Total 96 sections of the SPR with more or less homogenous abiotic character, human impact and distribution of macrophytes were selected. The position of river section was mapped into 1:10000 scale maps. In each section, the Plant Mass Estimate (PME) was evaluated using a five level scale. Selected abiotic parameters such as bank structure, bed material, flow velocity class, and the CORINE land use type were assessed according to Janauer (2003). Cover of woody species on banks was estimated, width of river, depth of water, pH and conductivity were estimated or measured. The last two characteristics were measured using the field equipment WTW pH/Cond 340i.

Data processing

Based on the PME data the numerical derivatives were calculated: the Relative Plant Mass (RPM) and the Mean

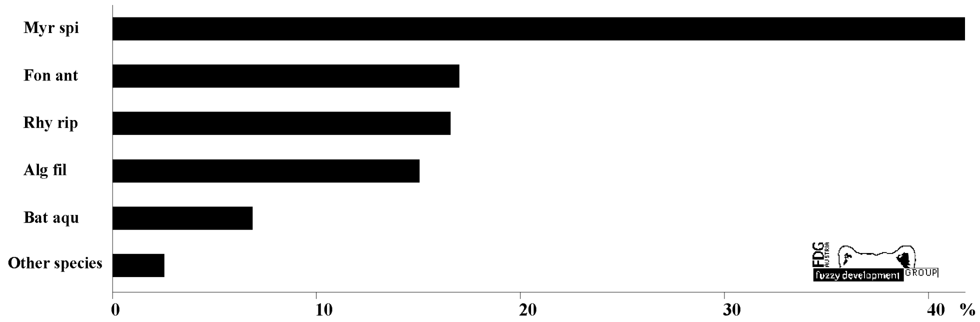

Fig. 2. Relative plant mass (RPM %) of macrophytes in the SPR.

Mass Indices (MMT, MMO) (Janauer 2003). The procedure to elaborate the distribution diagram and to calculate numerical derivatives was gained on-line on the web-site (*www.midcc.at*). For basic statistics (standard deviation, Spearman correlation coefficient) STATISTICA programme (StatSoft, 2001) was used. Species/PME data set was processed by the programme HIERCLUS from SYN-TAX 2000 package (Podani, 2001), Ružička's coefficient of similarity and beta-flexible clustering analysis ($\beta = -0.25$) were used. The index of species diversity was calculated using Shannon's formula – H' (Whittaker, 1972). For assessment of water quality based on European Water Framework Directive, Reference index (RI) of macrophytes was calculated basically according to Schaumburg et al. (2004b), but both amphiphytic and helophytic species were considered too (see Tab. 2, column 3 too). RI was transformed to 0–1 scale and the ecological status of SPR was proposed.

The nomenclature of the non-vascular and vascular plants follows Marhold & Hindák (1998).

Table 2. Total list of macrophytes, their growth forms and ecological species groups.

No.	Name of taxa	1	2	3
1	Algae filamentosae	Alg fil.	Sa	–
2	*Batrachium aquatile*	Bat aqu	Sa	B
3	*Callitriche palustris* agg.	Cal pal	Sa	A
4	*Fontinalis antipyretica*	Fon ant	Sa	B
5	*Jungermannia leiantha*	Jun lei	Sa	–
6	*Myriophyllum spicatum*	Myr spi	Sa	C
7	*Persicaria hydropiper*	Per hyd	Am	B
8	*Phalaroides arundinacea*	Pha aru	He	B
9	*Potamogeton nodosus*	Pot nod	Fl	C
10	*Rhynchostegium riparioides*	Rhy rip	Sa	B
11	*Sparganium erectum*	Spa ere	He	C
12	*Typha latifolia*	Typ lat	He	B

Legend: 1 Abbreviations; 2 Growth form: Am – amphiphytes, Fl – floating leaf rhizophytes, He – helophytes, Sa – submersed anchored macrophytes; 3 Ecological species groups according to Oťaheľová in Adamková et al. (2004; modified in this place): A – taxa which are abundant at reference sites, B – species with wide ecological amplitude and with occurrence in immediately negatively influenced waters, C – species of disturbed and artificial biotopes.

Results

Distribution and mass of macrophytes

Total 8 vascular plants and 3 mosses were detected in the SPR. Most of them belong to hydrophytes (7), only four to helophytes or amphiphytes. Algae were not determined and they were asigned into a common group Algae filamentosae (Tab. 2). *Myriophyllum spicatum* is the species with the highest RPM value, moss species (*Fontinalis antipyretica* and *Rhynchostegium riparioides*) and Algae filamentosae have a similarly higher RPM (Fig. 2). The RPM of other seven species was neglected and thus they were included in to the group "other species" in Fig. 2. Algae filamentosae and *Myriophyllum spicatum* are typical ubiquitous taxa; on the contrary *Batrachium aquatile*, helophytes *Sparganium erectum* and *Typha latifolia* as well as some other species (see Fig. 3), have a clumped distribution in SPR. Average value of species diversity was $H' = 1.948046$.

Interaction between environmental conditions and macrophytes

Among environmental variables, close correlations were detected between pH and conductivity of water, depth of water and flow class, respectively. In addition, the size of substrate increased with flow velocity and decreased with depth of water. Relation between land utilisation and cover of woody species on banks confirmed that trees retreated with the increasing intensity of land use (Tab. 3).

Relationship between macrophytes and selected environmental variables is shown in the Tab. 4. *Fontinalis antipyretica*, *Myriophyllum spicatum*, *Rhynchostegium riparioides* and partially *Jungermannia leiantha* belong to species group growing in shallower, faster flowing waters and prefer course-grained substrate (gravel or solid rock). As the first three species dominate in the SPR (see Fig. 2), the overall mass of macrophytes follows the same ecological characteristics. *Sparganium erectum* prefered more antrophogenic conditions (higher values of LT). Only one species, *Myriophyllum spicatum* was related to the cover of woody species on the banks (see Tab. 4).

Differentiation of water course

Three different parts of the SPR (I, II, III; next only groups) were identified by cluster analysis (Fig. 4).

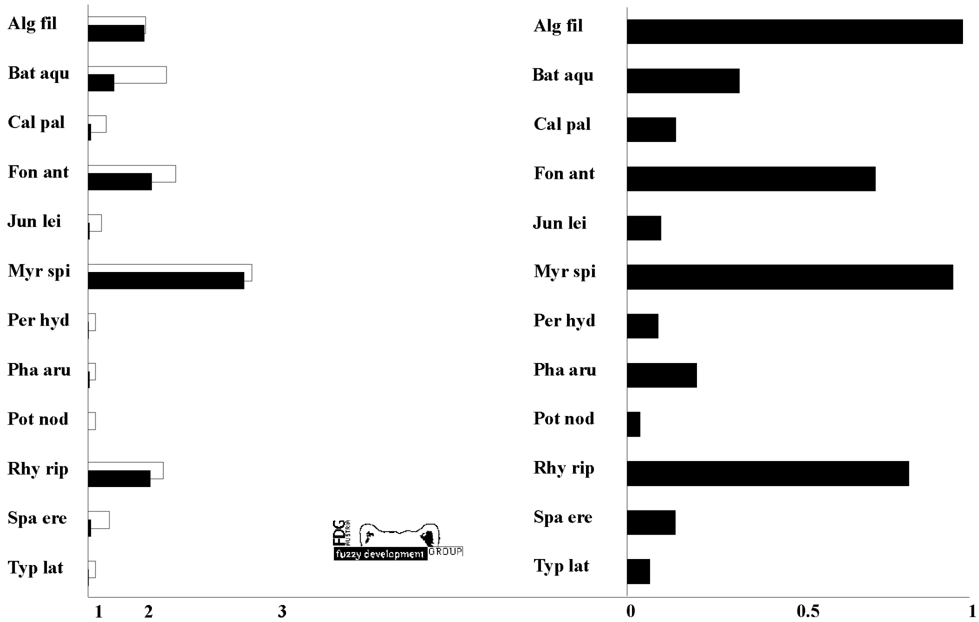

Fig. 3. Mass indices, MMT (dark columns) and MMO (empty columns); on the left side and distribution ratio on the right side.

Table 3. Correlation between environmental variables (Spearman correlation coeficient, P < 0.01).

	BM	FC	LTl	LTr	D	W	T	pH	C	R
Bed material_BM	.	−0.663	ns	ns	0.725	ns	ns	ns	ns	ns
Flow class_FC	.	.	ns	ns	−0.861	ns	ns	ns	ns	ns
Land use type_left_LTl	.	.	.	ns	ns	ns	ns	ns	ns	ns
Land use type_right_LTr	.	.	.	.	ns	ns	0.304	ns	ns	ns
Depth_D	.	.	.	.	.	ns	ns	ns	ns	ns
Width_W	.	.	.	.	.	.	ns	ns	ns	ns
Woody species on banks %_T	.	.	.	.	.	.	.	ns	ns	ns
pH	.	.	.	.	.	.	.	.	0.997	ns
Conductivity (μS/cm)_C	.	.	.	.	.	.	.	.	.	ns
Regulated_R	.	.	.	.	.	.	.	.	.	.

Legend: ns – not significant; the other symbols and abbreviations are presented in Table 1.

Table 4. Correlation between environmental variables and Plant Mass Estimate of macrophytes (Spearman correlation coeficient, P < 0.01; only species which were found in more than 5 river sections are presented).

	BM	FC	LTl	LTr	D	W	T	pH	C	R	SM
Sum of PME	−0.490	0.624	ns	ns	−0.608	ns	ns	ns	ns	ns	ns
Alg fil.	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Bat aqu	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Cal pal	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Fon ant	−0.460	0.551	ns	ns	−0.527	ns	ns	ns	ns	ns	ns
Jun lei	ns	0.262	ns	ns	−0.288	ns	ns	ns	ns	ns	ns
Myr spi	−0.388	0.516	ns	ns	−0.534	ns	−0.300	ns	ns	ns	ns
Per hyd	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Pha aru	ns	ns	ns	ns	ns	ns	ns	ns	ns	−0.291	ns
Rhy rip	−0.429	0.592	ns	ns	−0.547	ns	ns	ns	ns	ns	ns
Spa ere	ns	ns	−0.275	ns	ns	ns	ns	ns	ns	ns	ns

Meaning of symbols and abbreviations as in Table 1 and 3.

The groups are ecologically well defined. Group I was characterised by higher flow velocity class, lower depth of water, harder substrate, higher shading of woody species growing on banks, higher values of both macrophyte mass and number of species, as well as higher species diversity index. On the other hand, group III had lower flow velocity class, higher depth of water, finer substrate, less shading of woody species growing on banks, lower values of macrophyte mass, number of species and lower species diversity index. Group II was

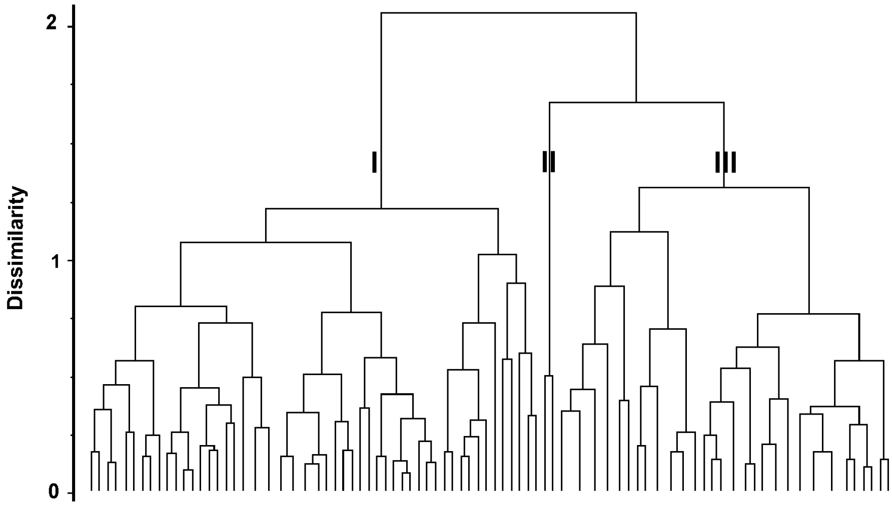

Fig. 4. Dendrogram of numerical classification of the SPR.
Legend: Order of the river sections (from left to right): Group I – 1 3 79 81 14 21 17 83 37 26 39 41 45 28 47 51 30 43 38 86 88 91 9 49 29 11 76 52 78 46 62 74 33 75 64 70 66 67 84 77 89 95 5 96 16 35 40 93 34 7 15 24 92 94 Group II – 2 4 Group III – 6 10 22 90 32 8 27 68 87 12 65 31 85 25 36 82 63 13 18 20 19 73 23 80 55 57 60 69 42 44 54 58 59 61 48 71 50 72 53 56

Table 5. Average values of selected ecological conditions, Plant Mass Estimate (PME), number of species and Shannon's diversity index (H') of identified river groups I–III.

		Mean	SD	Max	Min
Flow class	I	2.87	0.52	4	2
	II	2.00	.	2	2
	III	2.28	0.45	3	2
Depth of water	I	25.57	16.15	80	10
	II	67.50	.	75	60
	III	47.85	24.54	110	15
Woody species on	I	69.70	23.63	100	10
Banks_%	II	98.50	.	100	97
	III	80.60	16.24	100	35
Sum of PME	I	10.59	2.89	18	4
	II	1.50	.	2	1
	III	5.73	1.80	9	3
Number of species	I	4.89	1.33	8	2
	II	1.50	.	2	1
	III	3.70	0.65	5	2
H'	I	2.09	0.38	2.89	0.81
	II	.	.	.	.
	III	1.78	0.27	2.24	0.92

represented by only two samples, which were extremely species poor (Tab. 5).

Ecological status of SPR
Based on mass of macrophytes and their facility to ecological groups of macrophytes (see Tab. 2, column 3), RI = −39.293030 (0.3035 – transformed to 0–1 scale) was calculated for the SPR. Concerning the calculated RI value and high abundance values of eutrofic indicator *Myriophyllum spicatum*, the ecological status of the SPR can be evaluated as poor, according to interpretation published by Meilinger et al. (2005).

Discussion

Macrophytes versus environmental conditions
Fontinalis antipyretica, *Myriophyllum spicatum*, *Rhynchostegium riparioides* belong to the most frequent species in the SPR, together with Algae filamentosae. The first three species mentioned grew mainly in waters with flow velocity higher than 40 cm s^{-1}, where they were found on substrate with the mean size of over 5 cm. The occurrence and preference of *Fontinalis antipyretica* (Fon ant), *Myriophyllum spicatum* (Myr spi), and *Rhynchostegium riparioides* (Rhy rip) to the faster flowing waters and hard substrates are know from Northern Spain (Myr spi; Onaindia et al., 1996) or Great Britain (Fon ant; Dawson & Szoszkiewicz, 1999) and Orne river in France (Fon ant and Myr spi; Bernez et al., 2004) or the Ipeľ river in Slovakia (Fon ant, Rhy rip; Hrivnák et al., 2003). *Myriophyllum spicatum* has a wide ecological amplitude as well. It grows from standing to fast waters in fine to coarse substratum (Willby et al., 2000). It was found e. g. on sand bed material in lowland English rivers (Clarke & Wharton, 2001) and it prefers gravel and fine inorganic bed material in the Danube river (Janauer & Exler, 2004). Generally, the moss species are more typical for upstream reaches of rivers with higher flow velocity (cf. French & Chambers, 1996;Abou-Hamdan et al., 2005).

Light condition is an important factor influencing the composition and mass of macrophytes (Abou-Hamdan et al., 2005). Negative correlation between PME of *Myriophyllum spicatum* and cover of woody species on the banks indicates the preference of the species to river section with higher portion of light. Similar results found Khedr & El-Demerdash (1997) in Nile Delta.

Effect of regulation of water-course on macrophyte vegetation was not detected in the SPR, because only a relatively short part of SPR was regulated. It could be probably due to small-scale study too, because differences between macrophyte diversity in regulated and natural running waters in large scale are known (BAATRUP-PEDERSEN & RIIS, 1999; BERNEZ et al., 2004). Similarly, interaction between conductivity (C) and pH of water and macrophytes was not detected. The values of C and pH, were very homogenous (cf. Tab. 1) however, it is known that different types of aquatic vegetation sometimes prefer different conductivity and pH of water (PAPASTERGIADOU & BABALONAS, 1993; DAWSON & SZOSZKIEWICZ, 1999).

Ecological status

We used our data for the calculation of the RI index using both formula and ecological classification of species proposed for the German rivers (MEILINGER et al., 2005). The indices were calculated for river types MRS (fast flowing rivers and brooks of mountainous area with soft water) and MP (lowland river in mountainous areas), which are typologically the most similar to our studied area. For the MRS type the RI = −76.21243 was calculated (it means a good ecological status at the border to a moderate ecological status). For the MP type the RI = −39.70286 was calculated indicating the moderate ecological status. The comparison of RI values calculated by the German and Slovak methodology showed slight differences related probably to different river characteristics of German and Slovak rivers.

HUSÁK et al. (1989) published saprobic index (Si) of selected macrophytes (only vascular plants) as an indicator of organic pollution. The most frequent species in the SPR, *Myriophyllum spicatum* and *Batrachium aquatile* belong to species with higher Si values (2.3 and 2.2, respectively). *Myriophyllum spicatum* belongs to species growing in eutrophic waters rich in nutrients similarly to *Batrachium aquatile* and *Potamogeton nodosus* (HUSÁK & VOŘECHOVSKÁ, 1996; WILLBY et al., 2000; SCHNEIDER & MELZER, 2003, 2004). Within ecological classification of macrophytes in German rivers, *Fontinalis antipyretica* and *Rhynchostegium riparioides* were classified as tolerant species indicating eutrophication (SCHAUMBURG et al., 2004b). On the other hand, HUSÁK & VOŘECHOVSKÁ (1996) assigned *Fontinalis antipyretica* to positive indicators preferable waterbodies with predominantly soft water, poor in nutrients and unpolluted by both organic and inorganic matters. Our experiences are consistent to the former opinion.

All mentioned facts indicate that ecological status of the SPR cannot be considered as satisfactory. RI value, low species diversity, occurrence and higher abundance and mass of eutrophic species (*Batrachium aquatile*, *Fontinalis antipyretica*, *Myriophyllum spicatum*, *Potamogeton nodosus,* and *Rhynchostegium riparioides*) show the poor ecological status of SPR. On the other hand, prevailing landscape (pastures, meadows and forest vegetation), as well as relatively well developed stands of woody species on banks, reflect the moderate ecological status of the SPR.

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