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A RIVERSIDE TALE: ASSESSMENT OF ALTERED HABITAT EFFECTS ON MACROPHYTE ASSEMBLAGE ON THE RIVER TAMIŠ, SERBIA

SNEŽANA RADULOVIĆ[1], DUŠANKA LAKETIĆ[2] and DRAGANA VUKOV[1]

[1] *University of Novi Sad, Faculty of Sciences, Department of Biology and Ecology,* 21000 Novi Sad, Serbia
[2] *University of Belgrade, Faculty of Biology, Institute of Botany,* 11000 Belgrade, Serbia

Abstract - The aim of this study was to recognize the relationships between the physical characteristics of river reaches and the supported macrophyte assemblage, using the newly developed RHS (River Habitat Survey) method and dataset, and to test the following specific hypotheses: (i) whether there are correlations between the abundance of macrophyte groups and the physical environment variables, and (ii) whether these relationships vary between macrophyte groups with different morphology types. The Tamiš river possesses a highly diverse habitat potential, while high values of HMS capture *obviously* to *significantly* modified habitat classes, significantly distinguishing the R1 and L1 spot-check as a hot spot along the area studied.

Key words: RHS, macrophytes, habitats, diversity, HQA, HMS, WFD

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INTRODUCTION

Contemporary freshwater assessments primarily take into consideration the mechanisms relating to species richness variation with habitat heterogeneity. Aquatic macrophytes are considered to be sensitive to physical alteration in streams, being in close contact with the environmental conditions of rivers through the root-system, and especially through the leaves which are surrounded by, or floating in a dense chemical solution compared with terrestrial plants. Hence, this sensibility is used widely to establish the ecological quality of aquatic ecosystems (O'Hare et al. 2006, Furse et al. 2006). Phytobenthos is usually considered as an early warning indicator, while macrophytes, due to their longer life cycles and tolerance to short-term changes of environmental conditions, indicate a more persistent impairment (Brabec and Szoszkiewicz, 2006). Current survey methods usually record biological or hydromorphic patterns, or inventories of features (physical processes, or ecosystem functions or services). Their greatest use is likely to be in extending spatially extensive biological or water chemistry monitoring to integrate it with 'eco-hydromorphic' monitoring, driven on a pan-European level by the WFD (EU Water Framework Directive, Council Directive 2000/60/EC).

The WFD is the most comprehensive legislation ever enacted in Europe for addressing the integrity of fresh waters for both conservation and management needs. The aims of the WFD are to prevent the deterioration of aquatic ecosystems, to promote sustainable water use, to reduce pollution to groundwater and to surface water, and to contribute towards mitigating the effects of floods and droughts. The WFD is geographically far-reaching (it encompasses the whole of the EU); it covers all surface waters; requires 'programs of measures' within 'river basin management plans' to bring water bodies up to 'good status'; and embraces a much wider ecosystem perspective than previous legislation in terms of spatial coverage (river basins), habitat attributes (morphology, hydrology, water quality, riparian zones) and biological communities (macrophytes, phytobenthos, phytoplankton, benthic invertebrates and fish (Boon, 2004).

In contrast to biology, ways of assessing hydromorphology have only recently become available through the development of the RHS (River Habitat Survey) (Raven et al. 1998a, Raven et al. 1998b). Approximately 20,000 RHS surveys have been carried out in the UK (Environment Agency, 1997, 2003; Raven et al. 1998a) and RHS is also used in many other European countries (Germany, Sweden, Greece, France, Slovenia, Austria, Spain, Portugal, Italy, Czech Republic and now in Serbia). This has opened up possibilities for European countries to carry out essential work on riverine hydromorphology to address a range of WFD and non-WFD needs. However, there is an urgent need to understand how the physical structure of riverine habitats influences biological communities – a field of study that is still in its infancy.

The responses of distribution and abundance of macrophytes to environmental factors as possible indicators of ecological change in rivers and reservoirs in the region are often discussed (Blaženčić and Blaženčić 1997, Stevanović et al. 2003a, Stevanovic et al. 2003b, Blaženčić and Blaženčić 2004, Radulović 2004, Radulović et al. 2009, 20010, Vukov 2006, 2008, Hrivnak et al. 2009, Stanković et al. 2009, Matić V, 2009, Topuzović et al. 2009).

The aim of this study is to recognize the relationships between the modified and altered physical characteristics of river reaches and macrophyte assemblage. The RHS (River Habitat Survey) method and dataset were used for testing the following hypotheses: (i) whether there are correlations between the abundance of macrophyte groups and the physical environment variables, and (ii) whether these relationships vary between macrophyte groups with different morphology types.

Background of the study site

The Tamiš region is located in a temperate continental climate zone, with a slightly stronger continental influence caused primarily by the mountainous surroundings of the wider area of the Pannonian basin. The Tamiš river, one of Danube's main tributaries, rises in the Semenic Mountains, southern Carpathian Mountains, Caraş-Severin County, Romania. It flows 339 km through Romania and Serbia (the Banat region) to the Danube near the city of Pančevo (northern Serbia). The catchment area covers 13,085 km^2 (Romania 8,085 km^2, Serbia 5,000 km^2). After entering the Banat region the river becomes slow and meandering. In its lower course, the river is regulated, and for the last 53 km it is navigable. As a result, the Tamiš river has played a significant role within the Danube-Tisa-Danube hydro-system since 1967, when this watercourse was intersected by the canal Banatska Palanka - Novi Bečej. However, these regulation works had many negative impacts too.

MATERIAL AND METHODS

Field surveys were carried out during 2009-2010. Observations of the features and artificial modifications were made along a standard 500m length, with 6 RHS and 9 LEAFPACS spot-checks (Map. 1) of the river, following a strict protocol and data entry form: RHS (River Habitat Survey) provides a simple, cost-effective and practical way of characterizing the physical structure of rivers. It combines the basic principles, approaches and terminology of fluvial morphology, freshwater ecology and nature conservation (Raven et al. 1997). Channel features and modifications are recorded at ten equally spaced spot-checks along a 500m length of the river, together with an overall "sweep-up" summary for the whole site, including information on valley form and land use in the river corridor: (1) channel geometry; (2) substrates; (3) channel vegetation and organic debris; (4) erosion/deposition character; (5) flow; (6) longitudinal continuity as affected by artificial structures; (7) bank structure and modifications; (8) vegetation type/structure on banks and adjacent land; (9) adjacent land-use and associated features and (10) degree of (a) lateral connectivity of river and floodplain; (b) lateral movement of river channel.

This allows the relationship between physical variables channel modifications and habitat features to be analyzed at the individual spot-checks and 500m site levels. The RHS and derivative versions are use to investigate the relationships between habitat features and associated biota (Environment Agency 1997, Environment Agency 2003). It has also been used to investigate the influence of catchment land-use as well as the impact of flood defense works**.** Nevertheless, the RHS can provide broad contextual information for the management of individual rivers and catchments**.**

For nature conservation purposes, the main determining factors are the naturalness of the channel structure and processes and the character of adjacent land-use. Two indices broadly describe the diversity of the river habitat and landscape features (Habitat Quality Assessment - HQA score) and the extent and severity of artificial modification to the channel (Habitat Modification Class – HMS) (Raven et al. 1998a). Observed HQA values typically vary between 10 and 80 points, where 10 points indicate that a river has very few attributes characteristic of natural rivers and 80 points indicate that a river has many of the attributes indicative of a high degree of naturalness. The HMS quantifies the extent and impact of anthropogenic modifications such as bank reinforcement, channel re-sectioning, culverts and the number of weirs. Modifications are scored according to their extent and weighted according to their impact. Observed HMS values typically vary between 0 and 100 points, where 0 points indicate that a river has none of the attributes characteristic of modification and 100 points indicate that a river has many attributes characteristic of modification. The following scores have been determined for general reporting purposes (Szoszkiewicz et al. 2006).

HMS classes are given in the following way:

HMS	HMS Description	HMS Score
1	Pristine/semi-natural	0-16
2	Predominantly unmodified	17-199
3	Obviously modified	200-499
4	Significantly modified	500-1399
5	Severely modified	1400+

The WFD tool, known as LEAFPACS, considers species sensitivity to pollution and the actual abundance of plants represented in a water-body which are collated into a classification system. Macrophyte surveys are undertaken once between May and September and not normally repeated for three years. The LEAFPACS method is designed to distinguish the anthropogenic effects of nutrient enrichment or physical habitat modification from changes which would occur naturally across a gradient of increasing fertility and decreasing stream energy, by comparing each of the metrics derived from the observed community with the metrics that would be expected if the community was in reference condition. The classification method uses several key aspects of the aquatic plant community (vascular plants, bryophytes and macroalgae) to assess status. The assessment is based on the following characteristics of aquatic plants in response to fertility and hydraulic habitat characteristics (Holmes et al. 1998, Willby, 2008).

Data analysis

All geo-spatial data were derived using Trimble Nomad GPS, integrated into DIVAGIS and GPS PathFinder Office Software. Collected LEAFPACS field data were analyzed using the standard canonical analysis (Basic CA), CCA and UPGMA methods (Chord distance) using the FLORA software package (Karadzić, 2010). Red list taxa are given according to Stevanović et al. (1999). All information, including photographs of the sample site and map-derived data such as altitude, valley slope and distance from source and geology are entered on a computerized SRB-RHS-SERCON (System for Evaluating Rivers for Conservation in Serbia) software (Boon et al. 1997, Boon et al. 1998, Boon et al. 2002, Radulovic et al. 2008). DIVAGIS software was used for alpha diversity analysis.

Coordinates of RHS spot checks

Hab plot No.	LON_EX	LAT_EX	ALT_EX	LAT	LON
1	20,8487	45,4288	73,0000	+45.4287540	+20.8486787
2	20,6267	45,2841	75,0000	+45.2841115	+20.6267497
3	20,6360	44,8563	71,0000	+44.8563283	+20.6360122
4	20,7728	45,3578	74,0000	+45.3577500	+20.7727501
5	20,4830	45,1853	73,0000	+45.1852500	+20.4830278
6	20,4190	45,0823	71,0000	+45.0823333	+20.4189723

Coordinates of LEAFPACS spot check

Spot check	LON_EX	LAT_EX	ALT_EX	LAT	LON
1	20,8487	45,4288	73,0000	+45.4287540	+20.8486790
2	20,6267	45,2841	75,0000	+45.2841120	+20.6267500
3	20,6360	44,8563	71,0000	+44.8563280	+20.6360120
4	20,7727	45,3577	74,0000	+45.3577500	+20.7727500
5	20,4830	45,1852	73,0000	+45.1852500	+20.4830280
6	20,4190	45,0823	71,0000	+45.0823330	+20.4189720
7	20,8589	45,4015	73,0000	+45.4015180	+20.8588700
8	20,8655	45,3972	73,0000	+45.3971650	+20.8654840
9	20,7734	45,3577	74,0000	+45.3577333	+20.7734278
10	20,7734	45,3577	74,0000	+45.3577333	+20.7734278

RESULTS AND DISCUSSION

A total number of 31 macrophytes was recorded (Tab. 1). The most frequent aquatic vegetation fragments of the study area are, as expected, the intrazonal submersed community *Ceratophylletum demersi* Soó 1934 and *Myriophyllo - Potametum* Soó 1934. It is evident that, at some instance, the excessive growth of this species may detrimentally affect fishery and wildlife resources. Considering the presence of submersed invasive species such as *Elodea canadensis* and *Vallisneria spiralis* the overabundant submersed vegetation is typically the result of the introduction of invasive species which out-compete native plants and grow unchecked by authentic herbivores or parasites (Radulović, 2010).

Floating vegetation is represented by a pioneer community of *Salvinio-Spirodeletum polyrrhizae* Slavnić 1956 and later typical *Nymphaeetum albo-luteae* Nowinski 1928 and *Hydrochary-Nymphoidetum peltatae* Slavnić 1956 fragments. The stands of water lily communities are very shallow, slow and well-lit water. The habitats suitable for its optimum growth characterize a high organic production, with a thick layer of mud, which indicates very strong eutrophication. Compared with previous vegetation groups, typical *Phragmitetea* species are present with a somewhat similar presence level. Within this group association of emerged vegetation of reed in stagnant and slow-flowing waters *Scirpo – Phragmitetum* W. Koch 1926 is dominant.

The Serbian Red List taxa *Trapa nattans* agg. (as the edificator of *Trapetum natantis* Müller et Görs 1960) and *Nymphae alba* give a significant natural relevance to the researched area. *Wolffietum arrhizae* Miyawaki et J. Tx. 1954 ex Oberd 1957 (Radulović, 2010).

The riparian vegetation composition, structure and abundance are altered to a large degree by the river flow and flow-mediated fluvial processes. Widespread modification of flow regimes by humans has resulted in extensive alteration of riparian vegetation communities, given that the shallow parts of a river stretch are already overgrown with macrophytes, indicating the necessity of monitoring these dynamic but fragile ecosystems (Stevanović et al. 2003). Some of the negative effects of altered flow regimes on vegetation may be reversed by restoring components of the natural flow regime. Understanding the mechanisms relating species richness variation to habitat heterogeneity is one of the most crucial issues in ecology and conservation biology. Continuous areas of habitat have been progressively transformed into a patchy mosaic of isolated "islands" of available habitat as a result of human alterations (Holt et al. 1995, Hanski, 1999). Despite the ubiquity of these highly fragmented habitats and their implications for biodiversity, a lack of knowledge still exists on how community diversity varies from sites within large, contiguous habitat areas to those within smaller, fragmented areas.

HMS and HQA score

The relevance of habitat quality assessment protocols depends on comparing sites with similar overall characteristics. Groupings of similar sites was derived from the RHS database using various attributes such as location within a specific hydrological unit, vegetation criteria, similar geology, or, at a finer scale, valley form and channel plan-form. All assessed RHS spot-checks are highly classified (according to the high HQA score, Tab. 2, Fig. 1). Hence, irrespective of a degree of hydromorphological changes (Tab. 3), the Tamiš remains high in habitat diversity potential (Tab. 4).

Table 1. LEAFPACS report

Taxa	L1	L2	L3	L4	L5	L6	L7	L8	L9
Alisma plantago-aquatica L.							1		
Azolla filiculoides Lam.						1	1	1	
Butomus umbellatus L.				1				1	1
Ceratophyllum demersum L. ssp. demersum	2	2	3	2	1	3	2	2	2
Ceratophyllum submersum L. ssp. submersum						1	1		
Eleocharis palustris (L.) Roemer and Schultes							1		
Elodea canadensis Michx									1
Glyceria maxima (Hartman) Holmberg					1				
Hydrocharis morsus-ranae L.						2	1	1	1
Lemna gibba L.						2	2		1
Lemna minor L.						3	3	3	3
Lythrum salicaria L.									2
Myriophyllum spicatum L.	2								
Najas marina L.		2				1	1	1	1
Najas minor All.						1	1		1
Oenanthe aquatica (L.) Poiret								1	
Phragmites australis (Cav.) Trin. ex Steudel			1		1				
Polygonum hydropiper L.			2			2	2	1	
Potamogeton crispus L.	2								1
Potamogeton gramineus L.			1						
Potamogeton nodosus Poiret						1	1	1	
Potamogeton pusilus L.			1						
Rorippa sylvestris (L.) Besser						1			
Sagittaria sagittifolia L.			1	2				1	1
Salvinia natans (L.) All.		1		2	4	3	4	3	2
Sparganium erectum L. Subsp. erectum								1	
Spirodela polyrhiza (L.) Schleiden		5	1	2	2	3	2	2	
Trapa natans L.	2	2	4	3	4		1		
Typha latifolia L.				1				2	1
Vallisneria spiralis L.						3	1	1	1
Wolffia arrhiza (L.) Horkel ex Wimmer		5				3	2	2	1

On the other hand, the high values of the HMS (Tab. 3, Fig. 2) showed *obviously* to *significantly* modified (close to *severely modified*) habitat classes.

Using both the CA and UPGMA approaches (results given in Fig. 3 and Fig. 4), it was shown that the vegetation of the first site L1 (Tamiš – Stari Tamiš) was distinguishable from the others, and represents a unique habitat unit (due to its physical connection with the Old River Tamiš bed) clearly separated from the others – upstream from point L 2-5 (canal DTD point) and, especially, downstream L 6-9, capturing heavily the impacts of the artificially changed habitat (canal DTD) on the pristine vegetation status.

Comparative analysis

In order to characterize individual habitat types and to identify major habitat types within the Tamiš river system, the main environmental parameters with several modalities were used: HQA score, HM Score, Shannon-Wiener index, Hill 05, presence of invasive alien species, species richness, geology and

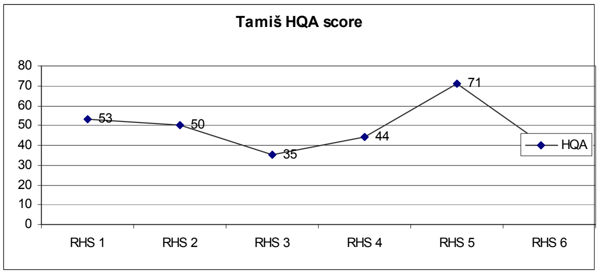

Fig. 1. HQA score

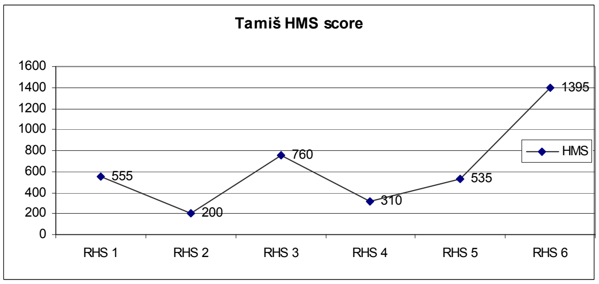

Fig. 2. HMS score results

pedology (Tab 5). These variables were analyzed by canonical correspondence analyses, including the Shannon diversity index for attribute types within each River Habitat Survey spot check. High values indicate a high diversity of attributes in the RHS sample site. Attributes were most diverse at L1 (old Tamiš riverbed), followed by L6 and L7 (before the river junction with DTD canal hydrosystem). However, this high level of L6 and L7 is due to allochthonous invasive species, which have a negative impact on pristine vegetation characteristic.

Comparing HQA and HMS scores along the studied river stretch, the result again distinguishes the L1 habitat unit, which is confirmed using CA and UPGMA methods (Fig. 5). Furthermore, analyzing the L2-L9 habitat units (without L1, in order to get a clearer distribution) it is obvious that the habitat units grouping are HMS and HQA (Fig. 6). Both scores are significantly important for this vegetation units grouping. Fig. 7 proves the significant level of the L1 habitat unit according to the presence of an invasive, alien species. Confirming the primary hypothesis, L1 differentiates according to the upstream and downstream location, while L 2-5 and L 6-9 are grouped.

Comparative analysis of geological and pedological characteristics (Fig. 8), combined with the Shannon index of diversity, verify L1 definitely as a highly specific habitat unit (chernozem with carbonates on fluvial sediments), whilst L2-5 (upstream fluvial saline soils and chernozem with signs of gleyification on loess, solonetz), L6-7 (downstream, alluvial loamy soil) as well as L8 and L9 (downstream alluvial soil) have been characterized as different habitat groups.

The gradient direction of the RHS spot-checks together with the main categories of attributed characteristics correlate best with macrophyte diversity. The categories and attributes in Fig. 6 capture the essential correlation between the HQA score, HM Score, as well as presence of invasive alien species (Fig. 7), geology and pedology (Fig. 8 LB left bank and RB right bank).

Other studies of RHS variability (Buffagni, A. and J. L. Kemp, 2002, Zbierska et al. 2002) have demonstrated that amongst the four geographical regions studied, the habitat of lowland rivers was the most distinct. Flow types were typically dominated by smooth flow, while gravel and pebble were the commonest substrate type. The relatively small contribution of silt and sand distinguishes the lowland rivers in the study of Szoszkiewicz (2006) from other studies describing lowland river attributes in the United Kingdom (Raven et al. 1998a, Raven et al. 2002) and in Poland (Zbierska et al. 2002). Natural berms also appeared to be a particularly distinctive lowland channel feature, in contrast with their rarity along lowland rivers in the United Kingdom (Raven et al. 1998a). The wetland land-use category, natural berm and peat bank categories, and smooth flow channel category were most strongly correlated with the direction of the variability characteristic of lowland rivers. The variability of features within each survey site was also lowest in the lowland rivers, with only the largely anthropogenic bank modification category having any appreciable variability (Szoszkiewicz et al. 2006). However, the analyses given in this paper identified the differences within the river stretches. Nevertheless, they confirmed the findings from

Table 2. HQA score results

RHS spotchecks	HQA Class	HQA score	HQA Flow Types sub score	HQA Channel Substrate sub score	HQA Channel Features sub score	HQA Bank Features sub score	HQA Bank Veg sub score	HQA In-stream Channel Veg sub score	HQA Land Use sub score	HQA Trees and Assoc Features sub score	HQA Special Features sub score
RHS 1	HIGH	53	5	5	3	8	12	3	4	10	3
RHS 2	HIGH	50	4	3	1	2	12	8	4	10	6
RHS 3	HIGH	35	7	6	0	5	6	6	0	3	2
RHS 4	HIGH	44	7	3	0	5	10	10	1	7	1
RHS 5	HIGH	71	4	3	1	10	12	10	8	18	5
RHS 6	HIGH	38	4	3	1	3	6	7	3	8	3

Table 3. Assessed HMS score

RHS spot check	HM Class	HM Score	HMS Culverts sub score	HMS Reinforced Bank and Bed sub score	HMS Resectioned Bank and Bed sub score	HMS Berms sub score	HMS Weirs sub score	HMS Bridges sub score	HMS Poaching sub score	HMS Fords sub score	HMS Outfalls/Deflecto
RHS 1	4	555	0	0	320	0	175	0	10	0	50
RHS 2	3	200	0	0	0	0	0	100	50	0	50
RHS 3	4	760	0	0	400	0	300	0	60	0	0
RHS 4	3	310	0	0	0	0	0	200	60	0	50
RHS 5	4	535	0	0	0	0	475	0	60	0	0
RHS 6	4	1395	0	160	440	200	475	0	70	0	50

other studies that were undertaken in Europe, primarily those carried out within the STAR 5th Framework Project (Standardization of River Classifications: Framework method for calibrating different biological survey results against ecological quality classifications to be developed for the Water Framework Directive).

The 'physical character' or 'condition' of a river channel refers to its form and functioning in relation to an undisturbed state and is usually described by the extent of artificial modification (e.g. near-natural to severely modified). Consequently, assessing the quality of river habitats and understanding both the impact of in-stream and catchment-wide pressures and the effectiveness of remedial actions is an imperative requirement for sustainable management and conservation. Only good management and reducing the human impact as far as possible, can provide the natural functioning of

Table 4. Potential HMS score

RHS spot check	HM Class	HM Score	HMS Culverts sub score	HMS Reinforced Bank and Bed sub score	HMS Resectioned Bank and Bed sub score	HMS Berms sub score	HMS Weirs sub score	HMS Bridges sub score	HMS Poaching sub score	HMS Fords sub score	HMS Outfalls/Deflectors
RHS 1	2	175	0	0	0	0	175	0	0	0	0
RHS 2	2	100	0	0	0	0	0	100	0	0	0
RHS 3	3	300	0	0	0	0	300	0	0	0	0
RHS 4	3	200	0	0	0	0	0	200	0	0	0
RHS 5	3	475	0	0	0	0	475	0	0	0	0
RHS 6	4	835	0	160	0	200	475	0	0	0	0

Table 5. Potential HMS score

LEAFPACS spot checks	L1	L2	L3	L4	L5	L6	L7	L8	L9
RHS spot checks	RHS 1	RHS 1	RHS 1	RHS 2	RHS 2	RHS 3	RHS 4	RHS 5	RHS 6
HQA score	53	53	53	50	50	35	44	71	38
HM Score	555	555	555	200	200	760	310	535	1395
Shannon-Wiener	1.386	1.723	1.99	1.909	1.694	2.642	2.771	2.715	2.662
Hill 05	4	5.792	7.657	6.867	5.711	14.498	16.49	15.559	14.671
Invasive species	no	no	no	no	no	yes	yes	yes	yes
Species richness	4	6	8	7	6	15	17	16	15
Geology	Sands	Sands	Sands	Sands	Sands	Loess	Sands	Sands	Silty-clay
Pedology Left Bank	carbonate-free fluvisol	carbonate-free fluvisol	carbonate-free fluvisol	chernozem	chernozem	fluvial saline soils	solonetz	alluvial sandy soil	alluvial sandy soil
Pedology Right Bank	carbonate-free fluvisol	carbonate-free fluvisol	carbonate-free fluvisol	fluvial saline soils	fluvial saline soils	fluvial saline soils	alluvial sandy soil	alluvial sandy soil	alluvial sandy soil

river systems and their ecological integrity as an important principle of river rehabilitation, as well as an essential part of an adaptation strategy to resist on aquatic biodiversity (Tab. 3, Tab. 4). Following this strategy the Tamiš HMS score could move up to two higher classes.

Recent theoretical work has shown that the decline of species richness with habitat loss is a non-linear process, with species extinctions

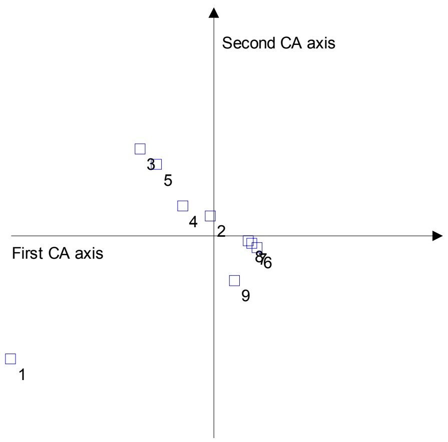

Fig. 3. CA analysis of the macrophyte distribution

becoming more and more frequent as habitat continues to disappear (Tilman et al. 1994; Stone 1995). However, these studies did not use spatially explicit models, making it difficult to infer relationships between the spatial patterns of habitat arrangement and species richness.

On the other hand, there is a wealth of evidence of opposite effects caused by aquatic plants on river hydraulics, with resulting patterns of sediment accumulation and erosion. Some long-term studies (Hamill, 1983, Gurnell and Midgley 1994; Gurnell et al. 2006) concluded that on a reach scale, seasonal macrophyte growth slows water movement, creating conditions that are suitable for sediment deposition (Cotton et al. 2006). However, simple empirical relationships between hydrological variables and vegetation ignore the fact that it is not the flow (or discharge, measured in volume of water per unit time) that the vegetation experiences. To a certain extent, the vegetation experiences the flow via secondary hydraulic variables, such as water velocity and stream power. Hence the influence of hydrology on river macrophytes is strongly determined by channel form – morphology rather than hydrology.

Legislation to underpin ecological assessment is essential, but there are many other reasons for

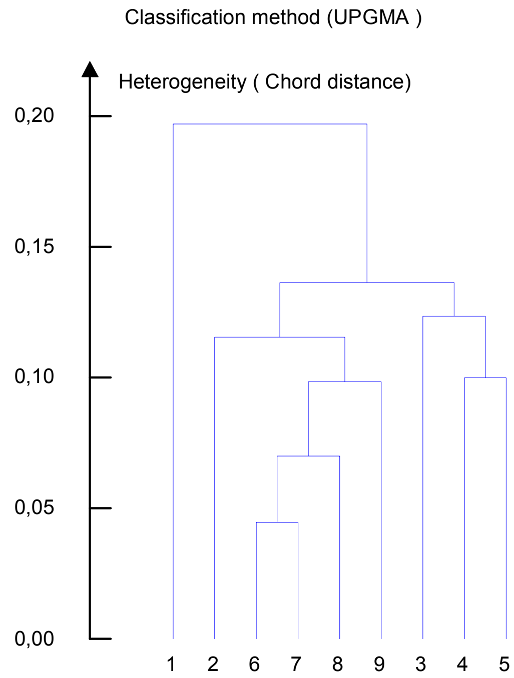

Fig. 4. CA analysis of the macrophyte distribution

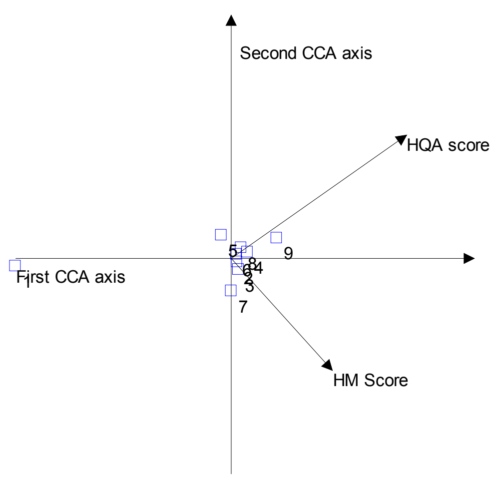

Fig. 5. CCA ordination of HQA and HMS scores.

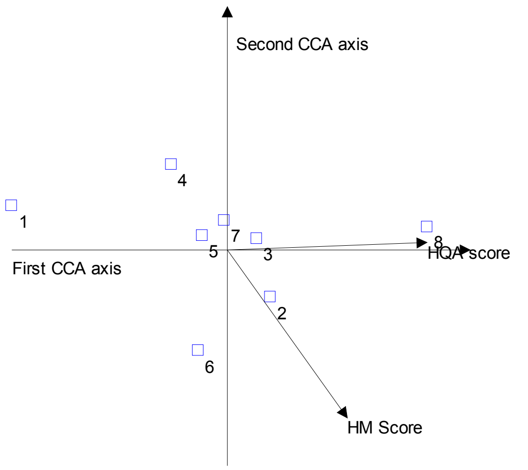

Fig. 6. CCA ordination of HQA i HMS score (without L1).

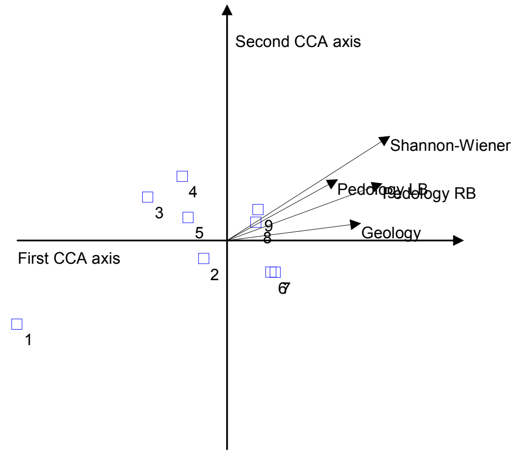

Fig. 8. CCA ordination of Shannon-Wiener index and geology and pedology.

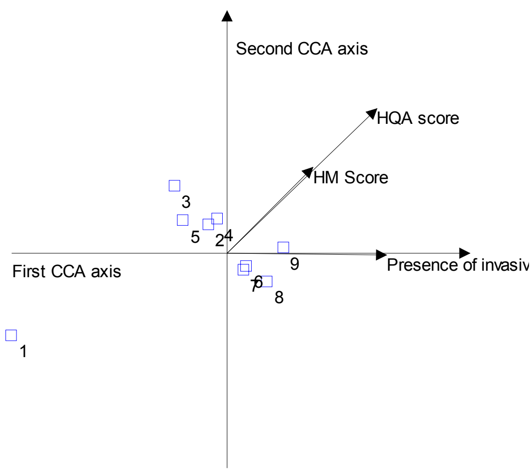

Fig. 7. CCA ordination of HQA and HMS scores and invasive species presence.

engaging in freshwater assessment. Running and standing waters are valuable to society in a variety of ways. There is an increasing recognition that freshwater ecosystems provide a wide range of 'goods and services', frequently unrecognized and therefore undervalued, including water purification, flood control, nutrient cycling, food production, and recreation. A truly comprehensive assessment of the 'value' of fresh waters, therefore, should encompass biology, ecology, economics, recreation and aesthetics, because there is so much more to life than just legislation (*sensu* Boon, 2005).

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