Macrophyte species composition in streams of Latvia under different flow and substrate conditions

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Abstract. The macrophyte species composition was studied in relation to different flow and substrate conditions in middle-sized streams of Latvia. The frequency of macrophyte species along 131 surveyed sites was determined. Each survey was supplemented by a description of environmental factors (substrate type, flow velocity, shading, stream width, and water depth). On the basis of field observations, five groups of stream stretches with different stream velocity and substrates were distinguished: (1) fast-flowing streams on gravelly substrate, (2) slow-flowing streams on gravelly substrate, (3) fast-flowing streams on sandy substrate, (4) slow-flowing streams on sandy substrate, and (5) slow-flowing streams with soft, silty substrate. The botanical differences between the identified stream types were described. A total of 58 macrophyte taxa were found in the streams. The most common macrophyte species were *Nuphar lutea*, found in 60% of all sites, followed by *Sparganium emersum*, *S. erectum* s.l., *Phalaris arundinacea*, *Alisma plantago-aquatica*, and *Lemna minor*. The number of species varied between 1 and 22 per site, the highest species richness (22) was found in slow-flowing streams with gravelly substrate. Species-poor macrophyte communities were characteristic of fast-flowing streams on sandy substrate. CCA analysis revealed that the development of macrophyte species in the investigated streams was most strongly dependent on the catchment area, altitude, and current velocity gradient. Analyses showed correlations between the number of taxa and stream width and catchment area, as well as the number of taxa and macrophyte cover with shading and altitude (negative correlation). Both the number of taxa and macrophyte cover correlated with substrate.

Key words: macrophytes, middle-sized streams, flow velocity, substrate type, Latvia.

INTRODUCTION

Streams are heterogeneous environments with differences in physical and chemical parameters. Different studies worldwide obviously indicate that the knowledge of the macrophyte species composition and abundance provides important information on the aquatic ecosystem (e.g., Best, 1995; Dawson & Szoszkiewicz, 1999; Baatrup-Pedersen et al., 2003). Macrophytes are a key component in the functioning of streams where they grow in relatively high abundance (Clarke, 2002).

The physical stream environment has a major impact upon the development and growth of submersed macrophytes (Baatrup-Pedersen & Riis, 1999). In shallow, low-energy streams where macrophytes are able to grow abundantly, plants greatly influence the functioning of the ecosystem (Sand-Jensen et al., 1989). Substrate and flow velocity are the two most important factors influencing the distribution of macrophytes in streams. And vice versa, the growth of macrophytes has important impacts upon flow resistance, flow velocities, and sediment dynamics.

Macrophytes grow abundatly under such current velocity and in sediments where they can be best rooted and withstand the erosive force of the water during periodic scour events (Chambers et al., 1991). Velocity is an important controlling factor of substrate stability and composition of macrophytes. Several researchers have argued that flow velocity is the main factor in controlling macrophyte composition and biomass in streams (Westlake, 1967; Nilsson, 1987; Chambers et al., 1991; Riis & Biggs, 2003; Haslam, 2006). Flow velocity has often been found to affect the distribution of macrophytes in streams (e.g., Riis et al., 2000; Demars & Harper, 2005).

River surveys have indicated that many macrophyte species are associated with sediment of particular particle size (Holmes, 1983; Haslam, 2006). Substrate stability is a significant controlling factor because a stable substrate allows rooting and establishment of macrophyte communities. Mobile substrates prevent this, resulting in a limited potential for plant community development (Riis & Biggs, 2003; Haslam, 2006). Despite the apparent importance of water movement in regulating macrophyte communities in lowland rivers, the nature of the processes and the factors controlling their dynamics are not well understood (Franklin et al., 2008).

For an assessment of the ecological status of a stream using macrophytes a certain minimum plant quantity is required. The variability of macrophyte richness is linked to physical factors in the environment, which make an important contribution to the pattern of macrophyte distribution (Abou-Hamdan et al., 2005).

Since there are still numerous unaffected streams in Latvia, knowledge of the riverine vegetation in Latvia could be of regional importance on a European scale; for example, Baatrup-Pedersen et al. (2008) found a high similarity of species-based predictions in Denmark before intensive land use started there around 1900 with vegetation in Latvian and Lithuanian streams.

The aim of the study was to examine the role of different environmental factors in the formation of macrophyte vegetation in middle-sized lowland streams in Latvia, focusing on the importance of flow velocity and substrate type of streams. The objectives were to investigate the macrophyte vegetation at 131 stream sites throughout the country, and to supplement each survey with a description of environmental factors (substrate type, flow velocity, shading, stream width, and water depth).

MATERIAL AND METHODS

Study area

The study area covers the whole territory of Latvia. There is a dense network of streams in Latvia. The total number of streams is up to 12 500, of which only 17 exceed 100 km (Klavins et al., 1999). The streams are classified as lowland streams with averagely low flow velocities and modest hydrological variability. However, spring flow velocities may be high and summer velocities low. Streams are running through Quaternary sediments containing predominantly calcareous material, therefore in most cases the waters in streams in Latvia are highly alkaline.

In this study, middle-sized (catchment area 100–1000 km^2) lowland streams according to the system A typology (European Commission, 2000) were studied. Vegetation and environmental variables were investigated at 131 stream sites (Fig. 1). Sampling sites were selected in stretches typical for the particular stream. The sites were selected on topographical maps (1 : 50 000) beforehand. According to the typology of streams in Latvia, the stream sites selected represent potamal and rithral stream types.

For each survey site data on the catchment area and altitude were obtained using the SIA Envirotech ArcGIS database.

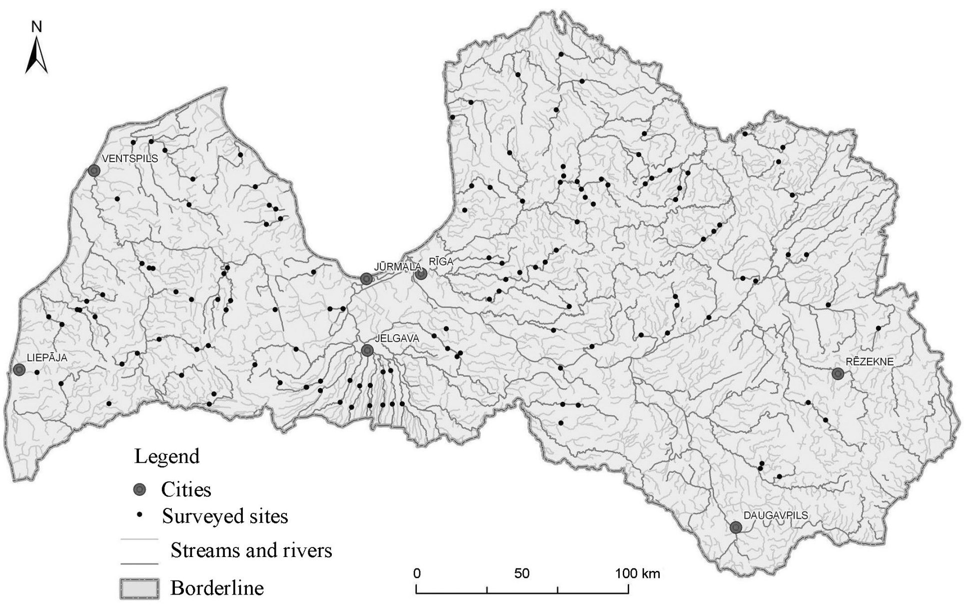

Fig. 1. Map of Latvia showing the distribution of survey sites.

Survey sites and macrophyte sampling

A field survey of aquatic macrophytes was performed in summers 2007–2009 during the vegetation period (25 June to 15 September). Sites were chosen to be representative for the characteristic conditions (stream velocity, substrate material, stream width, water depth) of the particular stream in the selected stretch. All regions of Latvia and all classes of stream ecological quality were included.

For macrophyte surveys a methodology developed for the STAR Standardization of River Classification project (Furse et al., 2006) was used because of the lack of standardized national methods. Sampling and sample processing were done according to the STAR protocols (Dawson, 2002).

The presence of macrophyte species in the selected stream stretch (100 m) was recorded together with their percentage cover using a nine-point scale according to the standard MTR methodology (Holmes et al., 1999). The study area was observed by wading over the whole stream bed or from the banks (mostly from both sides) in deeper streams, where a rake with a long handle was used for taking plants from the water. The macrophyte assessment was based on the presence and cover of submerged, emergent, floating-leaved, and free-floating vascular plants, bryophytes, and charophytes (Grinberga, 2010).

Flow velocity was estimated by following a four-grade scale: fast flow (>0.4 m/s), medium fast flow (0.2–0.4 m/s), slow flow (<0.2 m/s), no perceptible flow.

The sediment types were classified as follows: stones and boulders (>64 mm), gravel (2–64 mm), sand (0.06–2 mm), fine silt. Water depth was divided into four classes: 1 = <0.25 m; 2 = 0.25–0.5 m; 3 = 0.5–1 m; 4 = >1 m.

A five-point scale was used for the estimation of the stream width: 1 = <1 m, 2 = 1–5 m; 3 = 5–10 m; 4 = 10–20 m; 5 = >20 m, and a three-point scale for the estimation of the extent of the shading of the water surface: 1 = no shading over the water, 2 = shading present (<33%), 3 = shading extensive (>33%).

Data analysis

Relationships among environmental and vegetation variables were evaluated by Pearson correlation coefficients calculated by SPSS 12.0.1. (SPSS Inc., 2000). Analysis of Variance (ANOVA) was applied using SPSS to test differences between the cover of macrophytes and the number of taxa in five stream groups. The relationships between macrophyte species and environmental factors were performed with the program CANOCO (Lepš & Šmilauer, 2003) using Canonical Correspondence Analysis (CCA).

RESULTS

A total of 58 macrophyte taxa were found in the streams (Appendix). The most common macrophytes in all investigated streams were *Nuphar lutea*, found in 60% of all sites, followed by *Sparganium emersum* (59%), *S. erectum* s.l. (49%), *Phalaris arundinacea* (48%), *Alisma plantago-aquatica* (42%), *Fontinalis antipyretica* (36%), *Lemna minor* (35%), and *Elodea canadensis* (33%). The species richness ranged from 1 to 22 species per site.

Of all investigated sites 11% were fast-flowing streams, 40% medium fast, and 39% slow flowing. No perceptible flow was found in 10% of the sites.

The dominating sediment type in streams was gravel (55% of the sites). For gravelly streams a typical feature was presence of stones. No streams where stones and boulders dominated in the substrate composition were found. Sandy streams accounted for 29% and silty streams for 16% of the investigated streams. The greatest part of medium-sized streams were 0.5–1 m (52%) and 0.25–0.5 m (34%) deep. Very shallow streams (<0.25 m) made up 6%, and deep ones (>1 m) 8% of the selected streams.

The stream width varied from 1 to 20 m. Only one stream was very narrow (<1 m), while 24% of the investigated streams were 1–5 m, 61% 5–10 m, and 15% 10–20 m wide.

Shading is present in long stretches of medium-sized streams in Latvia. In spite of efforts to find unshaded investigation sites there was no shading over the water only in 23% of the sites, while extensive shading occurred in 22% of the cases, and sites with shading present made up 55%.

CCA analysis revealed that the growth of macrophyte species in the investigated streams was most strongly dependent on the catchment area, altitude, and current velocity gradient (Fig. 2). The catchment area was most strongly related to species characteristic for deeper and larger streams, e.g. *Potamogeton natans*, *P. pectinatus*, *Nymphaea candida*, and others. Altitude was related to species mostly distributed in small, shallow streams, e.g. *Callitriche* sp., *Veronica beccabunga*, *Potamogeton berchtoldii*, and others.

On the basis of flow and substrate conditions five major groups of streams were distinguished representing mutually different macrophyte communities: (1) fast-flowing streams on gravelly substrate, (2) slow-flowing streams on gravelly substrate, (3) fast-flowing streams on sandy substrate, (4) slow-flowing streams on sandy substrate, and (5) slow-flowing streams with soft, silty substrate.

The number of investigated stream sites in each group varied from 18 to 37 (Table 1). The mean species richness and mean macrophyte cover in a stream were the highest in Group 2, followed by Group 1 (Table 1).

For each group of streams five most common species are given in Table 2. The vegetation in Group 1 was dominated by *Fontinalis antipyretica* (78% of the sites), *Nuphar lutea* (70%), and *Sparganium emersum* (70%). In Group 2, *Nuphar lutea* (66% of the sites), *Sparganium emersum* (55%), *Sparganium erectum* s.l. (53%), and *Lemna minor* (50%) were present in at least 50% of the sites. In the fast-flowing sandy streams (Group 3) only *Sparganium emersum* (94%) occurred in high abundance. The macrophytes in Group 4 were dominated by *Phalaris arundinacea* and *Sparganium erectum* s.l. (78% and 72% of the sites, respectively).

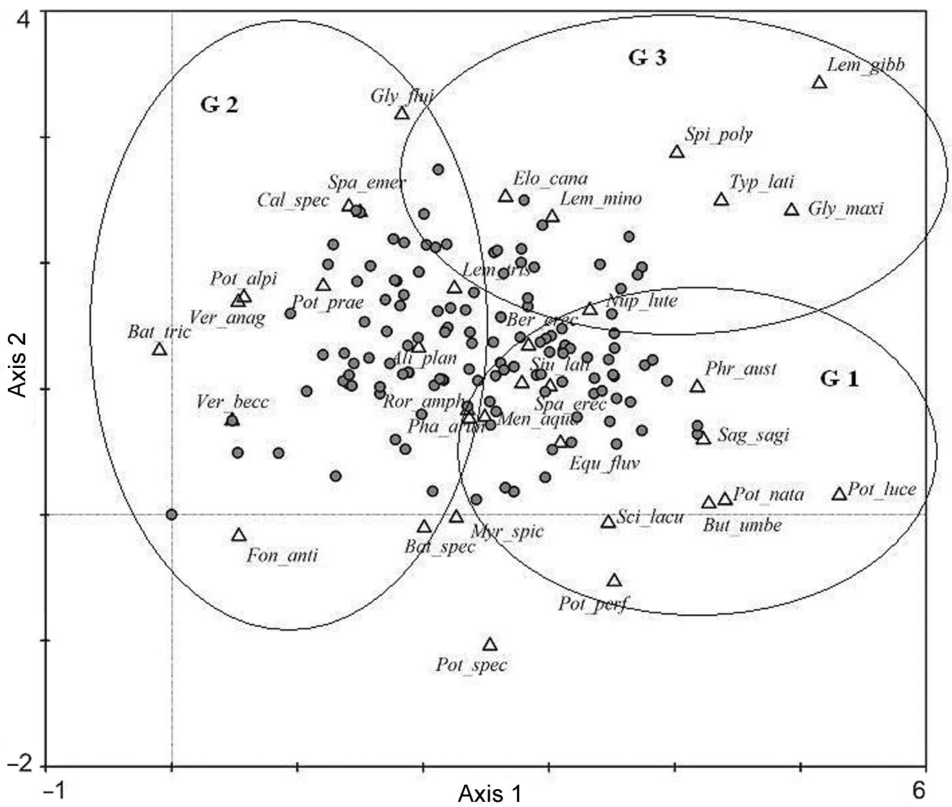

Fig. 2. CCA ordination diagram of macrophyte species and environmental variables in the investigated streams. For abbreviations of the taxa see Appendix.

In Group 5 the dominant species was *Nuphar lutea*, which was present in 86% of the sites. In both Group 4 and Group 5 *Nuphar lutea*, *Sparganium erectum* s.l., and *S. emersum* occurred in at least 50% of all sites.

There was a significant correlation between most of the environmental variables and the number of macrophyte taxa (Table 3). Stream depth was positively correlated with substrate and stream width. Stream velocity was negatively correlated with catchment area. Analyses showed positive correlations between number of taxa and stream width and catchment area, while number of taxa and macrophyte cover negatively correlated with shading and altitude. Both number of taxa and macrophyte cover negatively correlated with substrate.

ANOVA did not reveal statistically significant difference between the number of taxa in stream groups ($F = 1.5$; $p = 0.14 > 0.05$) and between macrophyte cover and stream groups ($F = 1.13$; $p = 0.33 > 0.05$). The greatest number of macrophyte taxa (Fig. 3) was found in streams of Group 2 followed by Group 1, while Group 3 and Group 5 were characterized by a low species number (Fig. 3).

Table 1. The frequency of aquatic macrophytes in stream groups (*n* = number of stream sites), total and mean number of taxa in a group, and mean macrophyte cover (%) of the stream groups

	Group 1 (*n* = 37)	Group 2 (*n* = 36)	Group 3 (*n* = 18)	Group 4 (*n* = 18)	Group 5 (*n* = 22)
Total number of taxa*	44	46	26	36	32
Mean number of taxa	10	8	3.4	4.4	4.5
Mean cover, %	42	53	12	37	32
Species					
Acorus calamus	4	1	–	–	–
Alisma plantago-aquatica	24	15	7	9	8
Amblystegium riparium	–	3	–	–	–
Batrachium sp.	13	6	1	2	1
Batrachium trichophyllum	–	1	1	–	–
Berula erecta	6	3	–	1	1
Butomus umbellatus	8	10	–	5	2
Callitriche sp.	9	6	3	4	2
Chara contraria	1	1	–	1	–
Chara globularis	3	4	–	2	–
Chara sp.	1	2	–	–	–
Cicuta virosa	4	–	–	–	–
Elodea canadensis	10	17	7	7	7
Equisetum fluviatile	5	7	1	2	2
Fontinalis antipyretica	29	14	5	4	–
Glyceria fluitans	9	4	2	1	1
Glyceria maxima	2	5	–	1	2
Hippuris vulgaris	2	4	–	2	–
Hydrocharis morsus-ranae	2	1	–	–	–
Iris pseudacorus	3	6	–	3	3
Lemna gibba	1	6	–	–	–
Lemna minor	19	18	2	7	8
Lemna trisulca	9	9	2	5	2
Mentha aquatica	16	14	3	5	3
Myriophyllum spicatum	6	4	–	–	2
Nuphar lutea	26	24	4	12	19
Phalaris arundinacea	21	15	6	14	9
Phragmites australis	10	7	3	5	8
Potamogeton alpinus	11	6	1	4	1
Potamogeton berchtoldii	–	2	–	–	1
Potamogeton crispus	1	–	–	1	–
Potamogeton gramineus	1	1	1	–	–
Potamogeton lucens	3	4	–	2	3
Potamogeton natans	4	1	–	2	2
Potamogeton perfoliatus	11	8	1	1	2
Potamogeton praelongus	6	2	1	2	–
Potamogeton sp.	6	2	–	2	–
Rorippa amphibia	13	7	1	2	3
Sagittaria sagittifolia	13	14	2	5	6
Scirpus lacustris	17	13	–	1	2
Sium latifolium	15	13	2	6	5
Sparganium emersum	26	20	17	10	11
Sparganium erectum s.l.	22	19	4	13	13
Spirodela polyrhiza	7	9	1	2	7
Typha latifolia	2	5	–	–	3
Utricularia vulgaris	–	2	–	–	–
Veronica anagallis-aquatica	7	10	2	6	1
Veronica beccabunga	20	7	6	6	4

* Excluding species found only in one site.
– Not found.

Table 2. The most common species (% of all sites) in stream groups

Taxon	%	Taxon	%
Group 1		Group 4	
Fontinalis antipyretica	78	*Phalaris arundinacea*	78
Nuphar lutea	70	*Sparganium erectum*	72
Sparganium emersum	70	*Nuphar lutea*	67
Alisma plantago-aquatica	65	*Sparganium emersum*	56
Sparganium erectum	60	*Alisma plantago-aquatica*	50
Group 2		Group 5	
Nuphar lutea	66	*Nuphar lutea*	86
Sparganium emersum	55	*Sparganium erectum*	59
Sparganium erectum	53	*Sparganium emersum*	50
Lemna minor	50	*Phalaris arundinacea*	41
Elodea canadensis	47	*Lemna minor*	36
Group 3			
Sparganium emersum	94		
Alisma plantago-aquatica	41		
Elodea canadensis	41		
Phalaris arundinacea	33		
Veronica beccabunga	33		

The greatest range of macrophyte cover was associated with Group 2, followed by groups 1 and 4 (Table 1). Group 3 had a very low macrophyte cover. Differences between values of Group 3 and Group 4 (both with sandy substrate), as well as Group 1 and Group 2 (both with gravelly substrate) indicate that stream velocity plays a crucial role in the formation of macrophyte vegetation in streams.

Alisma plantago-aquatica, *Elodea canadensis*, *Nuphar lutea*, *Sparganium emersum*, and *S. erectum* s.l. were detected in all groups of streams, which indicates their flow resistance and indifference to many environmental factors.

Fontinalis antipyretica was dominating and common in both fast- and slow-flowing streams on gravelly substrate (found in 78% and 39% of the stretches, respectively). However, it was infrequently present also in streams dominated by silty substrate, where it grew on boulders and decaying trees fallen into water.

The free-floating macrophyte species such as *Lemna minor*, *L. gibba*, *L. trisulca*, and *Spirodela polyrhiza* were limited by stream velocity. They reached their highest abundances in slow-flowing streams with sandy and soft, silty substrate.

The macrophyte composition in streams on sandy substrate significantly differed from the other sites. In fast-flowing streams on sandy substrate (Group 3) the macrophyte composition was species poor, with a sparse cover (Table 1).

Table 3. Pearson linear correlation coefficients among number of taxa, macrophyte cover, and environmental parameters

	Substrate	Stream velocity	Stream depth	Stream width	Shading	Catchment area	Altitude	Macrophyte cover
Substrate	1							
Stream velocity	0.232**	1						
Stream depth	0.475**	n.s.	1					
Stream width	n.s.	n.s.	0.297**	1				
Shading	n.s.	n.s.	n.s.	n.s.	1			
Catchment area	n.s.	−0.260**	n.s.	0.494**	n.s.	1		
Altitude	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	1	
Macrophyte cover	−0.312**	n.s.	n.s.	n.s.	−0.446**	n.s.	−0.382**	1
Number of taxa	−0.339**	n.s.	n.s.	0.251**	−0.294**	0.234**	−0.281**	0.628**

** $p < 0.01$; n.s. – not significant.

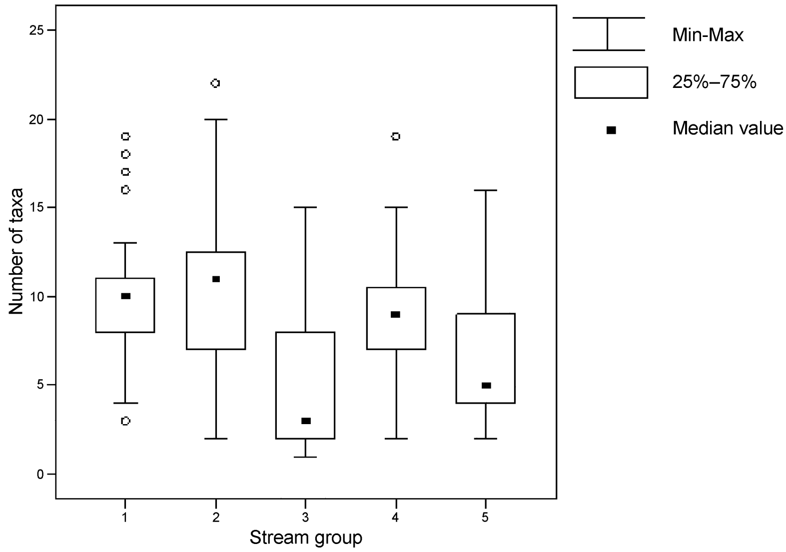

Fig. 3. Boxplots of the number of macrophyte taxa plotted against the stream groups.

DISCUSSION

In numerous studies it is found that there is not a single and most significant factor explaining the spatial patterns and composition of macrophyte communities. Several researchers have concluded that each individual species shows its own preferences for environmental factors (e.g., Madsen et al., 2001; Barendregt & Bio, 2003; Haslam, 2006). Willby et al. (2000) concluded that plant morphology is closely related to environmental factors in streams. Therefore, there is a necessity to increase the knowledge of stream vegetation, particularly of reference vegetation related to bioindication systems (Daniel et al., 2006).

The results of the present study in medium-sized streams in Latvia revealed that one of the most important factors affecting macrophytes was shading. This finding agrees with the conclusions of other investigations (e.g., Barko et al., 1986; Canfield & Hoyer, 1988; Trei & Paal, 2004). Despite efforts to choose less shaded stretches of streams, finding unshaded stretches was not possible in several streams (22% of the investigated stretches) due to natural site conditions.

Substrate type is another crucial factor influencing the number of species and macropophyte cover. Substrate stability is a significant controlling factor, because a stable substrate allows rooting and establishment of macrophyte communities (Riis & Biggs, 2003; Haslam, 2006). Substrate appeared to be the most important measured environmental variable distinguishing plant communities in Danish lowland streams (Baatrup-Pedersen et al., 2003). Bottom substrate was also found to be the most important common parameter discriminating the habitat types of several drainage basins in Estonia (Paal et al., 2007). In medium-sized streams in Latvia the frequency of submerged macrophytes was higher in streams with gravelly substrate where the water depths varied from 0.25 to 0.5 m.

In summer no large differences in current velocities in medium-sized streams of Latvia were found. The velocity was approximately up to 0.5 m/s, which is the optimal velocity for macrophyte growth. Current velocity had a stronger impact on vegetation in sandy streams because sand particles are more easily eroded, whereas larger particles require faster currents to initiate movement.

Stream stretches with low water velocity offer lake-like conditions, where other factors, e.g. water chemistry and light availability, might be more responsible for determining macrophyte diversity than current velocity and substrate type. Group 5, characterized by slow stream and soft, silty substrate, displayed a low diversity of macrophytes and their growth forms, where floating-leaved and free-floating macrophytes were frequent.

In sandy streams mosaic patches of *Sparganium emersum* and *Elodea canadensis* dominated, sparsely accompanied by *Veronica beccabunga* and emergent plants on the littoral. In such streams the species composition and abundance varied among different years, because the habitats were strongly modified by spring floods. This agrees with the experience of Bornette et al. (1994) and Riis et al. (2000), who found that in sandy streams the richness and diversity of aquatic vegetation are lower than in gravelly streams.

Sparganium emersum was the most common species in study sites growing in all groups of streams. It is deeply rooted and tolerant against disturbance (Preston & Croft, 2001), and therefore frequently occurred in fast-flowing sandy streams, where the growth of other species is limited by mobile substrate.

In Latvia no assessment system for stream macrophytes has been developed yet. Insufficient data on the macrophyte vegetation and its species composition in Latvian streams hinders both establishment of a suitable assessment system and implementation of a proper assessment. Results of studies in other countries suggest that a reliable bioindication system for water quality requires characterization of the relationships between the physical features of the river and its macrophytic vegetation (Daniel et al., 2006).

If a certain quantity of plants is not found in a stream, assessment of the water quality of this stream is impossible. In that case, the macrophyte component must be excluded from the classification of the entire quality element (Schaumburg et al., 2004). Results of this study indicate that in fast-flowing sandy streams in Latvia, macrophytes are not a suitable component of methods for quality assessment. It partially corresponds to the results by the Estonian researchers who found that it is rather doubtful to develop a reliable sample or system of indicator species for European oligo-mesotrophic to meso-eutrophic lowland water courses rendering evaluation of general water parameters of habitat characteristics (Paal et al., 2007).

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APPENDIX

MACROPHYTE TAXA WITH ABBREVIATIONS FOR CCA ANALYSES

Taxon*	Abbreviation
Acorus calamus L.	*Aco_cala*
Alisma plantago-aquatica L.	*Ali_plan*
Amblystegium riparium (Hedw.) B., S. et G.	*Amb_ripa*
Batrachium circinatum (Sibth.) Spach	*Bat_circ*
Batrachium sp.	*Bat_spec*
Batrachium trichophyllum (Chaix) Bosch	*Bat_tric*
Berula erecta (Huds.) Coville	*Ber_erec*
Butomus umbellatus L.	*But_umbe*
Callitriche cophocarpa Sendtn.	*Cal_coph*
Callitriche sp.	*Cal_spec*
Callitriche stagnalis Scop.	*Cal_stag*
Chara contraria A. Braun ex Kütz	*Cha_cont*
Chara globularis Thuill.	*Cha_glob*
Chara sp.	*Cha_glob*
Cicuta virosa L.	*Cic_viro*
Elodea canadensis Michx.	*Elo_cana*
Equisetum fluviatile L.	*Equ_fluv*
Fontinalis antipyretica Hedw.	*Fon_anti*
Glyceria fluitans (L.) R. Br.	*Gly_flui*
Glyceria maxima (Hartm.) Holmb.	*Gly_maxi*
Hippuris vulgaris L.	*Hip_vulg*
Hottonia palustris L.	*Hot_palu*
Hydrocharis morsus-ranae L.	*Hyd_mors*
Iris pseudacorus L.	*Iri_pseu*
Lemna gibba L.	*Lem_gibb*
Lemna minor L.	*Lem_mino*
Lemna trisulca L.	*Lem_tris*
Mentha aquatica L.	*Men_aqua*
Myriophyllum spicatum L.	*Myr_spic*
Nuphar lutea (L.) Sm.	*Nup_lute*
Nymphaea candida C. Presl.	*Nym_cand*
Nymphaea sp.	*Nym_spec*
Phalaris arundinacea L.	*Pha_arun*
Phragmites australis (Cav.) Trin. ex Steud.	*Phr_aust*
Potamogeton alpinus Balb.	*Pot_alpi*
Potamogeton berchtoldii Fieber	*Pot_berc*
Potamogeton crispus L.	*Pot_cris*
Potamogeton gramineus L.	*Pot_gram*

Continued overleaf

APPENDIX. *Continued*

Taxon*	Abbreviation
Potamogeton lucens L.	*Pot_luce*
Potamogeton natans L.	*Pot_nata*
Potamogeton pectinatus L.	*Pot_pect*
Potamogeton perfoliatus L.	*Pot_perf*
Potamogeton praelongus Wulfen	*Pot_prae*
Potamogeton sp.	*Pot_spec*
Rorippa amphibia (L.) Besser	*Ror_amph*
Sagittaria sagittifolia L.	*Sag_sagi*
Scirpus lacustris L.	*Sci_lacu*
Sium latifolium L.	*Siu_lati*
Sparganium emersum Rehmann	*Spa_emer*
Sparganium erectum s.l. L.	*Spa_erec*
Sparganium minimum Wallr.	*Spa_mini*
Sparganium sp.	*Spa_spec*
Spirodela polyrhiza (L.) Schleid.	*Spi_poly*
Typha latifolia L.	*Typ_lati*
Utricularia sp.	*Utr_spec*
Utricularia vulgaris L.	*Utr_vulg*
Veronica anagallis-aquatica L.	*Ver_anag*
Veronica beccabunga L.	*Ver_becc*

* According to Gavrilova & Šulcs, 1999; Āboliņa, 2001; Zviedre, 2007.

REFERENCES

Āboliņa, A. 2001. List of Latvian bryophyte species. *Vegetation of Latvia*, **3**, 47–87 (in Latvian).

Abou-Hamdan, H., Haury, J., Hebrard, J.-P., Dandelot, S. & Cazaubon, A. 2005. Macrophytic communities inhabiting the Huveaune (South-East France), a river subject to natural and anthropic disturbances. *Hydrobiologia*, **551**, 161–170.

Baatrup-Pedersen, A. & Riis, T. 1999. Macrophyte diversity and composition in relation to substratum characteristics in regulated and unregulated Danish streams. *Freshwater Biol.*, **42**, 375–385.

Baatrup-Pedersen, A., Larsen, S. E. & Riis, T. 2003. Composition and richness of macrophyte communities in small Danish streams – influence of environmental factors and weed cutting. *Hydrobiologia*, **495**, 171–179.

Baatrup-Pedersen, A., Springe, G., Riis, T., Larsen, S. E., Sand-Jensen, K. & Kjellerup Larsen, L. M. 2008. The search for reference conditions for stream vegetation in northern Europe. *Freshwater Biol.*, **53**, 1890–1901.

Barendregt, A. & Bio A. M. F. 2003. Relevant variables to predict macrophyte communities in running waters. *Ecol. Model.*, **160**, 205–217.

Barko, J. W., Adams, M. S. & Clesceri, N. L. 1986. Environmental factors and their consideration in the management of submerged aquatic vegetation: a review. *J. Aquat. Plant Manage.*, **24**, 1–10.

Best, E. P. H. 1995. The impact of mechanical harvesting regimes on the aquatic and shore vegetation in water courses of agricultural areas of the Netherlands. *Vegetatio*, **112**, 57–71.

Bornette, G., Henry, C., Barrat, M. H. & Amoros, C. 1994. Theoretical habitat templet, species traits and species richness: aquatic macrophytes in the Upper Rhône River and its floodplain. *Freshwater Biol.*, **31**, 487–505.

Canfield, D. E. J. & Hoyer, M. V. 1988. Influence of nutrient enrichment and light availability on the abundance of aquatic macrophytes in Florida streams. *Can. J. Fish. Aquat. Sci.*, **45**, 1467–1472.

Chambers, P. A., Prepas, E. E., Hamilton, H. R. & Bothwell, M. L. 1991. Current velocity and its effect on aquatic macrophytes in flowing waters. *Ecol. Appl.*, **1**, 249–257.

Clarke, S. J. 2002. Vegetation growth in rivers: influences upon sediment and nutrient dynamics. *Prog. Phys. Geogr.*, **26**(2), 159–172.

Daniel, H., Bernez, I. & Haury, J. 2006. Relationships between macrophytic vegetation and physical features of river habitats: the need for a morphological approach. *Hydrobiologia*, **570**, 11–17.

Dawson, F. H. 2002. Guidance for the field assessment of macrophytes of rivers within the STAR Project. http://www.eu-star.at/frameset.htm (visited 09-10-2010).

Dawson, F. H. & Szoszkiewicz, K. 1999. Relationships of some ecological factors with the associations of vegetation in British rivers. *Hydrobiologia*, **415**, 117–122.

Demars, B. O. L. & Harper, D. M. 2005. Distribution of aquatic vascular plants in lowland rivers: separating the effects of local environmental conditions, longitudinal connectivity and river basin isolation. *Freswater Biol.*, **50**, 418–437.

European Commission. 2000. *Directive 2000/60/EC. Establishing a Framework for Community Action in the Field of Water Policy. European Commission PE-CONS 3639/1/100 Rev. 1.* Luxembourg.

Franklin, P., Dunbar, M. & Whitehead, P. 2008. Flow controls on lowland river macrophytes: a review. *Sci. Total Environ.*, **400**(1–3), 369–378.

Furse, M., Hering, D., Moog, O., Verdonschot, P., Johnson, R., Brabec, K., Gritzalis, K., Buffagni, A., Pinto, P., Friberg, N., Murray-Bligh, J., Kokes, J., Alber, R., Usseglio-Polatera, P., Haase, P., Sweeting, R., Bis, B., Szoszkiewicz, K., Soszka, H., Springe, G., Sporka, F. & Krno, I. 2006. The STAR project: context, objectives and approaches. *Hydrobiologia*, **566**, 3–29.

Gavrilova, G. & Šulcs, V. 1999. *Flora of Latvian Vascular Plants. List of Taxa*. Institute of Biology of University of Latvia, Laboratory of Botany, Riga.

Grinberga, L. 2010. Environmental factors influencing the species diversity of macrophytes in middle-sized streams in Latvia. *Hydrobiologia*, **656**, 233–241.

Haslam, S. M. 2006. *River Plants. The Macrophytic Vegetation of Watercourses*. 2nd revised edn. Forrest Text, Cardigan.

Holmes, N. T. H. 1983. *Typing British Rivers According to Their Flora*. Focus on Nature Conservation, **4**. Nature Conservancy Council, Peterborough.

Holmes, N. T. H., Newman, J. R., Chadd, S., Rouen, K. J., Saint, L. & Dawson, F. H. 1999. *Mean Trophic Rank: A User's Manual*. R&D Technical Report E38. Environment Agency of England & Wales, Bristol, UK.

Klavins, M., Rodinov, V., Kokorite, I. & Klavina, I. 1999. Chemical composition of surface waters of Latvia and runoff of dissolved substances from the territory of Latvia. *Vatten*, **55**, 97–108.

Lepš, J. & Šmilauer, P. 2003. *Multivariate Analysis of Ecological Data Using CANOCO*. Cambridge, Cambridge University Press.

Madsen, J. D., Chambers, P. A., James, W. F., Koch, E. W. & Westlake, D. F. 2001. The interaction between water movement, sediment dynamics and submersed macrophytes. *Hydrobiologia*, **444**, 71–84.

Nilsson, C. 1987. Distribution of stream-edge vegetation along a gradient of current velocity. *J. Ecol.*, **5**, 513–522.

Paal, J., Trei, T. & Viik, M. 2007. Vegetation of Estonian watercourses, III. Drainage basins of the Moonsund Sea, the Gulf of Riga and Saaremaa Island. *Ann. Bot. Fenn.*, **44**, 321–344.

Preston, C. D. & Croft, J. M. 2001. *Aquatic Plants in Britain and Ireland*. Harley Books, Martins, Great Horkesley, Colchester, England.

Riis, T. & Biggs, B. J. F. 2003. Hydrologic and hydraulic control of macrophyte establishment and performance in streams. *Limnol. Oceanogr.*, **48**, 1488–1497.

Riis, T., Sand-Jensen, K. & Vestergaard, O. 2000. Plant communities in lowland Danish streams: species composition and environmental factors. *Aquat. Bot.*, **66**, 255–272.

Sand-Jensen, K., Jeppesen, E., Nielsen, K., van der Bijl, L., Hjermind, L., Nielsen, L. W. & Iversen, T. M. 1989. Growth of macrophytes and ecosystem consequences in a lowland Danish stream. *Freshwater Biol.*, **22**, 15–32.

Schaumburg, J., Schranz, C., Foerster, J., Gutowski, A., Hofmann, G., Meilinger, P., Schneider, S. & Schmedtje, U. 2004. Ecological classification of macrophytes and phytobenthos for rivers in Germany according to the Water Framework Directive. *Limnologica*, **34**, 283–301.

SPSS Inc. 2000. *Systat for Windows, Version 10*. SPSS Inc., Chicago, IL, USA.

Trei, T. & Paal, P. 2004. Macroflora in the watercourses of Saaremaa Island (Estonia). *Boreal Environ. Res.*, **9**, 25–35.

Westlake, D. F. 1967. Some effects of low-velocity currents on the metabolism of aquatic macrophytes. *J. Exp. Bot.*, **18**, 187–205.

Willby, N. J., Abernethy, V. J. & Demars, B. O. L. 2000. Attribute-based classification of European hydrophytes and its relationship to habitat utilization. *Freshwater Biol.*, **43**, 43–74.

Zviedre, E. 2007. Genus *Chara* L. in Latvia – freshwater species and their identification. *Acta Biologica Universitatis Daugavpiliensis*, **7**(2), 139–147.

Makrofüütide liigiline koosseis Läti vooluvetes erineva voolukiiruse ja substraadi tingimustes

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Uuriti makrofüütide liigilist koosseisu Läti keskmise suurusega vooluvetes erineva voolukiiruse ja substraadi tingimustes. Määrati makrofüütide esinemissagedus 131 jõelõigus. Iga vaatluse juurde kuulus ka keskkonnatingimuste kirjeldus (substraadi tüüp, voolukiirus, varjutatus, jõelõigu laius ja vee sügavus). Voolukiiruse ja substraadi alusel eristati viis vooluvete rühma, kus oli erinev makrofüütide kooslus: 1) kiirevoolulised jõelõigud kruusasel pinnal, 2) aeglasevoolulised jõelõigud kruusasel pinnal, 3) kiirevoolulised jõelõigud liivasel pinnal, 4) aeglasevoolulised jõelõigud liivasel pinnal ning 5) mudastunud põhjaga jõelõigud. Botaaniliste kirjelduste käigus leiti kokku 58 taksonit, millest kõige sagedasem oli *Nuphar lutea*, mis esines 60%-s kõikidest jõelõikudest. Järgnesid *Sparganium emersum*, *S. erectum* s.l., *Phalaris arundinacea*, *Alisma plantago-aquatica* ja *Lemna minor*. Liikide arv jõelõigus varieerus ühest kuni 22-ni; kõige liigirikkamad olid aeglase vooluga kruusased jõelõigud, liigivaesed aga kiire vooluga liivasel pinnal olevad. CCA-analüüs näitas, et makrofüütide kasv sõltub eelkõige valgala suurusest, jõelõigu kõrgusest merepinnast ja voolukiiruse gradiendist. Analüüs näitas ka korrelatsiooni taksonite arvu ja jõelõigu laiuse ning valgala suurusega. Taksonite arv korreleerus ka negatiivselt varjutatuse ja kõrgusega merepinnast. Nii taksonite arv kui ka makrofüütide katvus korreleerusid substraadiga.