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ENVIRONMENTAL FACTORS INFLUENCING THE VEGETATION IN MIDDLE-SIZED STREAMS IN LATVIA

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Abstract - In this study the species diversity and distribution of macrophytes in 131 surveyed sites of middle-sized streams of Latvia were investigated. The aim of the study was to determine the composition of macrophyte vegetation in Latvian streams in relation to the environmental factors (stream width, water depth, substrate type, shading and flow velocity). On the basis of these factors, five major groups of streams were distinguished representing mutually different typical macrophyte communities – (1) fast flowing streams on gravelly and stony substrate, (2) slow flowing streams on gravelly and stony substrate, (3) fast flowing streams on sandy substrate, (4) slow flowing streams on sandy substrate, and (5) streams with soft, silty substrate.
Totally, 47 macrophyte taxa were found in the streams. The most common macrophyte species were *Nuphar lutea* found in 65% of all sites, followed by *Sparganium emersum* (64%), *S. erectum* s.l. (48%), *Phalaris arundinacea* (50%), *Alisma plantago-aquatica* (54%) and *Lemna minor* (41%). The highest species richness (22) was found in slow flowing streams with gravelly substrate. Species-poor macrophyte communities were characteristic for fast flowing streams on sandy substrate.

Key words: environmental factors, macrophytes, middle-sized streams, Latvia

Introduction

Aquatic macrophytes are an important part of riverine ecosystems as a source of organic material for biota, a habitat and an influence on physical stream structure (Marshall & Westlake, 1978). In many lowland streams macrophyte vegetation may be abundant and reach high levels of biomass during the growing season (Clarke, 2002).

Hydrological conditions and substrate can be major determinants for many taxa (Westlake, 1975; Haslam, 2006). The close interaction between macrophytes and their environment has enabled Holmes et al., (1998) to classify UK rivers on the basis of their flora. In running waters, vegetation is strongly influenced by current velocity (Dawson, 1988; Westlake, 1975). Numerous studies (Chambers et al., 1991; Baatrup-Pedersen et al., 2003; Riis & Biggs, 2003) have shown current velocity and substrate type has crucial role for the distribution of macrophytes.

Butcher (1933) had already observed that the chief factor governing the distribution and abundance of aquatic macrophytes in English streams was water current. Other important factors included bottom substrate and light availability.

The vegetation dynamics in streams is usually intense, because streams are naturally disturbed ecosystems, and available habitats are continuously created and destroyed by flow-induced disturbance (Riis, 2008).

With increasing concern to develop quality assessment systems for streams in Europe, data are needed for understanding the role of environmental factors influencing macrophyte diversity in streams. There is a need for studies on medium to large rivers, rivers in populated areas, to understand the importance of physical and chemical habitat characteristics on macrophyte diversity and community composition at the local scale (Makkay et al., 2008).

The increase in species richness relates to habitat characteristics. Thus, middle-sized streams are likely to be physically more heterogeneous and experience lower levels of disturbance than small-sized streams, which may promote

the co-existence of a wider array of species (Vannote et al., 1980).
In comparison to lakes, very little research has been done concerning the vegetation in streams in Latvia. Insufficient information is available on stream vegetation including a country-scale survey on the distribution of macrophyte species and their abundance in different types of streams, as well as on factors controlling macrophyte growth.
The aim of this study was to determine the composition of macrophyte vegetation in the Latvian streams in relation to environmental factors (stream width, water depth, substrate type, shading and flow velocity). The composition of the macrophyte vegetation at 131 stream sites throughout Latvia was studied in summers 2007-2009.

Material and methods

Study area

The study area covers the whole territory of Latvia. In Latvia, there is a dense network of streams. The total number of streams reaches ca. 12 500, of which only 17 exceed 100 km. The streams of Latvia are classified as lowland streams with generally low flow velocities and low hydrological variability, while the spring flows might be high and summer flows low. Streams in Latvia are running through Quaternary sediments containing predominantly calcareous material, therefore in most cases the waters in streams in Latvia are highly alkaline (Klavins et al., 1999).
Following the System A typology of the Water Framework Directive (European Commission, 2000) and according to the size of the catchment area (100-1000 km^2), 174 streams are classified as middle-sized from which 85 were selected for this study. Vegetation and environmental variables were investigated at 131 stream sites. Sampling sites were selected in stretches typical for the particular stream, the sites were selected on topographical maps (1: 50 000) beforehand. The stream sites chosen were distributed throughout Latvia, and, according to the typology of streams in Latvia, they represent potamal and rithral stream types.

Survey sites and macrophyte sampling

A field survey of aquatic macrophytes was performed in summers 2007-2009 during the vegetation period (25th June to 15th 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 (Figure 1).

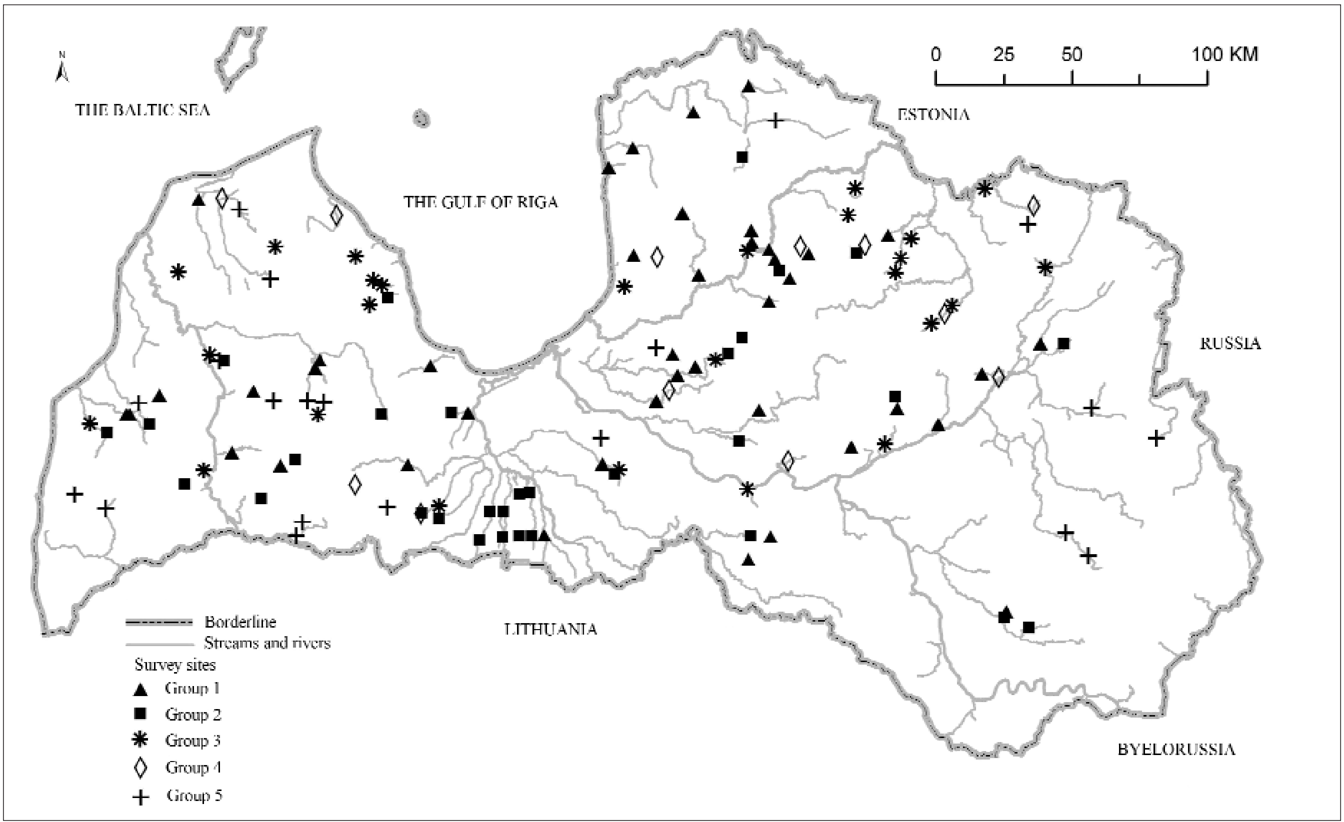

Figure 1. Distribution of the surveyed sites using different symbols for the five stream habitat types

Due to the lack of a standardized national method for macrophyte surveys a method developed for the STAR Standardization of River Classification project (Furse et al., 2006) was used. Sampling and sample processing was 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 nine-point scale according to standard MTR methodology (Holmes et al., 1999). Study area was observed by wading through the whole stream bed or from the banks (mostly both sides) in deeper streams, where a rake with a long handle was used for taking plants from the water. All taxa were identified by the surveyor except for samples of Characeae, which were identified by Egita Zviedre (Natural History Museum of Latvia), a specialist of this group. Taxonomy and nomenclature follows Gavrilova & Sulcs (1999) and Abolina (2001). *Sparganium erectum* was treated collectively as *sensu lato* (s.l.). Collected vascular plants and charophytes were deposited in the Natural History Museum of Latvia (LDM) (Charophyta), and the vascular plants and bryophytes in the herbarium of Institute of Biology, University of Latvia (LATV).
The macrophyte assessment was based on the presence and cover of submerged, emergent, floating-leaved, free-floating vascular plants, bryophytes and charophytes.
Stream velocity was estimated by following a four-grade scale: fast flowing (>0.2 m/s), medium fast (0.2-0.1 m/s), slow flowing (<0.1 m/s), no perceptible flow.
Bed stability was characterized into four classes: solid, stable, unstable and soft.
The sediment type 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 = >1m.
A five-point scale was used for estimation of the stream width: 1 = < 1 m, 2 = 1-5 m; 3 = 5-10 m; 4 = 10-20 m; 5 = >20 m, and three-point scale for estimation of the extent of 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). The Shannon index was calculated using the computer software PC-ORD (McCune & Mefford, 1999).

Results

The most common macrophytes in all investigated streams were *Nuphar lutea* found in 65% of all sites, followed by *Sparganium emersum* (64%), *S. erectum* s.l. (48%), *Phalaris arundinacea* (50%), *Alisma plantago-aquatica* (54%) and *Lemna minor* (41%). The species richness ranged from 1 to 22 species per site.
The stream stretches studied were grouped into five groups with different stream velocity and substrates: (1) fast flowing streams on gravelly and stony substrate, (2) slow flowing streams on gravelly and stony substrate, (3) fast flowing streams on sandy substrate, (4) slow flowing streams on sandy substrate and (5) slow flowing streams with soft, silty substrate.
Alisma plantago-aquatica, Elodea canadensis, Nuphar lutea, Sparganium emersum and *S. erectum* s.l. were detected in all types of streams (Table 1), which indicate their flow-resistance and indifferent character as to many environmental factors. *Sparganium emersum* was the most common species in study sites occurring in all groups of streams.

Table 1. The frequency of aquatic macrophytes in stream groups (n = number of stream sites, *Group 1* - fast flowing streams on gravelly and stony substrate, *Group 2* - slow flowing streams on gravelly and stony substrate, *Group 3* - fast flowing streams on sandy substrate, *Group 4* - slow flowing streams on sandy substrate, *Group 5* - slow flowing streams with soft, silty substrate. The nomenclature of vascular plants follows Gavrilova, Sulcs (1999), that of bryophyte species Abolina (2001), and that of the genus *Chara* Zviedre (2007).

Species	Group 1 **(n = 37)**	Group 2 **(n = 36)**	Group 3 **(n = 18)**	Group 4 **(n = 18)**	Group 5 **(n = 22)**
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 aspera	1				
Chara contraria	1	1		1	
Chara globularis	3	4		2	
Chara sp.	1	2			

Species	Group 1 **(n = 37)**	Group 2 **(n = 36)**	Group 3 **(n = 18)**	Group 4 **(n = 18)**	Group 5 **(n = 22)**
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
Schoenoplectus 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

Vegetation distribution and abundance in each group of streams were analyzed (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%), *Lemna minor* (50%) and *Elodea canadensis* (47%) dominated, whereas in fast flowing sandy streams (Group 3) only *Sparganium emersum* (94%) and *Elodea canadensis* (41%) occurred in higher abundance. The macrophytes in Groups 4 and 5 were dominated by *Nuphar lutea, S. erectum* s.l., *Sparganium emersum, Phalaris arundinacea* and *Lemna minor*.

Fontinalis antipyretica was dominating and common in fast and slow flowing streams on gravelly and stony substrate (found accordingly in 78% and 39% of the stretches), although 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,*

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

Group 1

Taxon	%
Fontinalis antipyretica	78
Nuphar lutea	70
Sparganium emersum	70
Alisma plantago-aquatica	65
Sparganium erectum	60

Group 2

Taxon	%
Nuphar lutea	66
Sparganium emersum	55
Sparganium erectum	53
Lemna minor	50
Elodea canadensis	47

Group 3

Taxon	%
Sparganium emersum	94
Alisma plantago-aquatica	41
Elodea canadensis	41
Phalaris arundinacea	33
Veronica beccabunga	33

Group 4

Taxon	%
Phalaris arundinacea	78
Sparganium erectum	72
Nuphar lutea	67
Sparganium emersum	56
Alisma plantago-aquatica	50

Group 5

Taxon	%
Nuphar lutea	86
Sparganium erectum	59
Sparganium emersum	50
Phalaris arundinacea	41
Lemna minor	36

L. gibba, L. trisulca and *Spirodela polyrhiza* are limited by stream velocity. They reached their highest abundances in slow flowing streams with sandy and soft, silty substrate.
There was a significant correlation among most environmental variables (Table 3). Stream depth and stream width were positively correlated with fine-textured substrate, stream velocity was negatively correlated with substrate and stream depth. Analyses show positive correlation between macrophyte parameters – Shannon index, cover and number of taxa and stream width.

Table 3. Pearson linear correlation coefficients among Shannon index, vegetation cover, species number and environmental parameters.

	Shannon index	**Cover (%)**	**Number of taxa**	**Substrate**	**Stream velocity**	**Stream depth**
Shannon index	1					
Cover (%)	0,493(**)	1				
Number of taxa	0,943(**)	0,527(**)	1			
Substrate	-0,189	-0,187	-0,189	1		
Stream velocity	-0,131	-0,206	-0,129	-0,450(**)	1	
Stream depth	-0,092	-0,015	-0,094	0,504(**)	-0,240(*)	1
Stream width	0,257(*)	0,306(**)	0,275(*)	-0,340(*)	0,184	0,107

*) $p < 0.05$; **) $p < 0.01$

The macrophyte composition in streams on sandy substrates significantly differed from other sites. In more than 60% of the investigated fast flowing sandy streams only *Alisma plantago-aquatica, Elodea canadensis, Phalaris arundinacea, Sparganium emersum* and *Veronica beccabunga* were found. Sandy streams as well as streams with soft, silty substrates are characterized also by greater depths (streams with soft and silty substrate often are deeper than 1m) (Table 4) which diminish light availability in water. The light availability is restricted also by shading of stream banks, their vegetation and water turbulence, particularly in streams with soft, silty substrates. In approximately one fourth of the stretches studied, shading exceeds 33% (Table 4).
Fast flowing streams with gravelly and stony substrates are characterized by low water level that provides good conditions for macrophyte growth.

Table 4. Percentages of stream width, depth and shading for the investigated stream sites.

	Group 1 (n = 37)	**Group 2 (n = 36)**	**Group 3 (n = 18)**	**Group 4 (n = 18)**	**Group 5 (n = 22)**	**All sites (n = 131)**
Stream width (m)						
<5	14	26	22	16	14	18
5 - 10	51	57	78	68	73	63
10 - 15	22	11	0	16	9	13
15 - 20	11	6	0	0	4	5
> 20	2	0	0	0	0	0
Stream depth (m)						
<25	8	17	0	0	0	7
0.25 - 0.5	49	34	33	31	4	33
0.5 - 1	43	46	61	53	64	51
>1	0	3	6	16	32	9
Shading (%)						
0	24	26	17	26	27	25
> 33	54	54	44	53	41	50
< 33	22	20	39	21	32	25

Figure 2 displays the number of taxa and macrophyte cover (%). Greatest number of macrophyte taxa is found in streams of Group 2 and Group 1, while Group 3 and Group 5 are characterized with low species number. The greatest range of macrophyte cover is associated with Group 2, Group 1 as well as Group 4. Group 3 is associated with very low macrophyte cover, whereas Group 1 is characterized by wide range of 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 has a crucial role for forming of macrophyte vegetation in streams.

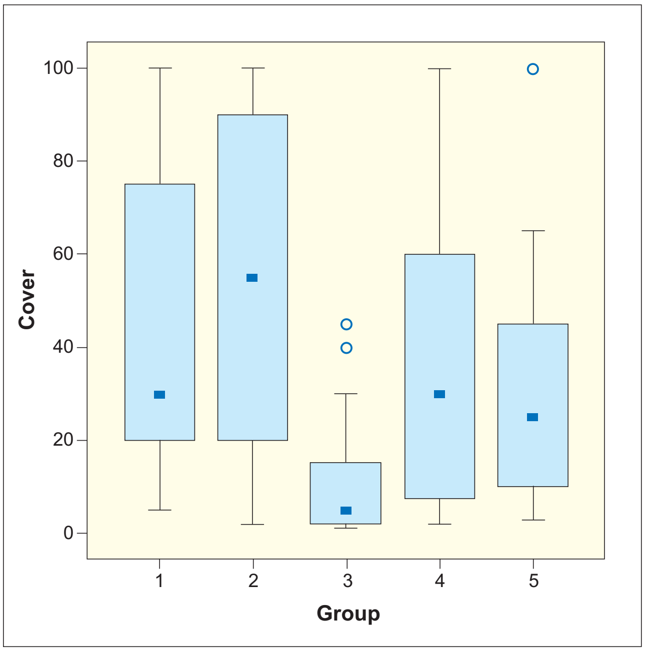

Figure 2a

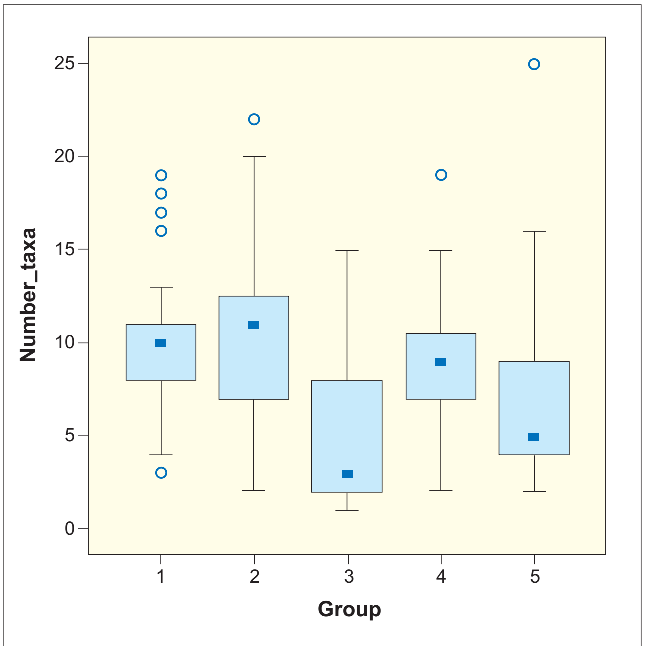

Figure 2b. Boxplots of macrophyte cover (%) and number of taxa plotted by the stream groups.

Commonly, in deeper sites of slow streams with sandy substrate the number of macrophyte species is small, the plants occur mostly in shallower waters. In streams with soft, silty substrates the macrophyte vegetation is formed by sparse cover of helophytes, floating-leaved and submerged plants (Figure 3).

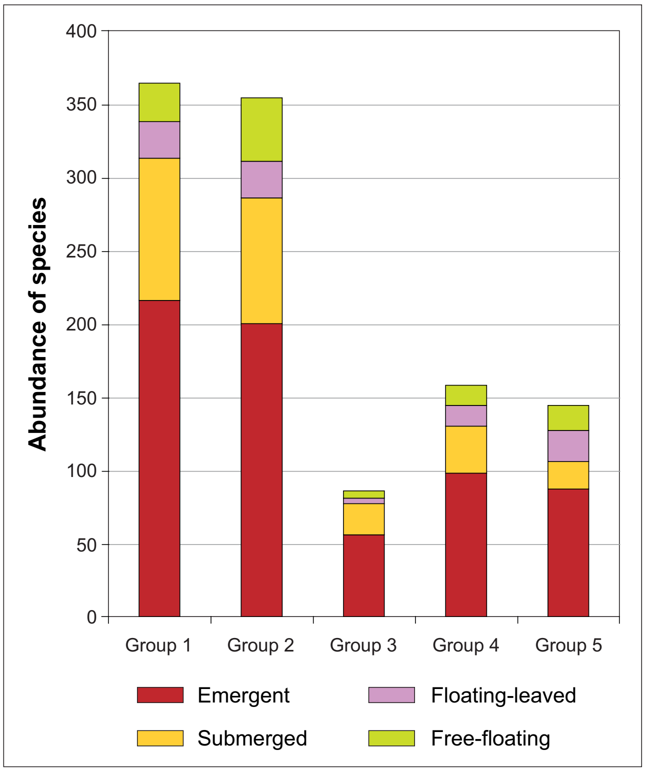

Figure 3. Distribution of macrophyte ecological groups.

Discussion

In numerous studies the species richness of macrophytes was found to be related to light conditions, nutrient concentrations and trophic status, substrate characteristics disturbance regimes, stream velocity, water level fluctuations and flood frequency.

In fast and slow flowing streams on gravelly and stony substrate there are mostly bryophytes and sparse helophyte stands. In narrow, fast flowing streams the formation of aquatic vegetation is limited by stream velocity and shading created by the river banks. More diverse species composition and denser macrophyte cover are characteristic for slow flowing streams on gravelly and stony substrates, particularly if the depth of water does not exceed one meter.

The macrophyte composition in streams on sandy substrate significantly differed from the other sites. In fast flowing streams on sandy substrate the macrophyte composition was species poor, with sparse cover. In such streams typically *Sparganium emersum* and *Elodea canadensis* dominate. *Sparganium emersum* 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.
Due to higher stream velocity, unstable substrate and strong effect of the spring floods conditions for the vegetation formation in fast flowing streams on sandy substrate are inappropriate, thus the definition of the ecological status of a stream by macrophytes requires a certain minimum plant quantity. However, the absence of macrophytes at a river site is not necessarily a result of degradation (Schaumburg et al., 2004). If certain plant quantity is not found in this kind of stream, the assessment of the stream is impossible. In that case, the macrophyte component must be excluded of the classification of the entire quality element (Schaumburg et al., 2004).
Clarke & Wharton (2001) recognized that until macrophytes can be used as trophic indicators, thorough research is needed to reliably establish the spatial and temporal variability of sediment characteristics in rivers and its link with the chemistry of the water column.
Results of this study indicate that in streams with sandy substrate stream velocity has a crucial role for forming of macrophyte vegetation. In fast flowing sandy streams of Latvia macrophytes are potentially not suitable element for quality assessment. This assume to Estonian researchers who found that it rather doubtful to develop for European oligo-mesotrophic to meso-eutrophic lowland watercourses some reliable sample or system of indicator species rendering evaluation of general water parameters or habitat characteristics (Paal et al., 2007).
In Latvia an assessment system for stream macrophytes has not yet been developed. The insufficient data of the macrophyte vegetation hinders both the establishment of a suitable assessment system and an implementation of a proper assessment without knowledge of typical species composition in the Latvian streams.

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