

Original research paper

Diatom indices and stream typology in Estonia¹

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Abstract

This paper deals with the use of diatom indices in the assessment of streams in Estonia. The problem addressed is how rational it is to determine different types of streams or stream reaches based on diatom research. At the moment, there are five different typologies of running waters in Estonia, two of which are analyzed here. Diatom indices can be employed to assess the ecological quality of water but not the status or type of stream. The most promising diatom indices for such assessment are the Trophic Diatom Index, Watanabe Index, Descy Index, and Schiefele & Schreiner Index.

Abbreviations

CEC – Descy & Coste Diatom Index; Descy – Descy Index; COD – Chemical Oxygen Demand; EU – European Union; IBD – Biological Diatom Index; H' – Shannon-Weaver Diversity Index; L-M – Leclercq & Maquet Index; SHE – Schiefele & Schreiner Index; SLA – Sládeček Index; SPI – Specific Pollution Sensitivity Index; Tax – number of taxa; TDI – Trophic Diatom Index; WAT – Watanabe Index; WFD – Water Framework Directive.

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INTRODUCTION

The implementation of the EU WFD requires that all surface water bodies achieve good quality by the year 2015. Therefore, the ecological status of the aquatic ecosystems in European countries has to be established against reference conditions (Directive 2000/60/EC). The legislation defines the reference conditions as perfect when there are no or only very slight deviations from an undisturbed situation. Considering this, a system of the criteria for the hydrochemical parameters of Estonian running waters was developed in 2001 (Loigu and Leisk 2001). At that time it was not thought that establishing the elements of the hydrochemical quality of water required the typification of streams. However, it was later concluded that, despite the small area of Estonia (ca 45 000 km²), the biota of its running waters could not be regarded as one type. Thus, Timm (2003) and Olli et al. (2003) developed two new stream typologies which correspond to the requirements of the WFD. Unfortunately, the latter typology was based on the above typology by Loigu and Leisk (2001) and considered only stream size and the hydrochemistry of water. The former typology did not take into account the requirements regarding all the biological elements. Most problems arose when the ichthyofauna of the streams was analyzed. Therefore, another attempt was made to improve the already existing typologies (Järvekülg et al. 2003b). One more typology, based on the concentrations of total nitrogen, total phosphorus and organic matter (COD), is in development (Järvekülg et al. 2003a); however, it does not take into account any of the hydromorphological features of streams.

It was demonstrated previously that water quality in Estonian streams is reflected by the epilithic diatom community (Vilbaste 2001). Nine of the diatom indices calculated with OMNIDIA (SPI, SLA, Descy, L-M, CEC, SHE, WAT, TDI, IBD) can potentially be employed to estimate the water quality of running waters (Vilbaste 2004). However, diatom indices have not yet been used officially in the monitoring of Estonian streams.

The aim of the current work was to study the sensitivity of the diatom indices to different types of Estonian running waters in order to determine how rational it is to distinguish between different types based on diatom research.

MATERIALS AND METHODS

Epilithic diatoms were sampled within the framework of the Biota of Rivers project which is part of the Estonian State Monitoring Programme. In total, 139 samples from 133 reaches of 21 watercourses were collected. Diatom frustules were cleaned with the hot acid combustion method and mounted using HYRAX as the medium. Diatom analyses were done using the latest version of

OMNIDIA software (Lecointe et al. 1993) to calculate the diatom indices according to the composition and structure of the diatom assemblages. For details see Vilbaste (2004).

The two typologies of running waters, one by Timm (2003) and the other by Järvekülg et al. (2003b), which consider the requirements for stream biota, were compared (Table 1). The former takes into account stream size, bedrock type and flow velocity. The latter considers stream size and bedrock type (calcareous and siliceous waters together were treated separately from waters rich in humic substances), as well as two selected factors - 1) the natural hydromorphological character of the stream reach and 2) the temperature regime of the water. *STATISTICA* software was used to perform statistical analysis.

RESULTS

According to the nonparametric Kruskal-Wallis ANOVA median test (Table 2), the response of all the studied diatom indices to the criterion of stream size in both typologies was nonexistent or very weak (DESCY, CEC). The same applied to the flow velocity; Tax was the only index that relied on this criterion. Most of the studied indices were dependent on bedrock type (limestone or sandstone); however, four indices (TDI, DESCY, SHE, and WAT) were not affected by the character of the riverbed. Surprisingly, there was no significant difference in the index values of stream water on mineral and organic soils in the typology by Järvekülg et al. (2003b). The hydromorphology of the stream reach, like the flow velocity, played a minor role in the formation of epilithic diatom assemblages. Temperature regime, on the contrary, controlled the composition and structure of these assemblages in many cases (TAX, SPI, SLA, CEC, and IBD).

Two indices (TDI and SHE) did not respond to any criteria used in either typology. Additionally, DESCY, SHE and WAT were also not sensitive to any criteria of the typology by Timm (2003), nor did L-M respond to any criterion of the typology by Järvekülg et al. (2003b) (Table 2).

DISCUSSION

The WFD offers two options regarding the classification of running waters - system A and system B. Both of the studied typologies are based on system B as it is a more flexible classification variant that allows for the possibility of taking local conditions into account. Estonia belongs to the Baltic ecoregion. There is no need for longitude or altitude differentiation with Estonian running waters – all streams are situated on lowlands at an altitude of 0-200 m above sea level. Stream size is described by the size of its catchment area. Both typologies

Table 1

Comparison of two typologies of streams in Estonia; the number of studied stream reaches is showed in []

	Type of stream by Tiimm (2003)	Type of stream by Järvevälg et al. (2003b)
Size (catchment area)	<p>Very small (<100 km²) [39]</p> <p>Small (100-250 km²) [23]</p> <p>Medium (250-1000 km²) [61]</p> <p>Large (1000-2500 km²) [15]</p> <p>Very large (>2500 km²) [1]</p>	<p>Very small (<75 km²) [35]</p> <p>Small (75-300 km²) [31]</p> <p>Medium (300-1000 km²) [55]</p> <p>Large (1000-5000 km²) [17]</p> <p>Very large (>5000 km²) [1]</p>
Geology (bedrock type)	<p>Calcareous streams (limestone) [88]</p> <p>Siliceous streams (sandstone) [51]</p> <p>Organic (impact of peatlands)² [0]</p> <p>Slow flow velocity (< 0.2 m s⁻¹) [45]</p> <p>Fast flow velocity (> 0.2 m s⁻¹) [94]</p>	<p>Calcareous and siliceous (low concentration of humic compounds; COD_{Cr} <35 mgO l⁻¹) [105]</p> <p>Organic soil (high concentration of humic compounds; COD_{Cr} >35 mgO l⁻¹) [27]</p>
Selected factors	<p>Slow flow velocity (< 0.2 m s⁻¹) [45]</p> <p>Fast flow velocity (> 0.2 m s⁻¹) [94]</p>	<p>Potamal (low slope, slow flow velocity, essential sedimentation) [43]</p> <p>Rithral (high slope, high flow velocity, extensive sedimentation absent) [96]</p> <p>Cold water (max. temp. <16°C) [52]</p> <p>Temperate water (max. temp. 16-21°C) [59]</p> <p>Warm water (max. temp. >21°C) [28]</p>

² No criteria given

Table 2

Significance of differences in the diatom indices on the basis of criteria in two stream typologies according to the nonparametric Kruskal-Wallis ANOVA median test; the number of types (see Table 1) is shown in (), significance is marked as *** – $p < 0.001$, ** – $p < 0.01$, * – $p < 0.05$, ns – not significant

	Index	Tax	H'	TDI	SPI	SLA	DESCY	L-M	CEC	SHE	WAT	IBD
Typology	Criterion											
	Size (5)	ns	ns	ns	ns	ns	ns	ns	*	ns	ns	ns
	Geology (2)	*	*	ns	*	**	ns	***	**	ns	ns	*
Timm (2003)	Flow velocity (2)	**	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
	Size (5)	ns	ns	ns	ns	ns	*	ns	ns	ns	ns	ns
	Geology (2)	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Järvekülg et al. (2003b)	Hydromorphology (2)	**	*	ns	ns	ns	ns	ns	ns	ns	*	*
	Water T°C (3)	*	ns	ns	**	*	ns	ns	**	ns	ns	**

use five size classes, and differentiation between the classes is made on quite a similar basis (Table 2). Timm (2003) distinguishes between streams running on limestone bedrock and those running on sandstone bedrock. Waters where the impact of natural organic matter (humic substances) is evident are noted, but they are not treated within the typology. The mean flow velocity is used as a selected factor, and two types of stream reaches are distinguished on the basis of it - slowly running waters and fast running waters (Table 1).

In the typology by Järvekülg et al. (2003b), waters on limestone (calcareous) and sandstone (siliceous) bedrock are treated together under mineral waters, and separately from waters that are rich in humic substances from the influence of peatland organic waters. The cut-off between these different types is $\text{COD} = 35 \text{ mgO l}^{-1}$ (Järvekülg et al. 2003a). Waters on limestone and sandstone are examined jointly, as there are no significant dissimilarities in the average values of the hydrochemical composition between either type. Alkalinity was $3.29 \text{ mg-eq l}^{-1}$ and $3.75 \text{ mg-eq l}^{-1}$, Ca^{XX} concentration was 62.3 mg l^{-1} and 62.7 mg l^{-1} and pH was 7.90 and 7.93 for the calcareous and the siliceous areas, respectively (Olli et al. 2003). It appears that the COD value used is insufficient for separating natural mineral and organic waters as the analyses showed no significant differences between values of diatom indices (Table 2). The benthic diatom assemblages in mire-fed stream reaches are different compared with those in mineral waters (Vilbaste and Truu 2003). Thus, at least some of the diatom indices should respond to the differences in organic and mineral waters. For this reason, another criterion should be chosen for categorizing these waters, e.g., water colour.

The main hydromorphological conditions of the stream reach and the temperature regime of the water are two selected factors in the typology by Järvekülg et al. (2003b) (Table 1). The stream reaches are divided into rithral (rapids) and potamal reaches consistent with hydromorphological characteristics. According to the summer maximum temperature of the water, three groups (cold, temperate, and warm) of stream reaches are distinguished.

Diatom indices respond differently to the selected criteria of the studied typologies. In the present study, the size of the watercourse and flow velocity did not affect significantly any of the studied indices, while bedrock type and water temperature sometimes played a noteworthy role (Table 2). Although stream size is an important factor in the formation of benthic diatom assemblages (Vilbaste and Truu 2003 and references therein), the diatom indices were not notably dependent on it (Table 2). Some indices (SLA, L-M, CEC) were quite sensitive to the character of the riverbed; however, at the same time, they did not respond to the concentration of organic matter in the water. The hydromorphology of a stream site is an essential ecological factor for the stream biota. The whole of the benthic diatom flora is very different in the soft

bottom pools (with a viable motile epipellic component) and on the rapids (with the prevalence of attached species) of the same stream. However, the variability of the epilithic diatom communities occurring on stones both in pools and on rapids is not very high, as species of attached diatoms prevailed in both cases and the number of sporadic taxa is considerably lower compared with the soft bottom communities (Vilbaste 2001).

Some diatom indices were sensitive to water temperature (Table 2). As a rule, temperature in spring-fed streams is at its minimum upstream, increases along the watercourse and reaches its maximum downstream. Water temperature is proxy to stream size for such type of streams. Conversely, in this study the diatom indices did not respond to stream size (Table 2). They expressed the quality of stream water irrespective of how large the stream was. It is possible to assess the ecological quality of water in the case of running waters by means of benthic diatoms. However, changes in hydrology and channel structure are not necessarily seen in the composition and structure of the benthic diatom assemblages (Eloranta and Soininen 2002). TDI and SHE, which are indifferent to all criteria in the studied typologies, as well as DESCY and WAT, which depended weakly only on one criterion, are the most promising diatom indices for the assessment of ecological quality of water in Estonia.

CONCLUSION

The ecological quality of water, but not the status or type of stream, can be assessed by means of diatom indices. Four diatom indices, TDI, SHE, DESCY, and WAT, are recommended for such assessment.

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REFERENCES

- Directive 2000/60/EC of the European Parliament and of the council of 23 October, 2000, Official Journal of the European Communities, 22.12.2000, 1-72*
- Eloranta P., Soininen J., 2002, *Ecological status of some Finnish rivers evaluated using diatom communities*, Journal of Applied Phycology, 14, 1-7
- Järvekülg A., Järvekülg R., Pall P., Piirsoo K., Porgasaar V., Trei T., Viik M., Vilbaste S., 2003a, *Preliminary hydrobiological types of Estonian rivers*

- (*Eesti jõgede esialgsed hüdrobioloogilised tüübid*), [in:] Loodusuurijate Selti Aastaraamat. 81, 234-271
- Järvekülg R., Pall P., Piirsoo K., Timm H., Vilbaste S. Trei T., Viik M., 2003b, *Typology of rivers in L. Peipsi-Võrtsjärv river basin, suggested by river biology working group*, [in:] *Final report of the relevant system of indicators and criteria for evaluating the ecological status of very large nonstratified lake and its river basin in WFD context*, Nõges, T. (ed.), MANTRA East, Tartu University, 76-81
- Lecointe C., Coste M., Prygel J., 1993, "Omnidia" software for taxonomy, calculation of diatom indices and inventories management. *Hydrobiologia*, 269/270, 509-513
- Loigu E., Leisk Ü., 2001, *Classification of chemical status of rivers*, [in:] *Environmental impact and water management in a catchment area perspective*, Seepõld M. (ed.), Tallinn Technical University, 46-53
- Olli K., Loigu E., Leisk Ü., Piirimäe K., Timm H., 2003, *Indicators and criteria to assess the ecological status of rivers in the Lake Peipsi catchment area*, [in:] *Final report of the relevant system of indicators and criteria for evaluating the ecological status of very large nonstratified lake and its river basin in WFD context*, Nõges, T. (ed.), MANTRA East, Tartu University, 18-28
- Timm H., 2003, *Quality elements for classification of the biological state of Estonian running waters according to EU Water Framework Directive (Euroopa Vee raamdirektiivile vastavad kvaliteedielemendid bioloogilise seisundi klassifitseerimiseks Eesti vooluveses)*, Eesti Vabariigi Keskkonnaministeeriumi Info- ja Tehnokeskus, Tallinna Tehnikaülikool, 47 pp
- Vilbaste S., 2001, *Benthic diatom communities in Estonian rivers*, *Boreal Environmental Research*, 6, 191-203
- Vilbaste S., Truu J., 2003, *Distribution of benthic diatoms in relation to environmental variables in lowland streams*, *Hydrobiology*, 493, 81-93
- Vilbaste S., 2004, *Application of diatom indices in evaluation of water quality in Estonian running waters*, *Proceedings of Estonian Academy of Science, Ecology*, 53, 37-51