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Original article

Evaluation of European diatom trophic indices

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ABSTRACT

Freshwater diatoms are considered to be reliable indicators of the trophic status of rivers and lakes. In the past 30 years, a number of indicator indices have been developed and used for the assessment of trophic conditions all over Europe. It is however still not clear whether the ecologic signature of diatoms differs between these indicator indices. The present study assessed a large number of published European indices on the response of freshwater diatoms to trophic conditions by evaluating the consistency in the use of taxa and their trophic score from seven European indicator indices. The STAR (Standardisations of River Classifications) diatom database, a large set of samples from European running waters, was used to test the application of trophic classifications in water quality assessment. The analysis of taxa in common within the trophic indices showed that there are considerable differences between the indices, for example in the score of trophic values. There was more agreement in classification of taxa within the oligotrophic and the hypertrophic preferences than within the mesotrophic range. Based on these results, a list of diatom taxa, that are consistently used in different trophic indices, was composed. It included 159 'reliable' taxa that are not sensitive to regional setting, water type and taxonomic uncertainty. The list was further accompanied by a description of the taxa's trophic preferences. The large deviation in trophic scores for a number of diatom taxa could most probably be explained by taxonomic uncertainties. Application of these taxa for trophic assessment was questionable. The test set of the 359 STAR samples showed that differences between the trophic indices also lead to a significant variation in the water quality assessment results. Although trophic indices provide an excellent biomonitoring tool, they should be applied with caution, considering the recommendations provided in this paper.

1. Introduction

Trophic conditions are one of the most important determining factors influencing the freshwater diatom communities in rivers and lakes (Harper, 1992). The reliability of diatoms as indicators of the trophic conditions in aquatic environments has been demonstrated in multiple studies (Pan and Lowe, 1994; Pan et al., 1996; Potapova and Charles, 2007; Stevenson and Pan, 1999; see also Whitton and Rott, 1996). With the increasing eutrophication of European aquatic environments, the number of indicator indices used for the assessment of trophic conditions has risen. These indicator indices were developed independently for both lotic and lentic ecosystems, more often originated from regional datasets, and served mostly as basis for regional water quality assessment [Coring et al., 1999 (Germany); Hofmann, 1994; Hürlimann and Niederhauser, 2002 (Switzerland); Kelly and Whitton, 1995 (UK); Rott et al., 1999 (Austria); van Dam et al., 1994 (The Netherlands)]. The software package Omnidia (Lecointe et al., 1993) includes some 30 diatom indices and accompanying lists of taxa with ecological scores and is often used to assess water quality in various geographical regions assuming the cosmopolitan nature of diatoms. In some cases, users adjust the indices by incorporating new or corrected autecological information to apply in their specific region (A. Jarlman, pers. comm.).

The large variation in indicator indices also caused confusion and arbitrariness among researchers performing quality assessments. It is unclear whether there are significant differences between the results of the indices, and if so, what these differences are and what causes this variation. On the one hand, the cosmopolitan nature of diatoms should display a constant trophic preference. On the other hand, primarily in studies from the North America, it has been shown that European indicator indices may need to be calibrated to regional conditions (e.g. Fore and Grafe, 2002; Potapova and Charles, 2007). Moreover, a number of European phycologists argued that indices developed in certain regions of Europe were not effective in others (Kelly et al., 1998; Pipp, 2002; Rott et al., 2003).

In this study, we tested the causes of variation between trophic diatom indicator indices by mutually comparing individual species'

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Table 1
Overview of trophic indices from the Diatom Indicator Database. 'Source' refers to the publication used for the calculations in this study.

Index	Original reference	Source	Number of taxa	Water type	Country	Ecoregion
GM B&O	Behrendt and Opitz (1996)	Coring et al. (1999)	172	Rivers	Germany	14
GM Seen	LAWA-AK Gewässerbewertung – Stehende Gewässer (1998)	Coring et al. (1999)	173	Lakes	Germany	9
Trophy D	Schmedtje et al. (1998)	Hürlimann and Niederhauser (2002)	106	Rivers	Germany	9
TDI	Kelly and Whitton (1995)	Coste, Omnidia	1603	Rivers	United Kingdom	18
Rott	Rott et al. (1999)	Coste, Omnidia	533	Rivers	Austria	4, 8
Hofmann	Hofmann (1994)	Coste, Omnidia	540	Lakes	Germany	9
van Dam	van Dam et al. (1994)	Coste, Omnidia	899	Lakes (and weakly brackish) waters	Netherlands	13, 14

trophic scores. We extracted a common trophic preference score list to be used in a wide geographical area based on consistent species scores derived from different indices. We evaluated trophic diatom scores and the consistency of indicator indices results by applying them on a large set of samples from European running waters. As a result, we determined a list of recommendations to be applied in order to get a more objective and consistent diatom-based trophic evaluation.

2. Materials and methods

2.1. Trophic indices

2.1.1. Rescaling the indices

The Diatom Indicator Database version 3.2 (http://www.freshwaterecology.info) was developed within the EU Eurolimpacs project and represents the state-of-the-art knowledge of the ecological response of diatom taxa to climate change. It contains 17 trophic diatom indices originating from studies in running and standing freshwaters throughout different ecoregions in Europe and outside. The Diatom Indicator Database uses a standardised taxonomic diatom list (CEMAGREF taxa list, updated version May 2008). The indices and scores tested in this study were extracted from this database.

In order to compare the trophic indices and the trophic diatom species scores, first the classification scheme of Rott et al. (1999) was defined as the reference scale. This classification includes per trophic class both a word description and a phosphorus concentration range. Both were used for rescaling each of the indicator indices. Of the 17 trophic diatom indices present in the Diatom Indicator Database, only seven trophic indices could be converted to the reference scale (Table 1). The remaining 10 indices either appeared not compatible or were duplicates of others. For example, three versions of the list of van Dam et al. (1994) are included in the Diatom Indicator Database, only the index extracted from the Omnidia program was used in this analysis. The seven selected indices still needed additional conversion to a uniform scale. Several indices had broader class boundaries than the Rott scale and, therefore, in the reference scale the lowest two and the highest two classes of the Rott scale were combined (Table 2). The seven selected indices are originally based on data from running and standing waters in Germany, United Kingdom, Austria and the Netherlands, and correspond to ecoregions 4, 8, 9, 13, 14, and 18 (Illies, 1978).

Table 2
Final reference scale adopted for the analyses.

Trophic class	Description	*P* optimum (μg/l)
1	Oligotrophic	<10
2	Oligo-mesotrophic or β-mesotrophic	≥10, <20
3	Mesotrophic	≥20, <30
4	Meso-eutrophic or α-mesotrophic	≥30, <50
5	Eutrophic	≥50, <100
6	Eu-hyper(poly)trophic	≥100

2.1.2. Consistency of index scores

The consistency in trophic scores per taxon between the seven trophic indices was analysed pairwise by counting the number of taxa with identical scores, either based on word descriptions or on phosphorus boundaries. Furthermore, the similarity, using the Sørensen Similarity index (Sørensen, 1948), between the taxa lists of the seven trophic indices was calculated for both the full taxa lists as well as only for those taxa lists had in common. The latter comparison was evaluated by mutually comparing all indices and by comparing pairs of indices using box plot diagrams. In the box plots, the proportion of taxa with identical scores was divided by the total number of taxa in common for each pair of indices.

2.1.3. Reliability of taxon scores

If a taxon occurs in at least three out of the seven indices and represents the same trophic score, or if it occurs in four or more indices and represents the same or two adjoining trophic scores it is defined as a 'reliable' taxon. "Reliable taxa' are not determined by water type, nor by geographical region but only based on the rubric described above. So-called 'unreliable' taxa occur in at least three out of the seven indices and have scores in at least two non-adjoining classes.

2.2. STAR data

A dataset of 359 samples from 13 European countries was used to evaluate the variation in trophic index scores in water quality assessment. The samples were collected and analysed in the period 2001–2005 as part of the EU-funded research project STAR [Standardisations of River Classifications: Framework method for calibrating different biological survey results against ecological quality to be developed for the Water Framework Directive (Furse et al., 2006a)]. The samples comprise running waters ranging from small-sized, shallow mountain streams to medium-sized lowland streams and cover all water quality classes (Furse et al., 2006b).

In total, 132,087 diatom valves belonging to 620 taxa (including species, varieties and formas; on average 368 valves per sample) were identified using a taxonomically consistent nomenclature according to Omnidia 4.2 (Lecointe et al., 1993).

2.2.1. Trophic assessment

The trophic scores of Rott and TDI were calculated by using the Omnidia 4.2 software. Hofmann and van Dam indices were calculated by means of weighted averaging. As the index results could not be brought to a common scale, the correlation between the indices was based on rank correlation, in order from oligotrophic to hypertrophic by using GenStat 10.2 software (VSN International Ltd, Hemel Hepstead, UK, 2007). In case more than one sample had equal trophic scores the average ranking was given to each of the samples and was tested with a non-parametric rank correlation test of Kendall ($P < 0.05$).