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Review

Benthic algal assessment of ecological status in European lakes and rivers: Challenges and opportunities

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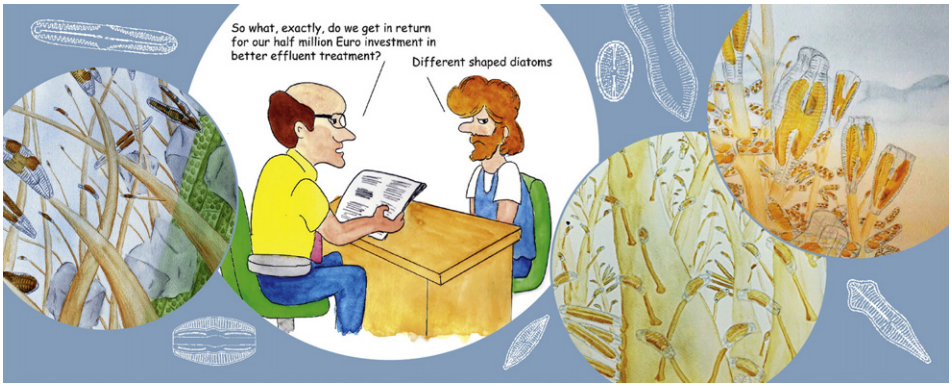
HIGHLIGHTS

- The 9th *Use of Algae for Monitoring Rivers* discussed the state of benthic algae assessments in Europe.
- We review the phytobenthos assessment tools currently used in Europe.
- Several challenges remain: focus on diatoms only, lake assessment, limited abundance assessment, setting ecological thresholds.
- Future work needs to develop diagnostic tools and strengthen the rationale of phytobenthos assessments.
- Communicating the phytobenthos status to non-technical audiences is a hitherto neglected issue.

GRAPHICAL ABSTRACT



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ABSTRACT

This opinion paper introduces a special series of articles dedicated to freshwater benthic algae and their use in assessment and monitoring. This special series was inspired by talks presented at the 9th International Congress on the *Use of Algae for Monitoring Rivers and Comparable Habitats* (Trento, Italy, 2015), the latest of a series of meetings started in 1991.

In this paper, we will first provide a brief overview of phytobenthos methods in Europe. Then, we will turn towards the 'dark side' of phytobenthos and describe four particular problems for phytobenthos assessment in the European Union: (1) over-reliance on a single group of algae (mostly diatoms) to the exclusion of other groups; (2) relatively low adoption of benthic algae for ecological assessments in lakes; (3) absence of measures of phytobenthos abundance; (4) approaches used to define boundaries between ecological classes.

Following this, we evaluate the strengths and limitations of current phytobenthos assessment methods against 12 criteria for method evaluation addressing four areas: ecological rationale, performance, feasibility of implementation, and use in communication and management. Using these criteria, we identify and discuss three general challenges for those developing new methods for phytobenthos-based assessment: a weak ecological rationale and insufficient consideration of the role of phytobenthos as a diagnostic tool and for communicating ecosystem health beyond a narrow group of specialists.

The papers in the special series allow a comparison with the situation and approaches in the USA, present new methods for the assessment of ecological status and acidification, provide tools for an improved management

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of headwaters and petrifying springs, discuss the utility of phytobenthos for lake assessments, and test the utility of functional measures (such as biofilm phosphorus uptake capacity, PUC).

Contents

1. Introduction

This issue of *Science of the Total Environment* contains a series of papers presented at the 9th International Congress on the *Use of Algae for Monitoring Rivers and Comparable Habitats*, held in Trento, Italy, in June 2015. This is the latest in a series of meetings that started in Dusseldorf in 1991 and it is instructive to look back at the proceedings from that first meeting (Whitton et al., 1991) in order to reflect on the progress that has been made in the intervening years.

Scanning the contents of Whitton et al. (1991) leaves the impression that this meeting consisted largely of applied scientists in search of an application. Several of the plenary papers, in particular, contained more bright ideas than evidence and, with a few exceptions (e.g., Coste et al., 1991), the approaches discussed at the meeting had not been formally adopted, or were only used to a limited extent, by national and regional governments for routine monitoring. This highlights the paradox that bedevils any discussion of "monitoring": the process has meaning only if embedded within a broader process of "management". In the case of the environment, management is ultimately shaped by the prevailing legislation.

At the time of the first meeting, the European Economic Community was much smaller (12 Member States) than the present European Union (28 Member States) and the environmental legislation that it produced was more limited in scope. The Dangerous Substances Directive (EC, 1976), for example, quotes target concentrations for toxic metals and organic compounds in terms of Environmental Quality Standards, defined on the basis of laboratory-based toxicity tests rather than observation of effects in the field. Chemical monitoring alone was sufficient to fulfill Member State's obligations under this Directive. There were situations where biology could provide complementary evidence, but this was not mandatory (Premazzi and Chiaudani, 1992).

The situation gradually changed over subsequent years: first the Urban Wastewater Treatment Directive (UWWTD: CEC, 1991) and then the Water Framework Directive (WFD: EC, 2000) posed questions that necessitated direct observation of the condition of algal communities in rivers and lakes. A core principle of the European Union is "subsidiarity" which means that the EU may act only when the actions of individual countries are insufficient (EU, 2002, Article 5). In the case of environmental legislation, this means that each individual Member State has a responsibility to develop an approach appropriate to its own circumstances. During this period, the *Use of Algae for Monitoring Rivers* meetings started to provide opportunities for those involved in the development of methods to share their experiences and also to learn about approaches adopted elsewhere in the world (e.g. Charles, 1996). A workshop held alongside the third meeting, at Douai in France, for example, stimulated discussions which led to the development of European Standards for sampling and analyzing diatoms (CEN, 2003, 2004; Kelly et al., 1998).

The need for collaboration between countries increased with the adoption of the WFD which not only set ambitious ecologically-based targets to ensure the long-term sustainable use of Europe's waters, but also required that these targets were harmonized between Member States. The core principle of subsidiarity remained, leading to a proliferation of methods around the European Union (Birk et al., 2012), albeit with substantial "convergent evolution" (Kelly et al., 2015). The necessity to intercalibrate national methods to ensure consistent outcomes provoked a huge amount of scientific debate and consensus-building (Kelly et al., 2009a, 2014; Poikane et al., 2014b). During the period since the adoption of the WFD, the European Union has expanded from 15 to the present 28 Member States, a number of whom have experienced significant fiscal "hiccups" counteracting the generally upward trend of economic growth. The latter, in particular, has emphasized the importance of ensuring that methods are practicable and cost-effective, as well as firmly grounded in ecological theory.

A major difference, then, between the 1st and 9th Meeting in this series is that benthic algae are now embedded into the routine ecological assessment procedures of the countries from which participants are drawn (both within and beyond Europe) although there are few grounds for complacency. The 9th meeting breaks with tradition by including both rivers and lakes within its ambit, recognizing that many of the processes which influence the condition of algal assemblages in lake littoral zones and shallow rivers are similar (Cantonati and Lowe, 2014) and the methods adopted for their assessment also show considerable overlap (DeNicola and Kelly, 2014; Kelly et al., 2014). The papers in the special series of papers allow a comparison with current approaches in the USA (Hausmann et al., 2016; Tang et al., 2016), present new methods for the assessment of acidification and ecological status (Juggins et al., 2016; Kelly et al., 2016b), discuss the importance of quantitative estimates of headwater stream productivity, provide tools for better management of petrifying springs (Cantonati et al., 2016), critically review the utility of phytobenthos for lake assessments (Kelly et al., 2016a), and test the utility of functional measures (such as biofilm phosphorus uptake capacity, PUC; Proia et al., 2016).