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RAPPER: A new method for rapid assessment of macroalgae as a complement to diatom-based assessments of ecological status

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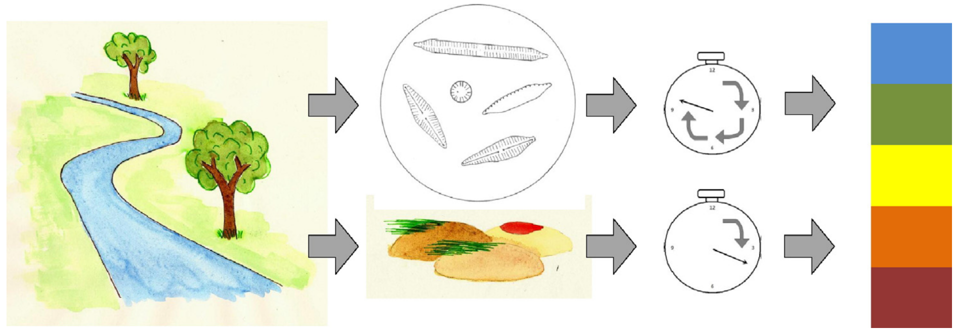
HIGHLIGHTS

- There is a need for high level ecological "triage" methods to complement traditional approaches to ecological assessment
- Identification of macroalgae, combined with assessment of cover, permits sites at risk of eutrophication to be identified
- The method has several potential applications including "citizen science".

GRAPHICAL ABSTRACT



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ABSTRACT

Most methods for ecological assessment developed since the onset of the Water Framework Directive require substantial effort by skilled analysts and are therefore expensive to use. RAPPER ("Rapid Assessment of PeriPhyton Ecology in Rivers") is a high level ecological "triage" method that enables rapid screening of sites within a water body to enable managers to identify areas subject to nutrient pressures. The method involves a survey of macroscopic algae within 10 m lengths of watercourses, taking samples for subsequent identification, and assessing cover. Genus-level identification is used to ensure rapid assessment and comparability, and that the method can be used by a wide range of users. Genera of alga that form conspicuous growths recognisable with the naked eye are designated as either "stress-tolerant" ("S-taxa") or "competitive" taxa ("C-taxa"), depending on their preference for locations with low or high nutrient concentrations. Genera whose representatives span a wide range of nutrient conditions, or for which few data are available, are placed in a third class, "unclassified". The presence of S-taxa and the relative cover of C-taxa are then used to determine whether a site is at risk from eutrophication. Field trials in Scotland demonstrated that the method discriminates between sites with low and high nutrient concentrations. Significant differences were also observed in values of the Trophic Diatom Index between RAPPER classification categories. RAPPER can be used alone (allowing greater spatial or temporal coverage within water bodies at lower cost than conventional assessment methods) or to increase confidence in assessments of the condition of the phytobenthos by incorporating algae other than diatoms. The outcomes also relate directly to the experiences of non-technical stakeholders, and will have benefits for communicating ecosystem health concepts to the wider public, for example through "citizen science".

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1. Introduction

The period since the adoption of the Water Framework Directive (WFD; European Union, 2000) has seen the countries of the European Union developing new approaches to ecological assessment in order to evaluate the state of Europe's surface waters (Birk et al., 2012). One consequence of this is a harmonised view of what constitutes "good ecological status" for any particular type of water body throughout the region (Birk et al., 2013; Pardo et al., 2012; Bennett et al., 2011). The next stage, however, requires a shift from the national and regional scale evaluations in order to target appropriate measures to restore failing water bodies to good status.

Evaluation of phytobenthos is one component of ecological status assessment in freshwaters that Member States have a duty to perform. The term 'phytobenthos', in this case, refers to photosynthetic algae and cyanobacteria associated with submerged surfaces. Their inclusion in the WFD reflects the important role that benthic algae play in freshwater ecosystem functioning (Allen, 1995; Stevenson et al., 1996) as well as the potentially harmful consequences of excessive algal growths on the provision of ecosystem services (Sturt et al., 2011; Everard, 2012; Camp et al., 2014). Most Member States have, subsequently, developed methods for assessing phytobenthos largely using diatoms, a diverse and sensitive group of algae, as proxies for the full phytobenthic community (Kelly, 2013).

Several studies have demonstrated strong relationships between benthic diatoms and inorganic nutrients (Potapova and Charles, 2007; Kelly et al., 2008a; Bennion et al., 2014). As a large number of water bodies throughout Europe have elevated concentrations of nitrogen and phosphorus (European Environment Agency, 2012), many are likely to exhibit phytobenthic communities different from those expected under reference conditions and, therefore, fail to achieve good ecological status. This, in turn, raises further questions, both about the management of nutrients within water bodies and about the interpretation of ecological status concepts by catchment managers. There is, in particular, a need to understand how a sample, reflecting the state of a part of the phytobenthos at a particular point in space and time, relates to broader ecosystem functioning, in order that investment in remediation measures has a high probability of success.

The UK's current WFD assessment tools fulfil the statutory obligations to produce quantitative classifications of ecological status on the basis of deviation from reference conditions. These methods are however relatively slow and resource intensive. In the case of phytobenthos assessment, sample analysis and interpretation may be performed by staff who have not visited the site and may, indeed, be based in another part of the country. The impetus for the work described here arose from discussions about reducing the inherent uncertainty associated with diatom-based assessments (Besse-Lotoskaya et al., 2006; Kelly et al., 2009a; O'Driscoll et al., 2014). In theory, confidence can be raised by increasing effort; however, as diatom analysis is a relatively resource intensive method which requires highly-skilled staff, this has significant cost implications. The discussion then considered the use of complementary evidence that could be collected at the same time as the diatom sample. Having recognised the potential for macroalgae to complement diatom analyses, the discussion quickly broadened out to consider other situations where the assessment of macroalgae may have value, independent from diatom analyses.

Formal WFD assessment tools provide information on the condition of a water body; however, the high costs means that this may be possible only at a low level of spatial detail. Against this background there is, we believe, potential for a rapid assessment method that can be performed at a large number of sites within a water body, in order to target appropriate measures for restoring ecological status. Such methods also have the potential for use by less-specialised staff and, indeed, by stakeholders. It is important to emphasise that RAPPER is not envisaged as a replacement for current diatom and macrophyte assessment methods. Rather, we believe that it could form one of a number of complementary strands of high-level evidence that will have particular value in the early stages of evidence gathering and risk assessment and which can provide rapid input to the decision-making process.

We also believe that there is a place for assessments based on visually-obvious components to communicate concerns about the condition of the stream ecosystem to non-technical staff. This has been largely overlooked in the development and evaluation of WFD assessment tools (see, for example, Hering et al., 2010); however, public participation is a core principle of the WFD (Article 16; European Union, 2000), albeit one that most member states are struggling to enact (De Stefano, 2010). There is, therefore, a strong case for new approaches to assessment which complement the formal evaluation of ecological status (Kelly, 2014).

2. Materials and methods

2.1. Site selection

RAPPER was tested through a sampling programme in Scotland during 2014. 90 sites were selected to provide good geographical coverage across Scotland, as well as encompassing a range of water quality. All sites were also sampled for benthic diatoms in previous years and results from these analyses provided an a priori estimate of ecological status for each. Benthic diatom samples were collected and analysed at the same time as the macroalgal surveys following CEN (2014a,b). Environmental data were measured in situ (width, depth, substrate composition) or obtained from the Scottish Environment Protection Agency's database (chemical variables). Substratum composition was assessed using the Krumbein phi scale, following Wright et al. (1984). Environmental data are summarised in Table 1.

The a priori estimate of ecological status based on benthic diatom results indicated that the majority of sites were at moderate ecological status (71%), 26% at high status and only 3% at poor ecological status. No sites classified as bad ecological status were available.

2.2. Assessment of macroalgae composition

An assessment of the composition and abundance of macroalgae was performed at the same time as diatom samples were collected. This was based on Holmes and Whitton (1981) and the macroscopic phytobenthos survey described in CEN (2009). It involves a survey of an approximately 10 m length of the stream, located at the same point from which the diatom samples were collected. The abundance of all algal growths that were visible with the naked eye was recorded and either identified in the field or a small subsample was returned to the laboratory for identification. These surveys were performed between May and October 2014 by biologists who were either experienced macrophyte surveyors or who had attended a specialist course on macroalgal identification. Cover was assessed using a 9-point cover scale (Table 2). These were amalgamated into three categories for data analysis; the threshold between categories corresponds to the cover associated with good/moderate and moderate/poor boundaries based on the filamentous algal metric within the UK's macrophyte assessment tool, LEAFPACS (Willby et al., 2009). The good/moderate boundary in LEAFPACS is placed at 7.5% cover; however, as cover is assessed using a semi-quantitative scale in both LEAFPACS and RAPPER (Table 2), the boundary has been placed at the lower limit of the class within which this threshold falls (5%). Similarly, the moderate/poor boundary occurs at 17.5% cover in LEAFPACS, so has been placed at the upper limit of the class in which this threshold falls (25%).

When identification was not possible in the field, samples were brought back to the laboratory for confirmation. Periphyton taxa were identified using Gutowski and Foerster (2009); John et al. (2011) and drafts of an as yet unpublished key written specifically for UK rivers.

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