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Comparability of river quality assessment using macrophytes: A multi-step procedure to overcome biogeographical differences

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HIGHLIGHTS

- A novel approach for WFD-intercalibration with two options was successfully applied.
- Data was the first wide field-based assessment for Mediterranean river macrophytes.
- Macrophyte-based metrics for Mediterranean rivers rely in scoring-indicator species.
- Forthcoming biomonitoring must incorporate ecological accuracy of macrophyte metrics.

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ABSTRACT

This paper exposes a new methodological approach to solve the problem of intercalibrating river quality national methods when a common metric is lacking and most of the countries share the same Water Framework Directive (WFD) assessment method. We provide recommendations for similar works in future concerning the assessment of ecological accuracy and highlight the importance of a good common ground to make feasible the scientific work beyond the intercalibration.

The approach herein presented was applied to highly seasonal rivers of the Mediterranean Geographical Intercalibration Group for the Biological Quality Element Macrophytes. The Mediterranean Group of river macrophytes involved seven countries and two assessment methods with similar acquisition data and assessment concept: the Macrophyte Biological Index for Rivers (IBMR) for Cyprus, France, Greece, Italy, Portugal and Spain, and the River Macrophyte Index (RMI) for Slovenia. Database included 318 sites of which 78 were considered as benchmarks. The boundary harmonization was performed for common WFD-assessment methods (all countries except Slovenia) using the median of the Good/Moderate and High/Good boundaries of all countries. Then, whenever possible, the Slovenian method, RMI was computed for the entire database. The IBMR was also computed for the Slovenian sites and was regressed against RMI in order to check the relatedness of methods ($R^2 = 0.45$; $p < 0.00001$) and to convert RMI boundaries into the IBMR scale. The boundary bias of RMI was computed using direct comparison of classification and the median boundary values following boundary harmonization. The average absolute class differences after harmonization is 26% and the percentage of classifications differing by half of a quality class is also small (16.4%). This multi-step approach to the intercalibration was endorsed by the WFD Regulatory Committee.

1. Introduction

Macrophyte assemblages are undoubtedly key-elements of freshwaters and act as primary "ecosystem engineers" of fluvial systems (Gurnell et al., 2012). In fact, it is difficult to find scientific literature

Abbreviations: EU, European Union; EQR, Ecological Quality Ratio; GIG, Geographic Intercalibration Group; IC, Intercalibration Exercise; MedGIG, Mediterranean Geographic Intercalibration Group; RM, Mediterranean river types; WFD, Water Framework Directive.

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devoted to river plants that do not bring up the role of macrophytes in structuring and creating habitats, in the air–water–sediments exchanges, in the regulation of water temperature and light, and in sustaining other aquatic communities, such as fish, periphyton and invertebrates. There is also an enormous amount of evidence of the steady responses of diversity and abundance of river plants to abiotic factors (Haslam, 1987a; Bornette and Puijalon, 2010), and especially to nutrient enrichment (e.g., Demars and Harper, 1998), sedimentation (e.g., Jones et al., 2012) and hydrological alterations (e.g., Biggs, 1996; Franklin et al., 2008). These plant communities have the capability of incorporating the effects of successive anthropic disturbances over long periods of time, frequently years, which can be advantageous for the assessment of ecological status of rivers.

Numerous assessment systems were developed worldwide in the last decades using different components of the macrophyte assemblages, such as the vegetation structure, the species diversity or the relative position of macrophyte species in pressure gradients (Dodkins et al., 2012a). However, and surprisingly, until the advent of the Water Framework Directive (WFD; European Commission, 2000), macrophytes have been disregarded in the bioassessment of ecological water quality, in detriment of other biological quality elements, notably the phytobenthos, fish and benthic invertebrates. Despite the difficulties to overpass this lack of biomonitoring tradition in Europe, it turns out that most of the existing macrophyte-based methods were not compliant with the WFD requirements (but see e.g., Haslam, 1982), as they were generally not reference-based or specific to water types (Hering et al., 2010). Presently, only 15 different macrophyte-based national methods are being officially used for national WFD monitoring programs (Birk et al., 2010). Official methods designate the methods that are being used in the European wide harmonization of the classification of the ecological status — the so-called WFD Intercalibration Exercise (hereafter IC). Most of these national methods were developed recently (e.g., LEAFPACS for UK — Willby et al., 2009; RMI for Slovenia — Kuhar et al., 2011), and some have been tested for transferability in similar biogeographical regions and accepted as methods for other EU countries. This was the case of the Biological Macrophyte Index for Rivers, IBMR (Haury et al., 2006), originally developed for France and now applied in for the IC of seven EU countries (Birk and Willby, 2010). Nonetheless, a comparability of results was not done so far, and uncertainties were not fully assessed in most of assessment methods. Whereas Staniszewski et al. (2006) observed that IBMR has a notably low uncertainty in inter-surveyor sampling differences, temporal variation and influence of external effects such as shading other types of uncertainty such as considerations on sampling errors (precision), causality (meaning) and predictability (reliability) in macrophyte metrics have been overlooked (Demars, 2013). This is not a specific weakness of macrophyte metrics, but a larger problem of many bioindicators throughout various types of ecosystems (Moss, 2008), including other Biological Quality Elements of the WFD (diatoms, macroinvertebrates, fish). In addition, the lack of long-term biotic and environmental data at large spatial scales has likely hampered the accuracy studies including the knowledge of ecological responses of indices to single and multiple pressures.

The IC is a legal obligation that requires active developments in a relatively strict timeframe, aiming to achieve a coherent implementation of the WFD between EU countries by ensuring the comparability of the classification results of the biological assessment systems (European Communities, 2011). In particular, the IC is set to harmonize the boundaries between the classes of good and moderate status and high and good status from the member states' assessment methods and to confirm if these classes are consistent with the normative definitions of the WFD. Given this, a number of straightforward feasibility checks were settled in the IC framework to give a supportive guidance to the integration of different views. As the implementation of assessment methods followed different approaches in different countries, there are three methodological pathways, or options, for the intercalibration described in the Guidance Document for the common implementation strategy for the WFD (European Communities, 2011). The choice of the most suitable IC option depends on the similarities of the assessment methods of participating MS, including the conceptual basis of methods, the numerical evaluations, and of the sampling procedures. Option 1 is the simplest option; the boundaries are compared directly between countries that are using the same data acquisition and same numerical evaluation. Option 2 requires the use of a common metric to ensure comparability of national assessment systems, since countries use different data sampling and different assessment methods. The common metrics are ecologically meaningful biological measures produced during the IC exercise (as in Birk and Hering, 2009) or existing assessment methods (and parts of methods) that respond to pressures being intercalibrated (as in Buffagni et al., 2005). Finally, IC Option 3 – direct comparison – compares pair-wise differences of the different national assessment methods, usually at the sampling site level, requiring a sufficiently large and consistent international database.

Indirect comparisons via IC common metrics were used for most of biological quality elements and water bodies both in the first IC phase, 2004–2008 (Buffagni et al., 2005; Birk et al., 2006) and in the second phase, 2009–2012 (Kelly et al., 2009; Bennett et al., 2011). However, some difficulties were reported in using robust common metrics, namely due to low relations of national indices to common metrics, and to the scarcity of reference sites to standardize the common metrics (Birk and Hering, 2009; Hering et al., 2010).

The intercalibration exercise is undertaken within Geographical Intercalibration Groups (GIGs) rather than the ecoregions defined in Annex XI of the Water Framework Directive (European Communities, 2011). GIGs aggregate countries or parts of countries sharing common intercalibration types. The Mediterranean Geographical Intercalibration Group (MedGIG) is a geographically homogeneous region that share five Mediterranean river types (Annex I, European Communities, 2011) and includes South European countries, Cyprus, France, Greece, Italy, Malta, Portugal, Slovenia and Spain. Regardless the numerous studies done before the WFD publication relating river macrophytes' sensibility to stressors in this region (e.g. Haslam, 1987b; Papastergiadou and Babalonas, 1993; Ferreira, 1994; Romero and Onaindia, 1995), there was limited data availability for the IC and a poor advancement of national assessment systems. This has dictated an unsuccessful IC in the first phase. Indeed, a debate arose at its end whether South-European river macrophytes could reliably indicate human pressure, or if they could be compared across so diverse Mediterranean landscapes (European Commission, 2007).

For these reasons, a thorough first screening was performed over the existing and currently used national assessment methods. Most of these did not go beyond the intercalibration feasibility check (Aguiar et al., 2009a). Four different reasons were documented: i) they addressed different types of pressures at different habitats and spatial scales, namely the Riparian Vegetation Index (Aguiar et al., 2009b) and the Riparian Habitat Quality (Munné et al., 2003), ii) they followed different protocols of sampling and data processing, namely the IVAM (Moreno et al., 2008) and the IM (Suarez et al., 2005), iii) they lacked near-natural reference conditions (see Dodkins et al., 2012b), and iv) they had poor coverage of the impact–pressure relationships notably the Mean Trophic Rank (MTR; Holmes et al., 1999), due to large biogeographical differences between the country where the method was developed (UK) and the Mediterranean region.

Ultimately, two assessment methods surmounted the screening phase and were accepted for intercalibration in highly seasonal Mediterranean rivers — the Macrophyte Biological Index for Rivers (IBMR; Haury et al., 2006) for Cyprus, France, Greece, Italy, Portugal and Spain, and the River Macrophyte Index (RMI; Kuhar et al., 2011) for Slovenia.

This work presents a new methodological procedure for the intercalibration of the national methods, by sequentially applying Option 1 (for most of the countries) and the direct comparison (for the remaining metric). The combined approach outlined here is a novel contribution for the intercalibration of national systems and can be applied within