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Water quality assessment of rivers using diatom metrics across Mediterranean Europe: A methods intercalibration exercise

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HIGHLIGHTS

- Four diatom methods were compared using the Intercalibration Common Metric (ICM).
- The ICM correlated well with the national metrics and responded to nutrients.
- Upper class boundaries were adjusted and translated to national systems.
- Diatom assemblages for Good and Moderate quality classes were defined.
- Diatom patterns were affected by different taxonomic conventions but not by season.

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ABSTRACT

The European Water Framework Directive establishes a framework for the protection of water resources. However, common water management tools demand common understanding of assessment methods, so quality goals are equally met. Intercalibration of methods ensures the comparability of biological elements across similar geographical areas. Many aspects can influence the outcome of intercalibration: data sampling, treatment methods, taxonomic reliability of databases, choice of metrics for ecological quality status classification, and criteria for selecting reference sites. This study describes the potentials and constraints of the intercalibration of indices using diatoms for assessment of Mediterranean rivers. Harmonisation of diatom taxonomy and nomenclature was based on a previous ring test which took place at the European level. Four diatom indices (Indice de Polluosensibilité Spécifique—IPS, Indice Biologique Diatomées—IBD 2007, Intercalibration Common Metric Italy—ICMi and Slovenian Ecological Status assessment system) were intercalibrated using data from six European Mediterranean countries (Cyprus, France, Italy, Portugal, Slovenia and Spain). Boundaries between High/Good and Good/Moderate quality classes were harmonised by means of the Intercalibration Common Metric (ICM). Comparability between countries was assured through boundary bias and class agreement. The national boundaries were adjusted when they deviated more than a quarter of a class equivalent (0.25) from the global mean. All national methods correlated well with the ICM, which was sensitive to water quality (negatively correlated to nutrients). *Achnanthidium minutissimum* sensu lato was the most discriminative species of Good ecological status class. *Planothidium frequentissimum*, *Gomphonema parvulum* and *Nitzschia palea* were the most contributive to Moderate ecological status class. Some taxa were discriminative for both Good and Moderate ecological status classes due to low indication and ecological discriminative power but also due to differences in taxonomy between countries. This intercalibration exercise allowed establishment of common water quality goals across Mediterranean Europe, which is substantiated with the ICM.

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1. Introduction

The comparability of biological methods across geographic areas in Europe was never an issue before the publication of the Water Framework Directive (WFD—European Commission, 2000). The Biological Quality Elements (BQE) used in the WFD (phytoplankton, phytobenthos including the aquatic flora, invertebrates, and fish) were the basis of this approach. Class boundaries using these BQE should be established by taking into consideration characteristics such as taxonomic composition and abundance. The ultimate goal was to derive the 'ecological status', with specific objectives through programmes of measures defined in the River Basin Management Plans (Koller-Kreimel and Chovanec, 1999). The European Union partner countries, therefore, are framed by a single legislative framework that sets uniform standards in water policy throughout the European Union. However, this goal was slowed down by the evidence that implementation could not be straightforward and European-wide, and that it was necessary to establish common quality goals at the ecoregion level. For more than a decade, the different partner countries developed their respective assessment systems and, even under a common perspective of assessment, methodological approaches followed different pathways. Intercalibration of methods and procedures was, therefore, necessary to address common river management goals (Birk et al., 2013). This objective was already foreseen in the WFD description by means of intercalibration exercises (IC) that could assure comparable classifications within the different ecoregions, where comparable levels of ecosystem alteration could be attained when classifications were similar.

The use of aquatic communities for water quality evaluation is at the base of the BQE use, and is not recent (Kolkwitz and Marsson, 1908). Among the different biological elements used in the WFD, the use of diatom assemblages in routine monitoring of the ecological status of water bodies has been widely applied in many European countries as good proxies for phytobenthos. Diatom indices are the most common tool to summarise the information provided by the diatom assemblages. Most of the indices used in Europe are based on Zelinka and Marvan's (1961) approach, which considers the weighted averages of taxa sensibility to pollution (i.e. nutrients, organic degradation), as well as pH and salinity. Among them, the IPS (Cemagref, 1982), the TDI (Kelly and Whitton, 1995), and the TI (Rott et al., 1999) are some of the most commonly used. Because diatom species respond to environmental changes (Ponader and Potapova, 2007; Prygiel et al., 1996), indices routinely used demand taxonomic identification to be done at the species level. These requirements of fine taxonomy, together with the frequent nomenclatural changes, complicate the reliable comparison of quality results based on diatoms, and are an additional reason for intercalibration.

The WFD follows a reference approach (Hughes et al., 1986; Reynoldson et al., 1997) where the ecological status classification of a given water body is presented as a deviation of the biological community from the same biological element but in unaltered (pretended pristine) condition. However, reference conditions can be defined in different ways, and this also affects the class boundaries and its comparison (Pardo et al., 2012; Stoddard et al., 2006). Reference conditions in the Mediterranean region are particularly difficult to establish, not only due to the long history of human disturbances (Feio et al., 2014–in this issue; Hooke, 2006) but also due to the relatively unpredictable seasonal and multi-year variations in water availability that further introduce difficulties when comparing results (Dodkins et al., 2012; Feio et al., 2014–in this issue).

The comparison between different systems of ecological classification is also influenced by differences in sampling and sample processing, as well as in the criteria for site selection, and the choice of parameters for non-biological data (also contributing to quality classifications) including hydromorphological, physical and chemical parameters. As a result, classifications are embedded in ecological noise and sampling variability and therefore "inferences regarding biological condition are influenced by a variety of individual and combined decisions regarding data collection, treatment and summary" (Cao and Hawkins, 2011), and likewise affecting the comparability of results. In the Mediterranean ecoregion, five common river types were proposed based on catchment size, geology and hydrological regime (ECOSTAT, 2004), but the biological classification does not completely match the abiotic one, adding an additional obstacle in the comparison of the partner countries' results. This paper summarises the results of the intercalibration process carried out in order to constrain the listed limitations, and to provide a common framework for the successful comparison of diatom assessments of river quality across the Mediterranean European region.

2. Methodology

2.1. Sample collection and processing

The European Mediterranean countries Cyprus, France, Italy, Portugal, Slovenia, and Spain (Fig. 1) provided data for intercalibration (Table 1). Participating countries collected their samples according to standard methods (EN, 2003; Kelly et al., 1998), adapted to the specific requirements in each country.

Diatoms were used as proxies for phytobenthos (Kelly et al., 2008) and most countries (except Slovenia that used a multi-habitat sampling methodology) based their approach on epilithic diatoms. About three quarters of the samples were collected in spring/summer, the seasons when effects on the biota are the most visible because of lower flows and associated higher concentration of dissolved materials. Diatom identification followed standard floras, mainly Krammer and Lange-Bertalot (1986, 1988, 1991a, 1991b). Counting of the diatom cells followed standard procedures (EN, 2004) with a minimum of 400 valves identified and counted.

Diatom data were harmonised by screening for inconsistencies and merging synonyms. This was the case of the taxa: *Achnanthes lanceolata* (Brebisson) Grunow and its synonym *Planothidium lanceolatum* (Brebisson ex Kützing) Lange-Bertalot, and *Navicula pupula* Kützing and its synonym *Sellaphora pupula* (Kützing) Mereschkowsky, among others. Harmonisation of taxonomic issues also used the criteria from a previous European ring test (Kahlert et al., 2012), mostly based on expert criteria. Environmental data were also harmonised between countries, and sites with missing values or non-comparable variables (e.g. alkalinity and hardness) were eliminated from the dataset.

2.2. Datasets

Three datasets were prepared for the intercalibration exercise. The first one was a biological dataset with diatom taxa list and relative abundance per sample. Another included site information (i.e. geographical localisation, identification of site/sample) and environmental data (hydromorphological, physical, and chemical data). The third one included the environmental pressures affecting the sites.

Each site was allocated to one of the five river types defined for Mediterranean Europe (ECOSTAT, 2004) which were based on catchment area, geology and hydrological regime. The river type including very large rivers (catchment area > 1000 km^2) could not be intercalibrated due to insufficient number of reference sites. The four river types which were intercalibrated were described as follows:

Type 1—small rivers (<100 km^2), siliceous geology, highly seasonal hydrological regime;
Type 2—medium size rivers (100–1000 km^2), siliceous geology, highly seasonal hydrological regime;
Type 3—small and medium rivers (<1000 km^2), non-siliceous, highly seasonal regime;
Type 4—small and medium rivers (<1000 km^2), temporary hydrological regime.