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Harmonisation of a new assessment method for estimating the ecological quality status of Greek running waters

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ABSTRACT

During the last decades, a great number of indices have been developed throughout Europe to fulfil the requirements of the Water Framework Directive (WFD) and to assess the ecological impacts of anthropogenic pressures. The development of a methodology for assessing the ecological quality status of Greek rivers and streams was urgently needed because the existing European indices were not adapted efficiently to the particular hydrological and climatic conditions of this Mediterranean region. After selecting the most appropriate typological system, four systems were tested using a different number of reference samples based on a vast number of criteria from impaired to at least impaired sites. The most suitable typological system was found to be the river types (IC) from the Mediterranean Intercalibration exercise. Reference or minimally disturbed sites to evaluate the Ecological Quality Ratio (EQR) for each river type were selectedpreviously to the development and selection of the most appropriate metrics or biotic index based on benthic communities for the assessment of the ecological quality of the rivers. In this frame, 42 European metrics and indices, were tested against a) their response to three quality gradients (undisturbed, slightly disturbed and disturbed), b) their acquisition of a low interquartile coefficientand c) a low Spearman's correlation between the metrics and indices. Hence, 9 metrics and indices were examined for their response to human pressures and the Hellenic Evaluation System 2 (HESY2) was selectedand successfully intercalibrated with the assessment methods of the other countries, using the option of indirect comparison based on near-natural reference sites (reference benchmarking). This index showed a significant correlation with some anthropogenic pressures (e.g. P-PO_4^{3-}, artificial and agricultural areas) in all IC types. HESY2 estimates also more than 86% of the moderate samples correctly and beside this, it provides a precise, explicit and simply applicable assessment of the ecological quality status in Greek streams and rivers. HESY2 is applied for the assessment of the ecological quality in Greek running waters and will be further justified considering the results of the forthcoming National Monitoring Program (2017–2022).

1. Introduction

The EU Water Framework Directive (WFD) (Directive 2000/60/EC) requires member states to prevent further deterioration, to protect and enhance the status of aquatic ecosystems and to restore all water bodies with less than good ecological status. Good ecological status is required to meet services and goods for human well-being and sustain aquatic ecosystems' life (Munné et al., 2015). The WFD demands bioassessments to be expressed as a ratio (Ecological Quality Ratio, EQR) at a five scale system between one (High) and zero (Bad). EQR is the value of an observed biological parameter for a specific type of water body to the expected value under reference conditions of the same type. According to the WFD, aquatic organisms (benthic macroinvertebrates, macrophytes, diatoms, phytoplankton and fish) are used as biological quality elements to assess the ecological quality status of European surface water bodies. Because of their sensitivity to different degrees of local disturbances, benthic invertebrates have long been used to assess environmental impacts resulting from anthropogenic activities in coastal and transitional waters and freshwater ecosystems (e.g. Borja et al., 2011; Chainho et al., 2008; Chaves et al., 2005; Medeiros et al., 2012). Twenty-eight European countries, based on a questionnaire survey, reported 297 assessment methods applied to rivers (30%), coastal waters (26%), lakes (25%) and transitional waters (19%); more than 50% of the methods were based on macroscopic plants (28%) or benthic invertebrates (26%) (Birk et al., 2012a).

In May 2001, the European Commission with the member states started a Common Implementation Strategy (CIS) to develop guidance documents for a common understanding of approaches and to limit the

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risk of inadequate application. Some of these guidance documents concern the intercalibration (IC) process, which aims at the consistency and comparability in the classification results of the ecological quality monitoring systems operated by each member state (EC, 2005). Indirect comparisons using river types and IC common metrics was applied for most of the biological quality elements in the first IC phase (2004–2008) (Birk et al., 2006; EC, 2005) and in the second one (2009–2012) (Bennett et al., 2011; EC, 2011). According to this method, a common multimetric assessment index was generated by specific European countries, and the national assessment methods were compared against this common index focusing on the High/Good and Good/Moderate quality boundaries (Buffagni et al., 2006). The option, however, of the direct comparison between countries using the same data and the same numerical evaluation is rarely used (Aguiar et al., 2014; Gassner et al., 2014; Sandin et al., 2014). Thus, as the implementation of assessment methods did not follow the same approaches due to biogeographic, typological and data acquisition differences, the biological data of different countries had to be compared with concern (Birk et al., 2013) and a benchmarking procedure was applied in order to correct the differences above. The IC exercise led to the development of new innovative approaches (Birk et al., 2013) with three alternative methodologies (EC, 2015), helping the member states to acquire correct and comparable tools for monitoring and assessment of the state of their water bodies and to develop efficient river basin management plans as to future environmental changes (Birk et al., 2012a). The IC process (1) supports the translation of member states' assessment systems making different methods comparable, (2) is used to harmonize water quality boundaries at an extended geographical scale (e.g. the Mediterranean region) or even a pan-European scale (for very large rivers), (3) is based on tolerance, richness/diversity and abundance information which may reflect a variety of impacted types and (4) encourages the use of IC common metrics (ICM) and multimetric indices (Buffagni et al., 2007). The choice of the most appropriate IC option depends on the similarities of the assessment methods of participating member state (the methods concept, reference criteria, sampling procedures, water body types and anthropogenic pressures addressed) (Poikane et al., 2015). Consequently, benchmarking could be based on near natural reference sites (reference benchmarking) (Pardo et al., 2012), on sites at similar impairment levels (alternative benchmarking) (Birk et al., 2012b) or in using pressure–response gradients (continuous benchmarking) (Birk et al., 2013).

The IC exercise is undertaken within Geographical Intercalibration Groups (GIGs) sharing common types among the countries (Poikane et al., 2014). The Mediterranean GIG (MedGIG) identified five river types covering all the countries of this geographical region (van de Bund et al., 2004), namely (1) small rivers with mixed geology and highly seasonal flow (R-M1 type), (2) medium rivers with mixed geology and highly seasonal flow (R-M2 type), (3) large rivers with mixed geology and highly seasonal flow (R-M3 type), (4) small/medium mountainous rivers with non-siliceous geology and seasonal flow (R-M4 type) and (5) small temporary rivers with mixed geology (R-M5 type). In Greece, small and medium rivers with mixed geology, siliceous or carbonate geology (R-M1, R-M2 and R-M4) were studied by Skoulikidis et al. (2004), Artemiadou et al. (2008) and Ntislidou et al. (2013). It should be noted that temporary river basins have been occasionally monitored and assessed for their ecological status (EQS) (e.g. Argyroudi et al., 2009; Kalogianni et al., 2017; Skoulikidis et al., 2011), although they cover approximately 40% of the entire country (Skoulikidis et al., 2017).

The essential requirement for the IC process is the definition of reference sites and samples, since typology and type specific reference conditions are crucial for the determination of the EQR values of both metrics and indices used for the EQS assessment. According to the CIS Guidance Document n° 30 (EC, 2015), only assessment methods meeting the requirements of the WFD can be intercalibrated. The MedGIG successfully finalized the IC process for river macroinvertebrates in 2012, which was completed in two phases (EC, 2008; EC, 2013). Although Greece participated in the first phase for the types R-M1, R-M2 and R-M4 (EC, 2007), for the second one it did not contribute with data.

Hence, the aim of this work was to establish an ecological assessment system for Greek rivers based on benthic macroinvertebrates by a) defining and establishing reference conditions, b) selecting the most appropriate typological system and c) developing and/or harmonising a biotic metric or index to assess the ecological quality status of rivers. The classification method was verified for WFD compliance and IC feasibility and the class boundaries were intercalibrated with the accepted boundaries from the MedGIG IC exercise (MedGIG, 2012) according to the procedure of the CIS Guidance Document n° 30 (EC, 2015).

2. Material and methods

2.1. Database and sampling methods

A nation-wide database consisting of 612 sites (Fig. 1) (1500 samples) from 293 rivers,streams and tributaries (164 basins) throughout Greece has been set, including typology and sampling site information (physicochemical and hydromorphological data) and sampling data (e.g. benthic macroinvertebrate abundance, metrics, indices). Samples covered a wide temporal variability and were collected from a four-year survey for the Greek National Water Monitoring Program (summer 2012–summer 2015) and from studies conducted in northern and central Greece (see Lazaridou and Ntislidou, 2015). The database covered the IC river types R-M1, R-M2, R-M4 and R-M5 accounting for 411, 537, 394 and 158 samples, respectively.

Benthic macroinvertebrates were collected with the semi-quantitative 3-min kick/sweep method (Armitage and Hogger, 1994) plus a 1-min effort when bank vegetation existed (Kemitzoglou, 2004; Wright, 2000), using a 250 mm × 230 mm, D-shaped pond net (0.9 mm mesh size) (EN 27828:1994). During the 3-min sampling, all microhabitats were covered proportionally according to the matrix of possible river habitats (modified from Chatzinikolaou et al., 2006). Sampling was conducted biannually, during high flow (spring) and low flow (summer, autumn). Taxa were identified atthe family level, except for Ostracoda, Hydracarina, Aranae and Oligochaeta (apart from Tubificidae) and the relative abundance of each taxon was determined.

Physicochemical elements i.e. dissolved oxygen (DO, mg l^{-1}), water temperature (°C), pH and conductivity (μS.cm^{-1}) were measured in situ. Biological oxygen demand (BOD_5, mg l^{-1}) and nutrients ($N\text{-}NO_2^-$, $N\text{-}NH_3^+$, $N\text{-}NH_4^+$and $P\text{-}PO_4^{3-}$, mg l^{-1}) were measured following APHA (1985) or a photochemical method with a Nova 400 Analyzer by Merck. The Habitat Modification Score (HMS) from the River Habitat Survey (Raven et al., 1998) was assessed for each site to evaluate hydromorphological quality.

2.2. Reference site selection and typology

Reference samples were selected in accordance with the European guidelines (MedGIG, 2012; van de Bund, 2009) and referred either to high (spring) or low (summer, autumn) flow period or both. Initially, for the establishment of reference samples three databases (A, B and C with 73, 54 and 149 reference samples respectively) were designed, each one ranging from at least disturbed to more disturbed sites based on a vast number of selection criteria (Fig. 2). Database B had the strictest criteria and the least disturbed sites and reference samples from Database C were used as benchmark samples. Then, four typological systems were tested to find the most appropriate for Greece:

a) System A, as proposed by the WFD.
b) A typological system based on fish biogeography used in some River Basin Management Plans (RBMPs) of Greece (RBMP typology).