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Original article

Choosing the best method for stream bioassessment using macrophyte communities: Indices and predictive models

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ABSTRACT

The bioassessment and monitoring of the ecological status of rivers using macrophytes has gained new momentum since macrophytes were recognised as biological quality elements for the implementation of the European Water Framework Directive (WFD; EU/2000/60).

Our objectives were to test the suitability of two predictive modelling approaches to macrophyte communities as a tool for water quality assessment, and to compare their performance with other more common approaches—the use of macrophytes as indicators of the trophic status of rivers and multimetric indices. We used floristic and environmental data that were collected in the spring of 2004 and 2005 from around 400 sites on rivers across mainland Portugal, western Iberia.

We build two predictive models: MACPACS (MACrophyte Prediction And Classification System) and MAC (Macrophyte Assessment and Classification) based on RIVPACS and the BEAST methods, respectively. Whereas MACPACS is derived from taxa occurrence data, MAC uses a quantitative measure of taxa abundance. Both models showed good performance in predicting reference sites to the correct group and low rate of misclassification errors. However, they performed differently. MAC depicts a reliable response to the overall human-mediated degradation of fluvial systems, as does the multimetric index (RVI, Riparian Vegetation Index), but MACPACS presented only a poor correlation with the Global Human Disturbance Index and with the nutrients input. The incorporation of abundance data in vegetation predictive models appears to be particularly important to the detection of high levels of degradation. The values for correlations with physical–chemical pressure variables were lower than expected for MTR (Mean Trophic Rank) due to an insufficient number of scoring species found in Portuguese fluvial systems. Our results suggest that the most effective methods for bioassessment in Mediterranean-type rivers are either the RVI or the MAC predictive model.

1. Introduction

The translation of floristic data into ecological-based systems for the assessment of river quality has been a primary challenge for aquatic plant experts and conservation scientists since the late 1980s. Numerous aquatic plant-bioassessment methods have been developed using diverse aspects of plant and vegetation attributes, such as the richness and abundance of species assemblages (Haslam and Wolseley, 1987; Lange and van Zon, 1983; Stromberg et al., 2006), vegetation structure (e.g. González del Tánago and García de Jalón, 2006), species attributes and functional groups (e.g. Brazner et al., 2007; Ferreira et al., 2005; Mack, 2007; Rothrock et al., 2008), and the use of macrophyte species as indicators of trophic status (e.g. Haury et al., 2006; Holmes et al., 1999; Schneider and Melzner, 2003). Also, different types of data treatment have been used to relate floristic changes and human disturbance, including multivariate analysis (e.g. Dodkins et al., 2005; Schaumburg et al., 2004), classification and decision trees (e.g. Cohen et al., 2005), and univariate methods (e.g. Hering et al., 2006). Having said this, most of the operational bioassessment methods using river plants are based on sensitive species (i.e. indicator indices) or on functional groups (i.e. multimetric indices).

The new European water legislation—the Water Framework Directive (WFD; European Comission, 2000)—includes macrophytes in the biological quality element of aquatic flora. This has promoted the development of a number of national assessment methods and a more intensive exchange of information between countries and experts than had been the case with previous national and transnational programmes. In Portugal, the plant-based assessment methods (e.g. Aguiar et al., 2004; Espírito-Santo et al., 2000; Ferreira et al., 2004) that were initially proposed were simple and user-friendly, based on field expertise, and lacked a river

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typological framework and a reference condition approach *sensu* Reynoldson et al. (1997). Subsequently, multivariate and multimetric approaches were used to overcome these limitations. Ferreira et al. (2002) used the Bray–Curtis multivariate distance and an overall canonical procedure to identify reference conditions and measure deviation due to perturbation; in another study the Iberian Multimetric Plant Index (IMPI; Ferreira et al., 2005), a partial canonical correspondence analysis of the floristic data with anthropogenic variables, was used to account for environmental differences. Both the aforementioned studies were conducted on a small scale and restricted to semi-arid southern rivers. The quality of the results then led IMPI to be applied to nationwide data for the implementation of the WFD in order to obtain a spatial upgraded index (Riparian Vegetation Index, RVI; Aguiar et al., 2009).

Predictive models are an alternative approach to indices, and comprise a sequence of statistical steps with the aim of comparing the observed biota at a test site with the expected/predicted biota from a set of sites representing the reference condition for a given area. These models have been developed and applied worldwide in the ecological assessment of streams, mainly in relation to macroinvertebrate communities (e.g. Feio et al., 2007a, 2009a; Kokeš et al., 2006; Poquet et al., 2009; Reynoldson et al., 1995; Simpson and Norris, 2000; Wright, 1995), but also with diatoms (Chessman et al., 1999; Feio et al., 2007b, 2009b; Mazor et al., 2006; Philibert et al., 2006), and fishes (Joy and Death, 2002; Mugodo et al., 2006). However, as far as we know little effort is being made to develop predictive modelling with macrophytes for stream-quality assessment.

In the light of these studies it is important to analyse the performance of the aforementioned approaches.

With the present study we therefore aimed to: (i) test the suitability of two predictive modelling approaches to macrophyte communities as a water-quality assessment tool; and (ii) compare their performance with other more common approaches using river plants—the use of macrophytes as indicators of trophic status and multimetric indices. We applied the methods originally used for macroinvertebrates to develop the MAC (Macrophyte Assessment and Classification) and the MACPACS (MACrophyte Prediction And Classification System), which are respectively based on the BEAST (Reynoldson et al., 1995, 1997) and RIVPACS (Wright, 1995, 2000) methods. We used the Mean Trophic Rank (MTR; Dawson et al., 1999; Holmes et al., 1999), which was originally developed to fulfil the requirements of the Urban and Waste Water Directive in the UK (91/271/EC), and was designed to respond to nutrient enrichment; and as a multimetric approach, we used the Riparian Vegetation Index (Aguiar et al., 2009), a typological-adapted index, based on structural and functional components of the riparian and aquatic vegetation.

2. Materials and methods

2.1. Site selection and sampling

Data on macrophyte species composition and disturbance variables was collected from around 400 sites on rivers across mainland Portugal, western Iberia (Fig. 1). Apart from a few mountainous areas and the occidental northern part of the country, Portugal has a Mediterranean climate that is characterized by a strong seasonal and inter-annual variability of rainfall patterns, with mild winters and dry summers. Due to a water deficit in the summer season and to historical features of human occupation, rivers and riparian woods in Iberia have been impacted for millennia, and pristine locations no longer exist. Major human disturbances are related to water diversion and regulation and with deforestation and agricultural land use of the catchment (Hooke, 2006).

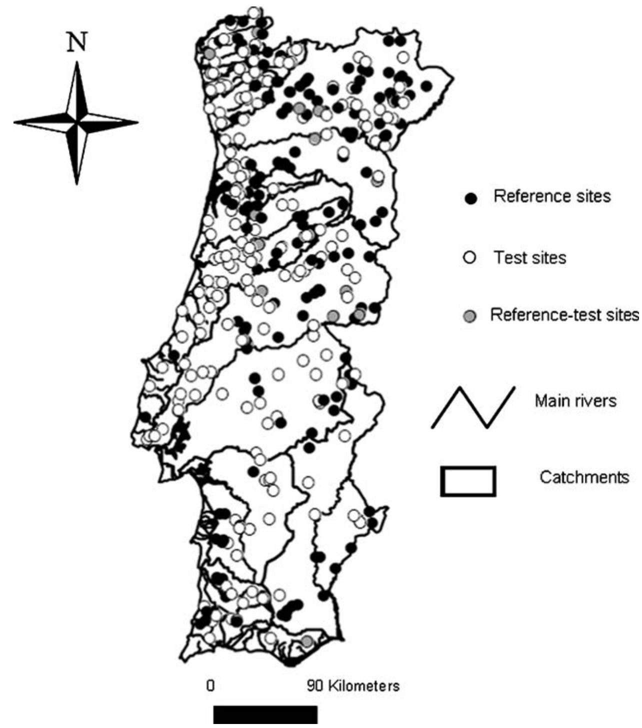

Fig. 1. Location of all catchments and main rivers in Portugal with respective reference (a) and test sites (b) and localization of Portugal in Europe.

Both reference and test sites (i.e. impacted sites) were previously selected following a preliminary screening using digital databases from the Water Institute (INAG IP) and the Portuguese Water Resources Information System (http://www.snirh.pt), expert judgement, and prospective field campaigns. The reference sites met the common criteria of: (i) good chemical quality (nitrate, nitrite, phosphates, ammonia, pH, BOD5, COD)—i.e., values allocated to the A or B categories of water for multiple human uses (INAG IP, http://snirh.inag.pt/snirh/dados_sintese/qual_ag_anual/classificacao.html); (ii) minimal changes in the riparian zone; (iii) no signs of recent changes in the channel morphology and all expected habitats present; (iv) low levels of urbanization and industrial activities in the catchment area; (v) minimum impacts on the natural hydrological regime; and (vi) low levels of fine sediment load. The quality status of the sites was pre-classified using a composite pressure score (Global Human Disturbance Index, GHD), 1–5 ranked, from four variables at the segment level and four variables at the site level (see Table 1), as used in Pont et al. (2006). A river segment is defined as 1 km for small rivers (catchment <100 km^2), 5 km for medium-sized rivers (100–1000 km^2), and 10 km for large rivers (1000–10,000 km^2). Other disturbance variables were recorded or estimated for each site using available information from national databases and field assessment of potential site stressors. These include several indicators of riparian corridor condition, morphological changes in the channel and bank, land use in the surroundings of the sites, and also indices of biological condition (e.g. IBMWP and ICM for macroinvertebrates; Alba-Tercedor and Sánchez-Ortega, 1988) and hydromorphology, namely those obtained using the River Habitat Survey methodology (Environmental Agency, 2003), the Habitat Quality Assessment (HQA), and the Habitat Modification Score (HMS) and the Riparian Forest Quality index (QBR; Munné et al., 2003). A one-day field campaign in May (middle of sampling period) 2004 and May 2005 was carried out to collect water for chemical analysis (e.g., nitrates, total N, ortho-phosphates; Table 1).