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Water quality assessment of Portuguese streams: Regional or national predictive models?

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ABSTRACT

The European Water Framework Directive (WFD 2000) brought the need in European Union countries to establish consistent quantitative methods for the water quality assessment of streams, using aquatic communities. With this work we aimed to develop predictive models using macroinvertebrate communities that could be used in Portugal as an alternative to the more traditional indices and metrics. We used data from 197 reference sites and 174 sites suspected of being impaired, which were obtained in a national survey conducted in 2004–2005 by the Instituto da Água (INAG, Portugal). The spatial scale at which to develop predictive models was an issue to address because the Portuguese territory covers a wide variety of landscapes in a small area. We built three models using the AUSRIVAS methods, a national and two regional (North and South) models that produced acceptable assessments. However, the regional models, predicted more taxa than the National model, were more accurate and had lower misclassification errors when placing sites into pre-defined groups. The regional models were also more sensitive to some disturbances related to water chemistry (e.g., nutrients, BOD_5, oxidability) and land use. The exception was for the northern costal area, which had few reference sites. In the northern costal area the National model provides more useful results than the regional model. The 5-class WFD quality assessment scheme, adapted from the AUSRIVAS bands, appears to be justified because of the good correspondence between the human disturbance level and the classes to which test sites were allocated. Elimination of the AUSRIVAS X band in the WFD scheme has produced a clearer relationship. The predictive models were able to detect a decline in river health, responded to several causes of degradation and provided site-specific assessments.

1. Introduction

The use of bioindicators to assess river health is becoming legislated and mandatory in Europe with the introduction of the Water Framework Directive (WFD) (Directive 2000/60/CE, 2000). Macroinvertebrates were selected as one of the WFD biological quality elements (BQE) because of their ubiquity, easy sampling methods, long aquatic life phases that allow the assessment of changes in river condition through time, and taxonomic diversity with a variety of sensitivity to environmental stress (Hellawell, 1977; De Pauwn and Vanhooren, 1983; Furse et al., 2006). Fundamentally, the BQE stipulated in the WFD do not specify methods but should be developed to meet the need to detect changes in river health, indicate causes of degradation and measure the success of stream rehabilitation.

In Portugal, the most used assessment method based on macroinvertebrates has been the biotic index IBMWP (former

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BMWP; Alba-Tercedor and Sánchez-Ortega) but other alternative methods have also been developed following the multimetric (Pinto et al., 2004) and predictive modeling approaches (Feio et al., 2007a,b). Predictive models, although conceptually simple, are a powerful statistical tool developed for the bioassessment of rivers at various scales (site to nationwide) and used in assessment schemes around the world (Wright et al., 1984; Reynoldson et al., 1995; Parsons and Norris, 1996; Kokeš et al., 2006; Feio et al., 2007a,b). Through predictive models the observed fauna at a test site is compared with the fauna expected/predicted from a set of sites representing the reference condition for a given area (Reynoldson et al., 1997; Simpson and Norris, 2000).

RIVPACS (River InVertebrate Prediction And Classification System, Wright et al., 1984; Armitage et al., 1987; Wright, 1995), developed in the United Kingdom, led the way with broad-scale assessment using the predictive modeling approach. The spatial scale at which to develop predictive models needs addressing in a small but spatially variable country such as Portugal (Mainland Portugal occupies 91,985 km^2). A single model could be used as was done in U.K. (Wright, 1995). Yet, the Portuguese territory has a wide diversity of landscapes and stream types that could represent strong environmental gradients across the country (http://www.iambiente.pt/atlas/est/index.jsp). In Australia, its large size and varied landscape meant regional models were needed (Simpson and Norris, 2000).

The biological assessment method adopted for the WFD needs to align with pre-existing requirements (Directive 2000/60/CE, 2000). Typically, the RIVPACS/AUSRIVAS models produce a site-specific list of the expected taxa and an Observed/Expected ratio (O/E). The O/E scores for each test site are then allocated to a condition band where the deviation of the assemblage from that expected represents the biological condition of the stream. Band A corresponds to sites similar to reference condition and bands B, C and D represent decreasing condition corresponding to increasing levels of degradation. The WFD also requires a similar grading scheme for the assessment system under development, where the range of ecological quality scores could be divided into 5 classes. The first class represents reference condition (high ecological status) and another 4 classes indicate increasing levels of degradation (good, moderate, poor and bad) (Directive 2000/60/CE, 2000; Furse et al., 2006). Thus, the AUSRIVAS system seemed appropriate for adoption in Portugal since it allows the assessment of stream water quality based on changes in macroinvertebrates community structure; gives further information such as the site-specific expected taxa list; produces an ecological quality ratio (O/E) as required by the WFD; simplifies the interpretation of the results through a banding scheme and can be applied regionally.

The objectives of this study were: (1) to develop an AUSRIVAS type biological assessment scheme that uses the 5 WFD classes of ecological status to evaluate the condition of Portuguese rivers (excluding islands) at a national/broad scale; (2) to build regional/local-scale models, and (3) to determine which approach (regional/local scale or national/broad scale) is better suited to biological assessments throughout mainland Portugal.

2. Methods

2.1. Study area

Portugal is located on the west side of the Iberian peninsula with its borders defined by mountains and rivers. The interior and the north of the country are mountainous and lowlands to the south and coastal regions. The highest mountain is Serra da Estrela (2000 m). The larger Portuguese rivers, Tagus and Douro, have their sources in Spain and the largest river entirely in Portuguese territory is the Mondego River. The Portuguese climate is temperate Mediterranean in the south (precipitation below 600 mm yr^{-1}) and Atlantic-humid in north and western coast (precipitation >2800 mm yr^{-1}; Atlas do Ambiente). In the NE the precipitation (1000–3000 mm yr^{-1}) is often in the form of snow during winter. The coastal area is densely populated and largely cultivated while the inlands have scattered villages, less industry and agriculture.

2.2. Field sampling

The data used in this work were collected throughout Portugal (excluding islands, Fig. 1). Several teams under the supervision of the Instituto da Água (Portugal), selected and sampled 197 reference sites (good condition or best available for selected stream types, Fig. 1). Sites were selected to represent the 27 stream types established by the Instituto da Água using the WFD System B (with the exception of rivers catchments >1000 km^2). According to the WFD system all Portuguese streams were originally grouped according to their hydromorphological the characteristics, geology, altitude and catchment area, latitude and longitude, and additional optional variables slope, runoff, precipitation, mean annual temperature and air temperature range (Directive 2000/60/CE, 2000; Alves et al., 2006). The reference condition for sites was defined by criteria based on previous knowledge, expert judgment and collected information. The reference sites met the common criteria of: (1) good chemical quality (nitrate, nitrite, phosphates, ammonia, pH, BOD_5, COD), i.e., values allocated to the A or B categories for water of multiple uses (INAG, http://snirh.inag.pt/snirh/dados_sintese/qual_ag_anual/classificacao.html); (2) minimal changes in the natural composition of the riparian corridor; (3) no signs of recent changes in the channel morphology and all expected habitats present, and (4) low levels of urbanization and industrial activities in the catchment area. Additionally, 174 sites suspected of being impacted were used to test the method and an additional 16 reference sites were used to validate the method. These sites were also distributed across the country and were sampled using the same procedures as for the reference sites used to develop the models (Fig. 1). A 50 m reach representative of the stream's habitat diversity, including a riffle (whenever that was possible) was defined for each site. Macroinvertebrates were sampled with a hand-net (0.25 m opening and 500 μm mesh size) and each sample comprised six composite collections. Collections were proportional to the area occupied by the most representative habitats (stones, sand and silt, boulders (>256 mm), submerged plants and algae) and each collection defined by an area 1 m × 0.25 m. The composite sample was preserved with formalin (4%) in the field and the invertebrates were later sorted in the laboratory under a