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Research article

The paradox of expert judgment in rivers ecological monitoring

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ABSTRACT

A great investment has been done in the last decades in the development of numerical and qualitative assessment methods to classify the ecological quality of water bodies. Yet, in spite of all attempts to avoid subjectivity, expert judgment is still used at numerous steps of the ecological classification and is considered by some authors as indispensible for management purposes. Thus, the aim of this study is to test the hypothesis that expert judgment, when done by the adequate experts (limnologists/river ecologist) with experience in the study area (i.e., natural conditions and expected communities), could be as good as quantitative indices and measures (i.e., result in the same classification), but quicker and with lower cost. For that we compared the classifications (on 13 aspects of rivers ecosystems) attributed by two experts to 20 sites (10 each) located in their study areas, with the classifications of ecological quality based on biological indices (for invertebrates and diatoms), hydromorphology and water chemistry, calculated by an independent team. Our results show that assessments made by experts and those calculated through indices (biological quality and hydromorphology) are globally very similar (RELATE test; Rho $= 0.442$; $p < 0.001$, 999 permutations). Most differences were of one class and experts tended to attribute a better condition than indices to the best quality sites but a worse condition to the worse quality sites. A Principal Components Analysis revealed that sites to which experts attributed a moderate quality had higher nitrate concentration and pH but were well oxygenated. The sites classified as poor and bad where those with stronger modifications in their habitats (given by the higher values of HMS). The difference between experts and indices is small but still represents 15% of sites, and includes both situations: the experts or the indices lead to the need of measures (i.e., classifications below class Good). Experts' evaluations on hydromorphological conditions of the channel and margins are also significantly correlated with the quality assessments made by the field team that has no experience in the study area ($Rh_0 = 0.518$; $p = 0.001$; 999 permutation), indicating geographic independence in the expert judgment. We concluded that expert judgment could be used in the determination of streams and rivers ecological quality, saving money and time and helping to redirect monitoring funds to actual implementation of restoration measures. Yet, classification' scoring methods may still be useful for a better targeting of restoration measures.

1. Introduction

In the past two decades a strong effort was put in the development of independent, accurate and objective (numerical and qualitative) assessment methods to classify the ecological quality of water bodies (rivers, estuaries, coastal waters), based on their aquatic communities, hydromorphology and water chemistry (e.g., Wright et al., 2000; Dolédec and Statzner, 2010; Aguiar et al., 2011; Feio and Poquet, 2011; Flor-Arnau et al., 2015). In Europe, the Water Framework Directive (European Commission, 2000) contributed highly to that progress and a great investment was made in the development of biological assessment methods comparable across member states (Borja and Dauer, 2008; Poikaine et al., 2011; Pardo et al., 2012; Birk et al., 2013; Feio et al., 2014a,b; Almeida et al., 2014; Aguiar et al., 2014). In consequence, the implementation of a monitoring plan requires nowadays a great investment in fieldwork, laboratory work and data analyses and involves numerous researchers and technicians

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and diverse and expensive equipment (e.g., boats, cars, electric fishing devise, microscopes, computers, software).

In spite of all efforts to avoid subjectivity, expert judgment is still present at numerous stages of the process of ecological classification: in the definition of reference conditions and selection of reference sites (Muxika et al., 2007); selection of relevant metrics, data transformation and definition of thresholds (Scardi et al., 2008); establishment of tolerance levels for fish (Segurado et al., 2011); evaluation of indices performance (Weisberg et al., 2008); determination of the need of additional monitoring from results of indices or models (Scardi et al., 2008); elaboration of restoration plans (Convertino et al., 2013). The term is so often used in rivers assessment that a Google search with the keywords "rivers" and "expert judgment" produces 137 000 results (54 800 in scientific publications; 21 March 2016).

In fact, even the concepts of ecological quality although intuitive are also vague and difficult to translate into a set of rules or a concise definition (Scrimgeour and Wicklum, 1996; Ode et al., 2016). Even in the WFD, where a strong effort was put in definitions, the term is applied but not explained; what is defined is the quality status, with high ecological quality meaning that there are none or only minor alterations in the quality elements (biological, physical and chemical and hydromorphological) compared to what should be found in non-disturbed conditions. This is similar to former notions of ecological integrity (Karr and Dudley, 1981): the capability of supporting and maintaining a balanced, integrated, adaptative community of organisms and functional organization comparable to the natural habitat of the region. But how much modifications can be included in the definition of "minor" - and which is the "natural" status of an ecosystem is sufficiently ambiguous and requires a great effort of agreement among scientists (e.g. Stoddard et al., 2006; Hawkins et al., 2010; Pardo et al., 2012; Feio et al., 2014b; Birk et al., 2012).

So, why is the expert judgment so disregarded, i.e. considered something to avoid, and at the same time so frequently used in ecological assessment of rivers? First arguments against its use are related to the problem of variability in expert judgment. That leads to the definition of "expert", as experts with different backgrounds may highlight different aspects leading to different evaluations (Weisberg et al., 2008; Burgman et al., 2011). Cognitive science suggests that experts are those with rare skills that develop only after much instruction, practice and experience (Camerer and Johnson, 1997). For the particular case of rivers ecological assessment, a large experience with rivers ecosystems and aquatic communities and knowledge of the study area should be required.

Some authors acknowledge that when time and resources are scarce expert judgment is a good solution (Burgman et al., 2011), which is presently the situation in Europe and worldwide due to the economic crisis. Our aim here is to test the hypothesis that expert judgment, when done by the adequate experts (limnologists/river ecologists) with experience in the study area (i.e., natural conditions and expected communities), could be as good as quantitative indices and measures (i.e., result in the same classification), but quicker and with lower cost.

2. Material and methods

Twenty stream sites were selected for this study, located in two climatic and geomorphological regions in Portugal: 1) in the north interior, where the climate is temperate with continental influence and rivers (permanent) run at 300 m of average altitude over siliceous rocks (INAG, 2008a); 2) in the south of Portugal where the climate is typically Mediterranean (high mean annual temperatures and low precipitation), the landscape is dominated by small hills and rivers (mostly temporary) run over siliceous and limestone beds at an average altitude of 180 m (INAG, 2008a). Within each region we selected 10 study sites (total of 20), covering different degrees of degradation (according to suggestions of experts), including potential high quality sites. Additional characterization of the study sites is shown in Table 1.

2.1. Experts' evaluations

We asked two Limnology experts to classify, based on the observation of sites, the ecological quality of the 10 study sites located in their usual study area, following a questionnaire (Table 2) with 13 questions. The questionnaire covers the most important aspects of rivers ecosystems that should be included in ecological monitoring programs, according to the WFD: (a) aquatic communities; (b) river hydromorphology; and (c) water quality. Thus, the questions addressed: **Q1**. Global ecological quality (reflecting an overview of the stream but not necessarily an average value of the remaining questions); **Q2**. Macroinvertebrate communities; **Q3**. Diatom communities; **Q4**. Fish communities; **Q5**. Plant (macrophytes) communities; **Q6**. Riparian vegetation integrity (considering cuts); **Q7**. Riparian vegetation composition (considering exotic and

Table 1
Additional information on the 20 study sites (N for northern sites; S for southern sites).

Sites	Latitude (N)	Longitude (W)	Stream width (m)	Stream depth (m)	Water temperature (°C)	Current velocity (m/s)	Conductivity (μS/cm)	pH
N1	41°21′52″	7°55′41″	4	0.27	16.6	0.2	26	7.0
N2	41°27′45″	8°07′43″	2.5	0.27	12.2	0.4	43	6.5
N3	41°31′26″	7°13′20″	20	0.37	19.6	0.4	54	9.1
N4	41°24′31″	7°36′31″	4.5	0.40	12.7	0.1	25	6.8
N5	41°36′02″	8°28′16″	6.7	0.47	17.2	0.3	96	7.0
N6	41°22′25″	8°18′38″	8.5	0.57	18.3	0.0	158	7.6
N7	41°22′15″	8°16′30″	6	0.42	17.3	0.2	137	7.4
N8	41°23′18″	8°41′25″	8	0.57	18	0.0	233	7.3
N9	41°21′60″	8°41′50″	12	0.37	20.2	0.5	250	7.5
N10	41°20′44″	8°33′50″	10	0.28	20.1	0.3	194	7.4
S1	37°19′16″	8°40′24″	2.5	0.17	15.8	0.4	166	7.3
S2	37°24′39″	7°56′26″	3.7	0.24	15.8	0.0	255	7.7
S3	37°12′27″	8°00′28″	3.5	0.38	17.1	0.1	722	7.3
S4	37°19′38″	8°44′57″	2.6	0.19	16.9	0.5	226	7.1
S5	37°31′39″	8°00′08″	6	0.30	19.2	0.0	300	7.9
S6	37°23′26″	8°39′21″	3	0.34	16.6	0.2	183	7.2
S7	37°11′22″	8°01′40″	3	0.22	18.1	0.3	647	8.2
S8	37°12′16″	8°32′11″	2.5	0.33	18.5	0.1	316	8.1
S9	37°11′12″	8°41′34″	2.5	0.26	16.6	0.0	454	6.9
S10	37°25′58″	8°45′04″	3.5	0.42	15.8	0.3	304	7.2