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Ecological and ecotoxicological responses in the assessment of the ecological status of freshwater systems: A case-study of the temporary stream Brejo of Cagarrão (South of Portugal)

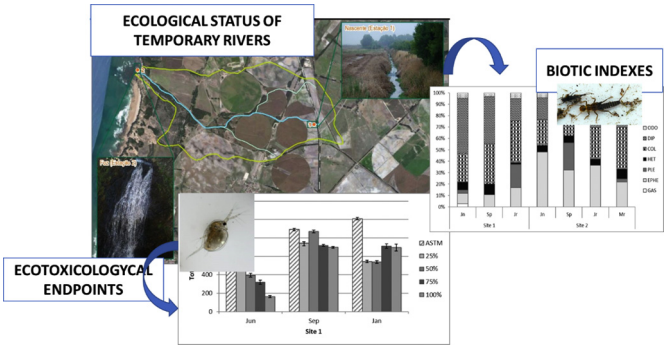
P. Palma [a,b,*], C. Matos [a], P. Alvarenga [c], M. Köck-Schulmeyer [d], I. Simões [a], D. Barceló [d,e], M.J. López de Alda [d]

[a] Departamento de Tecnologias e Ciências Aplicadas; Escola Superior Agrária, Instituto Politécnico de Beja, 7800-295 Beja, Portugal
[b] ICT, Institute of Earth Sciences, University of Évora, Rua Romão Ramalho 59, Évora, Portugal
[c] LEAF, Centro de Investigação em Agronomia, Alimentos, Ambiente e Paisagem, Instituto Superior de Agronomia, Universidade de Lisboa, Tapada da Ajuda, 1349-017 Lisboa, Portugal
[d] Institute of Environmental Assessment and Water Research (IDAEA), Spanish Council for Scientific Research (CSIC), Jordi Girona 18-26, 08034 Barcelona, Spain
[e] Catalan Institute for Water Research (ICRA), H2O Building, Scientific and Technological Park of the University of Girona, Emili Grahit 101, 17003 Girona, Spain

HIGHLIGHTS

- Multi-metric indices classify the ecological status as reasonable to mediocre.
- Sublethal ecotoxicological endpoints complement the biotic indices.
- Dry phase of the stream occurred very early comparing with previous years.
- Stream with risk to the ecosystem and to public health
- Temporal periods with toxic effects for crustaceans' species and biodiversity compromised.

GRAPHICAL ABSTRACT



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ABSTRACT

The objective of the study was to assess the integrated use of macroinvertebrate indexes and ecotoxicological parameters in the evaluation of the ecological status of a temporary stream with a strong agricultural influence. Water quality was analysed at two sampling sites along the stream, considering: chemical supporting parameters; hazardous substances (pesticides); benthic macroinvertebrate communities, through quality (Iberian Biological Monitoring Working Party and Iberian Average Score Per Taxon) and multi-metric indices (Southern Portuguese Index of Invertebrates and Ecological Quality Ratio); and ecotoxicological responses using lethal and sub-lethal bioassays. The water chemical characterization showed high levels of organic matter and nutrients, mainly in the dry period ((biochemical oxygen demand (BOD_5): 18.5–25.5 mg L^{-1}, chemical oxygen demand (COD): 60.8–193.7 mg L^{-1}; total phosphorus (TP): 0.17–0.33 mg L^{-1})), which may compromise the support of biological life. In accordance with the physicochemical results, the stream had an ecological status less than good. Of the 25 pesticides analysed, only five, namely terbuthylazine, 2-methyl-chlorophenoxyacetic acid, bentazone, mecoprop and metolachlor were quantified. In general, the concentrations of pesticides detected were low, except at the source of the stream in January 2012 (sum of pesticides 2.29 μg L^{-1}), mainly due to the concentration of bentazone (1.77 μg L^{-1}), both values surpassing the European Commission threshold values. The analysis of benthic macroinvertebrates showed low levels of abundance and family diversity, with communities dominated by resistant groups to organic pollution and pesticides, such as the Chironomidae family. In

* Corresponding author at: Department of Applied Sciences and Technologies, Escola Superior Agrária - Instituto Politécnico de Beja, Rua Pedro Soares S/N, Apartado 6155, 7800-295 Beja, Portugal.
E-mail address: ppalma@ipbeja.pt. (P. Palma).

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general, the reproduction ecotoxicological results showed a very marked decrease in the number of juveniles per female. The Spearman correlation identified pesticides, namely MCPA ($R = -0.89$; $p < 0.05$), as the main responsible for the observed effect. The results showed the linearity and complementarity of the two groups of biological responses, allowing to cover the interactions between the ecosystem's species and the different types of pollutants.

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1. Introduction

Nowadays, the preservation of the structure and function of freshwater ecosystems is essential to ensure economic, cultural, and recreational benefits for human population (Turner and Daily, 2008), and to guarantee the maintenance of ecological balance with the protection of biodiversity (Poff et al., 1997; Naiman et al., 2008). Nowadays, the global change scenario, which entails with the appearance of new stressors, namely changes of climatic patterns (including drought and temperature increase) or of economic, social, and demographic stressors, may influence negatively the quality of freshwater systems incrementing its scarcity and degradability (Stevenson and Sabater, 2010). All these new stressors and deviations impose new challenges for water management, which remain one of the keys for the next decades (Schinegger et al., 2012). Consequently, the implementation of appropriate management actions for each type of freshwater ecosystem ((wetlands, permanent rivers, temporary rivers and streams, and heavily modified waters bodies (HMWB)) requires periodic reviews of water policies and of monitoring programs (Araújo et al., 2014). Moreover, at present, some of these groups of freshwater ecosystems, namely, temporary waters, remain among the least studied freshwater systems worldwide (Acuña et al., 2014), with no parameters and standard values for the good chemical and ecological status. In fact, the Water Framework Directive (WFD) does not integrate assessment parameters for European Mediterranean (EU-Med) temporary waters (systems that are normally dry, at least during a part of the year; Gallart et al., 2016), since many of them are very small (lower than the stated threshold size of 50 ha; Van den Broeck et al., 2015; Nikolaidis et al., 2013). Despite this reality, temporary freshwater systems represent an important role in the Mediterranean region, once they constitute the most dynamic, complex and diverse systems concerning: (a) the hydrological regime (perennial, intermittent, which dry to a series of disconnected pools, or ephemeral, which dry completely; Bonada et al., 2007; Gallart et al., 2012); (b) the chemical characteristics, with great variability in the structural parameters and hazardous substances concentrations (Arenas-Sánchez et al., 2016; Petrovic et al., 2011); and (c) the biodiversity, housing both general opportunistic species, as well as temporary ponds species, which are extremely rare, with unknown mechanisms of resistance to extreme conditions (Cottarelli et al., 2010; Acuña et al., 2014; Van den Broeck et al., 2015). Moreover, under climate-change conditions, temporary freshwater systems probably may represent, the most dominant surface-water bodies of the Mediterranean region (Skoulikidis et al., 2017), giving them a major importance as source of water for local people and their livestock and agricultural activities, and, because of that, providing valuable ecosystem services including wildlife habitat, nutrient flux to adjacent ecosystems, flood control, water filtration, and cultural services (Calhoun et al., 2017).

To manage this kind of water body appropriately, incrementing its quality and avoiding the strong decrease of biodiversity observed, it is essential to understand its one dynamic, and determine, if possible, whose parameters (chemical and/or biological) are most sensitive to the pollutants detected in this type of scenario.

Presently, the ecological status of rivers/streams is determined by the assessment of ecological indices, which translate the biodiversity of the system. Relatively to temporary rivers, the structure and composition of the biological communities are adapted to the temporariness of hydrological regime, which induces a high heterogeneity at the system, hindering the definition of reference conditions, as well as the use of indicator species for defining the ecological status (Sánchez-Montoya et al., 2009). These facts highlight that the current classification, based in multi-metric indices, may not be sufficient to interpret the hydrological and biological variability present in the temporary rivers (Munné and Prat, 2009). In addition to this scenario, we cannot forget that, despite the biotic indices are relatively easy to apply, they do not identify causes of impairment, neither subtle effects at the individual level (Damásio et al., 2007; Muñoz et al., 2012), and, hence, when the detection of detrimental effects occur at the community level, it may be too late to recover the ecosystem (Clements and Rohr, 2009).

Many researchers think that the best option to assess the ecological status of water bodies is the use of a tool-box that adds multi-metric indices and ecotoxicological endpoints, especially in aquatic systems that present low biodiversity, such as temporary Mediterranean rivers (Colin et al., 2016; Reyjol et al., 2014; Palma et al., 2016; Van den Broeck et al., 2015; Skoulikidis et al., 2017). This type of strategy will allow a better understanding of the ecosystem functions and dynamics, filling the fragilities of each approach and the gaps between the results from laboratory experiments and field observations (Artigas et al., 2012; Beketov and Liess, 2012).

Considering all these facts, the aim of this study was to evaluate the effectiveness of the use of biological responses, integrating biotic indices and ecotoxicological endpoints, in the detection of pollution induced by agricultural activities in a temporary stream, Brejo of Cagarrão, located in the Mira River Basin, in the South of Portugal.

The selection of Brejo of Cagarrão as a case study was based on the following criteria: (i) it is a southern stream with a temporary hydrological regime; (ii) there is no water quality data for this watercourse; (iii) there are environmental and public health concerns associated with this stream, as it drains directly to Brejo Largo beach; (iv) some local fisherman reported the decrease of the communities of clams and mussels; and (v) it is a watercourse integrated in the Southwest Alentejo and Vicentine Coast Natural Park, a protected region due to its great biodiversity and coastal habitats (Decreto Regulamentar n.° 26/95, 1995).

Furthermore, this initial study is integrated in a research line about the quality, function and dynamic of temporary rivers/streams in Mediterranean areas, that intends to deliver a tool-box, which can be used for responding to the main alterations that influence the ecological status of temporary water streams. This action can be useful to support the risk management strategies of this type of systems, to minimize human influences and ensure ecosystem integrity and human safety.

2. Materials and methods

2.1. Study area

Brejo of Cagarrão is a temporary stream inserted in the Coastal Hydrographic Basin of Mira (Alentejo coast, South of Portugal). According to the Portuguese Water Institute (INAG) (2009), Brejo of Cagarrão is classified as a small river of the South of Portugal (≤100 km^2), which flows into the Atlantic Ocean, at the Brejo Largo Beach.

The Mira Basin presents a drainage area of 1576 km^2, with a lithology mainly constituted by schist, greywacke, and sandstones (85%), sands, little consolidated sandstones and clays (9%), and a slight percentage of metavolcanics (4%) (Mil-Homens et al., 2014).

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