Science of the Total Environment xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

A biological tool to assess flow connectivity in reference temporary streams from the Mediterranean Basin

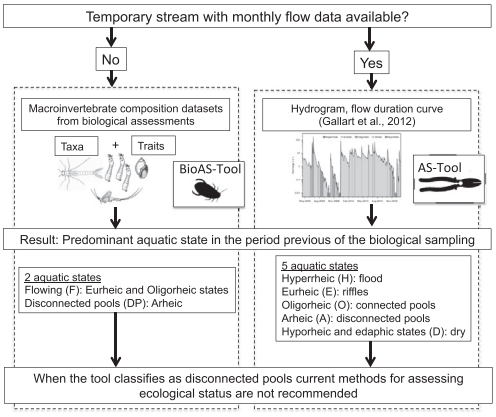
N. Cid [a,*], I. Verkaik [a], E.M. García-Roger [a,e], M. Rieradevall [a], N. Bonada [a], M.M. Sánchez-Montoya [b,f], R. Gómez [b], M.L. Suárez [b], M.R. Vidal-Abarca [b], D. Demartini [c], A. Buffagni [c], S. Erba [c], I. Karaouzas [d], N. Skoulikidis [d], N. Prat [a]

[a] Grup de Recerca "Freshwater Ecology and Management (FEM)", Departament d'Ecologia, Universitat de Barcelona, Catalonia, Spain
[b] Department of Ecology and Hydrology, Regional Campus of International Excellence "Campus Mare Nostrum"—University of Murcia, Spain
[c] Instituto di Ricerca Sulle Acque (CNR-IRSA), Italy
[d] Hellenic Center for Marine Research (HCMR), Greece
[e] Institut Cavanilles de Biodiversitat i Biologia Evolutiva, Universitat de València, Spain
[f] Leibniz-Institute of Freshwater Ecology and Inland Fisheries (IGB), Berlin, Germany

HIGHLIGHTS

- The effect of flow connectivity on macroinvertebrate communities was tested on temporary rivers.
- Using recursive partitioning, biological metrics were selected to classify flow connectivity.
- Biological trait-based metrics represented antecedent flow conditions of a stream reach.
- A Bio-AS Tool (based on both taxonomy and traits) is proposed.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 29 April 2015
Received in revised form 21 June 2015
Accepted 21 June 2015
Available online xxxx

Keywords:
Biological traits
Macroinvertebrates
Mediterranean Basin
Hydrological variability
Reference conditions
Ecological status

ABSTRACT

Many streams in the Mediterranean Basin have temporary flow regimes. While timing for seasonal drought is predictable, they undergo strong inter-annual variability in flow intensity. This high hydrological variability and associated ecological responses challenge the ecological status assessment of temporary streams, particularly when setting reference conditions. This study examined the effects of flow connectivity in aquatic macroinvertebrates from seven reference temporary streams across the Mediterranean Basin where hydrological variability and flow conditions are well studied. We tested for the effect of flow cessation on two streamflow indices and on community composition, and, by performing random forest and classification tree analyses we identified important biological predictors for classifying the aquatic state either as flowing or disconnected pools. Flow cessation was critical for one of the streamflow indices studied and for community composition. Macroinvertebrate families found to be important for classifying the aquatic state were Hydrophilidae, Simuliidae, Hydropsychidae, Planorbiidae, Heptageniidae and Gerridae. For biological traits, trait categories associated to feeding habits, food, locomotion and substrate relation were the most important and provided more accurate predictions compared to

* Corresponding author.
E-mail address: ncid@ub.edu (N. Cid).

http://dx.doi.org/10.1016/j.scitotenv.2015.06.086

taxonomy. A combination of selected metrics and associated thresholds based on the most important biological predictors (i.e. Bio-AS Tool) were proposed in order to assess the aquatic state in reference temporary streams, especially in the absence of hydrological data. Although further development is needed, the tool can be of particular interest for monitoring, restoration, and conservation purposes, representing an important step towards an adequate management of temporary rivers not only in the Mediterranean Basin but also in other regions vulnerable to the effects of climate change.

1. Introduction

Temporary streams are those watercourses that undergo a recurrent cessation of flow or the complete drying of their channel (Williams, 2006), including non-perennial, seasonal, intermittent, episodic or ephemeral flow regimes (Datry et al., 2014a; Datry et al., 2014b). Although temporary streams are very common in many regions of the world, historically they have been neglected by ecologists (Larned et al., 2010) and there remains a general lack of understanding, protecting, and managing this type of freshwater ecosystem (Acuña et al., 2014). In Europe, one of the challenges of the Water Framework Directive (WFD) is the ecological status assessment of temporary streams (Nikolaidis et al., 2013).

The hydrological variability of temporary streams and associated ecological responses has hampered the assessment of their ecological status because tools and metrics have been primarily developed for perennial streams (Sheldon, 2005; Fritz et al., 2008; Munné and Prat, 2011). The cessation of flow represents a critical stage for the river ecosystem where abrupt changes in habitat availability and quality occur, together with associated changes in aquatic communities (Boulton, 2003). Once connectivity is lost and pools become isolated, random and less predictive changes of the environmental conditions may occur, altering biological communities. For this reason, biological quality assessments using available standardized methods should be performed when stream mesohabitats (e.g. riffles, pools) are still connected (Bonada et al., 2006; Buffagni et al., 2009; Buffagni et al., 2010; Prat et al., 2014). In this context, several studies have been devoted to characterizing not only a given hydrological state but also all the different stages that a watercourse may undergo (Boulton, 2003; Williams, 2006). Recently, Gallart et al. (2012) developed a method based on rainfall-runoff models to describe six ecologically relevant aquatic states (AS) representing the different hydrological conditions of a temporary stream reach, ranging from a flood state (i.e. hyperrheic) to the complete absence of surface and subsurface water (i.e. edaphic). This approach resulted in a successful precondition classification tool, named AS-Tool, for the establishment of ecological status, and became a key element of the recently developed integrated assessment protocol for temporary streams in the Mediterranean Basin (i.e. MIRAGE-Toolbox, see Prat et al., 2014). This tool provides information on the frequency of occurrence of aquatic states before the sampling and therefore allows to decide whether biological quality may be measured by the same methods as in permanent streams or not. However, the application of the AS-Tool can be hampered by the absence of gauging stations, the lack of long-term environmental data, or by the influence of local factors such as streambed composition (e.g. bedrock or sand and gravel substrate) not captured by the models. For those cases where the AS-Tool cannot be applied, the MIRAGE-Toolbox aimed at providing an alternative method, named BioAS-Tool, based on the biological assessment of aquatic states (Fig. 1).

On the one hand, macroinvertebrates are widely used as indicators of stream biological quality, including the assessment of flow conditions (Extence et al., 1999; Gore et al., 2001; Suren and Jowett, 2006; Mérigoux et al., 2009; Dunbar et al., 2010). On the other hand, many biomonitoring programmes conducted in streams from the Mediterranean Basin have produced a large number of macroinvertebrate datasets, whereas hydrological data of the stream in question may be absent. Thus, the response of macroinvertebrate communities to changes in river flow may offer a surrogate method for assessing the aquatic state of temporary streams on the basis that macroinvertebrate communities continuously integrate local flow conditions. For example, the ratio EPT/OCH (i.e. the ratio between Ephemeroptera, Plecoptera and Trichoptera taxa, and Odonata, Coleoptera and Hemiptera taxa) has been used to describe stream flow connectivity in regions with Mediterranean climate (Bonada et al., 2006). Additionally, from a community trait perspective, temporary streams are characterized by macroinvertebrate communities with strategies to cope with extreme hydrological conditions of flooding and drying, as different authors have shown (Williams, 1996; Bonada et al., 2007a; Arscott et al., 2010a; Robson et al., 2011; García-Roger et al., 2013; Vidal-Abarca et al., 2013; Chessman, 2015). These traits explain how organisms respond to environmental constrains and thereby facilitate formulating a priori predictions (Statzner and Bêche, 2010). Thus, biological traits might be useful as indicators of flow connectivity, especially when considering large spatial scales (Statzner et al., 2001; Bonada et al., 2007b).

Climate change predictions in Europe indicate that in particular the Mediterranean region will face severe stream flow deficits (Schneider et al., 2013; Forzieri et al., 2014), increasing the vulnerability of temporary rivers (Acuña et al., 2014; Datry et al., 2014b) and causing permanent ones to become temporary (Datry, 2012; Schneider et al., 2013). Such predicted changes have important implications for the ways in which we currently assess ecological status due to potential shifts in river typology, community composition and, consequently, reference condition baselines (Logez and Pont, 2012; Pace et al., 2013). Thus, there is an urgent need to assess and monitor hydrological and ecological conditions in reference sites in the face of climate change (EC, 2009; Wilby et al., 2010), including reference temporary streams.

The aim of this study was to develop a biological tool (i.e. BioAS-Tool) to classify the aquatic state of temporary streams either as flowing (F) or disconnected pools (DP) using the taxonomic and biological trait composition of the macroinvertebrate community as predictors. Macroinvertebrates from seven reference streams across the Mediterranean Basin were sampled during three years in different seasons, incorporating biogeographic, seasonal, and inter-annual differences in community composition. The rigour of the development of the BioAS-Tool is based on using macroinvertebrate samples from reference streams where hydrological variability and aquatic state classification are well studied (Gallart et al., 2012). The tool aims to enable users to predict the aquatic state that a stream reach has been subjected to before the sample was taken, and thereby to adequately assess the ecological status. Firstly, we assessed the effect of flow connectivity in traditional stream flow indeces. Secondly, we examined shifts in community composition to select those biological predictors that best classified flow connectivity. Finally, we proposed a set of potential novel metrics that constitute the BioAS-Tool.

2. Methods

2.1. Study sites

This study was conducted in seven streams throughout the European Mediterranean Basin (Fig. 2). The streams belong to five different circum-Mediterranean eco-regions according to the classification by Illies (1978): Ibero-Macaronesian region (Enxöe and Taibilla), Pyrenees (Vallcebre), Western plains (La Vêne), Italy, Corsica and Malta

Please cite this article as: Cid, N., et al., A biological tool to assess flow connectivity in reference temporary streams from the Mediterranean Basin, Sci Total Environ (2015), http://dx.doi.org/10.1016/j.scitotenv.2015.06.086