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Least Disturbed Condition for European Mediterranean rivers

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HIGHLIGHTS

- Mediterranean Least Disturbed Streams (LDS) show various types of hydromorphological alterations.
- Common LDS thresholds were found for all river types in water quality and land use.
- But a lower threshold value for DO (60%) was retained for temporary streams.
- Invertebrate, diatom and macrophyte data were used to settle biological Least Disturbed Condition.

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ABSTRACT

The present report describes a three-step approach that was used to characterize and define thresholds for the Least Disturbed Condition in Mediterranean streams of four different types, regarding organic pollution and nutrients, hydrological and morphological alterations, and land use. For this purpose, a common database composed of national reference sites (929 records) from seven countries, sampled for invertebrates, diatoms and macrophytes was used. The analyses of reference sites showed that small (catchment <100 km^2) siliceous and non-siliceous streams were mainly affected by channelization, bank alteration and hydropeaking. Medium-sized siliceous rivers were the most affected by stressors: 25–43% of the samples showed at least slight alterations regarding channelization, connectivity, upstream dam influence, hydropeaking and degradation of riparian vegetation. Temporary streams were the least affected by hydromorphological changes, but they were nevertheless affected by alterations in riparian vegetation. There were no major differences between all permanent stream types regarding water quality, but temporary streams showed lower values for oxygenation (DO) and wider ranges for other variables, such as nitrates. A lower threshold value for DO (60%) was determined for this stream type and can be attributed to the streams' natural characteristics. For all other river types, common limits were found for the remaining variables (ammonium, nitrate, phosphate, total P, % of artificial areas, % of intensive and extensive agriculture, % of semi-natural areas in the catchment). These

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values were then used to select the list of reference sites. The biological communities were characterized, revealing the existence of nine groups of Mediterranean invertebrate communities, six for diatoms and five for macrophytes: each group was characterized by specific indicator taxa that highlighted the differences between groups.

1. Introduction

The Mediterranean climate (sensu KÖPPEN, 1923) is a variety of subtropical climate occurring not only in the Mediterranean basin but also in other areas of the world, such as California, western and southern Australia, southwestern Africa, central Asia and central coastal Chile. This climate is characterized by marked seasonal differences, with dry summers and mild winters. Rivers under the influence of a Mediterranean climate (hereby called Mediterranean rivers) show characteristic sequences of floods in autumn–winter and droughts that develop continuously and gradually over the summer (Resh et al., 1990; Gasith and Resh, 1999). The freshwater communities are thus adapted to the natural variability through shorter life spans, mechanisms to resist or avoid desiccation, and higher colonization rates (Lytle and Poff, 2004; Bonada et al., 2007; Stromberg et al., 2008; Santos, 2010). These Mediterranean communities are, therefore, different from those of temperate rivers, showing inter-annual fluctuations in richness and composition and in trophic structure (Ferreira et al., 2002a, 2002b; Bonada et al., 2007; Sabater et al., 2008; Feio et al., 2010). Certain functional processes are also characteristic of these systems. Leaf litter decomposition is slower than in temperate areas, and is performed by different shredders and fungi (Gonçalves et al., 2006). Riparian inputs to these streams occur over longer periods of time, rather than being concentrated in autumn (Gasith and Resh, 1999), less allochthonous organic matter is retained (Sabater et al., 2008) than in temperate streams.

Mediterranean river ecosystems have a highly endangered biodiversity, which cannot be dissociated from the long history of human disturbances (Zeder, 2008). Human competition for water enhances the natural deficit in water resources, due to a mean annual precipitation lower than the mean potential evapotranspiration (Gasith and Resh, 1999). Additionally, water diversion, flow regulation, increased salinity, pollution and introduced species have impacted the Mediterranean ecosystems over time (Moyle, 1995; Gasith and Resh, 1999; Aguiar and Ferreira, 2005; Hooke, 2006).

The need to prevent further deterioration and protect and improve the status of aquatic ecosystems is one of the main aims of the Water Framework Directive (WFD; European Commission, 2000). The directive establishes a framework for the determination of the ecological status of all water bodies and their regular bioassessment, which should be measured through the deviation from reference conditions. According to the WFD, the reference conditions for each type of water body correspond to the high status, where physical–chemical, hydromorphological and biological elements show no or only very little influence of anthropogenic activities. However, the exact meaning of "very little influence" is not given in the WFD (Moss, 2008) and other potential synonyms such as the terms "minor changes" or "minimally impaired" or "near natural", frequently used in the literature, are also very difficult to define in a rigorous and consensual way. Additionally, the WFD establishes the existence of an Intercalibration Exercise, which aims to assure that class-boundaries are defined according to the normative definitions and are comparable among the members of the European Commission. This implies that reference conditions should also be comparable among these countries (Birk et al., 2012), as they are the basis for the establishment of classification systems and class boundaries.

In practice, most of the currently used methods to define reference conditions are based on the information collected now or in the recent past from reference sites. These are usually selected based on knowledge of the changes caused by anthropogenic activities. Many authors have discussed the existing constraints of reference conditions for bioassessment and have attempted to establish criteria for selecting reference sites (e.g., Reynoldson et al., 1997; Landres et al., 1999; Ferreira et al., 2002b; Hering et al., 2003; Nijboer et al., 2004; Stoddard et al., 2006; Sanchéz-Montoya et al., 2009; Hawkins et al., 2010; Birk et al., 2012; Pardo et al., 2012; Smith and Tran, 2012). Stoddard et al. (2006) defined four types of reference conditions: 1) the condition of ecosystems at some time in the past (historical condition), 2) the best of today's existing conditions (Least Disturbed Condition); 3) the condition of systems in the absence of significant human disturbance (Minimally Disturbed Condition); and 4) the condition to be achieved with improved management (Best Attainable Condition). Here, we use the second concept, Least Disturbed Condition (LDC) to describe the present best available situation in European Mediterranean rivers, which is a practical concept to which all countries can be anchored at the same point on the impact gradient. Considering the long history of human presence, the intensive water demand in the Mediterranean Basin and the difficulty in knowing the condition before human influence, it is not possible for this region to set the high ecological status (pristine state), as a key starting point as defended by Moss (2008), even though this would be the ideal approach.

In the context of the Intercalibration Exercise, it is equally important to have enough representativeness of sites for all river types. In view of this, we propose here a selection method of "benchmarks" for IC purposes, which have a comparable and known level of anthropogenic degradation corresponding to no or only slight alterations. This study aims, therefore, to characterize the present abiotic and biological (for invertebrates, diatoms and macrophytes) LDC in Mediterranean rivers. We intend also to list the main impacts affecting the various stream types, while proposing a methodology for the selection of reference sites, based on common criteria. For this purpose, we followed a sequential approach using the available information on water chemistry and physics, hydromorphology and land use. Data were provided by seven Mediterranean countries (Portugal, Spain, France, Italy, Slovenia, Greece and Cyprus) participating in the 2nd phase of the Intercalibration Exercise (2008 to 2011) within the Mediterranean Geographic Intercalibration Group (MedGIG).

2. Material and methods

2.1. Dataset

For the composition of an initial dataset, the seven countries provided data from their national reference sites, that were selected based on their national criteria, and that could be included in one of four Intercalibration river types (previously defined by the Mediterranean GIG), as follows:

1. Type 1: small rivers (catchment area <100 km^2), siliceous geology (e.g., schist, granite), highly seasonal hydrological regime
2. Type 2: rivers with medium sized catchments (100–1000 km^2), siliceous geology, highly seasonal hydrological regime
3. Type 3: rivers with small and medium-sized catchments (<1000 km^2), non-siliceous (e.g. calcareous, ophiolite), highly seasonal regime
4. Type 4: rivers with small and medium-sized catchments (<1000 km^2), temporary hydrological regime.

Samples of invertebrates (455 samples: 157 of type 1; 30 of type 2; 208 of type 3; and 60 of type 4), diatoms (311 samples: 115 of