Ecological Indicators 11 (2011) 651–662

Contents lists available at ScienceDirect

Ecological Indicators

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

Original article

Effects of Mediterranean climate annual variability on stream biological quality assessment using macroinvertebrate communities

Antoni Munné[a,*], Narcís Prat[b]

[a] Catalan Water Agency, C/Provença, 204-208, 08036 Barcelona, Spain
[b] Department of Ecology, University of Barcelona, Avda. Diagonal, 645, 08028 Barcelona, Spain

ARTICLE INFO

Article history:
Received 8 April 2010
Received in revised form
14 September 2010
Accepted 15 September 2010

Keywords:
Biological quality
Macroinvertebrate
Annual variability
Mediterranean rivers
Dry periods
Water Framework Directive

ABSTRACT

Data on macroinvertebrates of selected reference sites were compiled from a long-term monitoring programme carried out in the Mediterranean Catalan Basins (NE Spain) that permitted analysis for nine years, from 1996 to 2004, using a homogeneous data collection procedure. This study aims to analyse the differences in composition and structure of macroinvertebrate communities at family level in five Mediterranean river types, and the values of biological quality metrics (IBMWP and IASPT indices, taxon richness and EPT) in reference conditions. Also differences between seasons (spring vs. summer) and between dry and wet periods were analysed. The dry and wet periods were determined using the Standardised Precipitation Index (SPI). A total of 29 reference sites were selected out of 184 sampling sites analysed, and 171 reference samples were available (from 1996 to 2004), of which 88 were sampled in dry periods, whereas 83 correspond to wet periods. Differences on community composition at family level were appreciated, clustering the rivers in three different groups: (1) rivers with a continuous flow regime located in siliceous zones; (2) rivers with a continuous flow regime located in calcareous zones; and (3) temporary rivers regardless of geology. Moreover, our results explain that the characteristics of hydrological periods (dry and wet) characterize the differences between communities better than just the season. The analysis of four biological quality metrics reveals clear differences between values obtained from dry and wet periods concerning taxon richness, EPT values and IBMWP biological indices, whereas the IASPT index does not show significant differences. The median taxonomic richness in wet periods is 32 macroinvertebrate families per sample while in dry periods this value falls to 22. Reference values of IBMWP index, the total number of taxa, and EPT metric are different between dry and wet periods in spring samples, while these differences are not relevant for IASPT index except for temporary streams. Hydrological specific conditions should additionally be considered in order to better calculate biological reference conditions, and to properly apply biological quality metrics used to establish the ecological status in Mediterranean rivers, especially in temporary ones. The use of the dry–wet period classification according to the climate characteristic results is a more accurate application of the Water Framework Directive in Mediterranean rivers. Implications of future climate change should be also considered from our results.

1. Introduction

The Water Framework Directive (WFD) (European Commission, 2000) requires the EU Member States to define reference conditions in order to: (1) characterize the biological communities, (2) define the quality class boundaries using biological quality metrics, and (3) identify and consequently correct impacts from human activities which significantly affect the ecological status of water bodies (Wallin et al., 2003; Noges et al., 2009). That is why reference sites need to be previously selected in each river type using areas where there is no human alteration or, if present, does not cause relevant ecological changes in the aquatic ecosystems (European Commission, 2003; Nijboer et al., 2004). Subsequently, reference conditions must be established by calculating the biological quality metrics in a significant number of reference sites within each river type. Moreover, reference conditions should be homogeneous within each river type, and be capable of differentiating river types for a correct ecological status assessment.

Methods based on biological community composition have occasionally been used to define river types (e.g., Heino et al., 2003; Dodkins et al., 2005), although biological assemblages can be heavily affected by human activities. Rivers may be mistakenly

* Corresponding author.
E-mail addresses: AnMunne@gencat.cat (A. Munné), nprat@ub.edu (N. Prat).

1470-160X/$ – see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.ecolind.2010.09.004

classified using biological communities when human pressures are present, hence the use of environmental descriptors is suggested for river classification purposes by the WFD. Thus, in most European countries, river types have been mainly defined using environmental descriptors (e.g., Dawson et al., 2002; Verdonschot and Nijboer, 2004; Munné and Prat, 2004; Ferréol et al., 2005), following the WFD requirements and, therefore, the number of river types defined tends to increase according to the high environmental heterogeneity. Nevertheless, it is not clear that biological assemblages are consistent with river types defined using environmental descriptors, and biological data should additionally be used to define homogeneous river types and their reference conditions (e.g., Sánchez-Montoya et al., 2007). Moreover, it is also well known that Mediterranean rivers are characterized by a high temporal variability, combining dry and wet periods and this makes the characterization of these rivers even more difficult. In Mediterranean streams, the hydrological regime is a key element that determines community composition (Poff, 1996; Bonada et al., 2007a), and its response to the interannual and seasonal hydrological variability (Gasith and Resh, 1999; Williams, 1996; Lake, 2003). Numerous studies have revealed the peculiarities of biological communities in Mediterranean and temporary streams (e.g., Boulton and Lake, 1992; Williams, 2006), where changes in the composition of the invertebrate community are found over time related to flow regime variation (Ortega et al., 1991; Blinn et al., 1995; Gallardo-Mayenco et al., 1995; Acuña et al., 2005; Bonada et al., 2007a). Thus, reference conditions could change between seasons, between dry and wet periods, and after hydrological events in the same river type, which complicates the biological quality assessment on Mediterranean rivers.

However, changes over time of ecological quality assessment and reference conditions have been scarcely investigated (e.g., Rose et al., 2008; Death et al., 2009), and their consequences for water management are virtually unknown. This study attempts to analyse the differences in composition and structure of macroinvertebrate communities at family level in various Mediterranean river types, and their effects on values of biological quality metrics in reference conditions. Our main objective is to analyse the differences among river types, and between dry and wet periods, using a data set from nine consecutive years (1996–2004). We analyse the performance of different metrics used for river quality monitoring in Mediterranean streams (IBMWP and IASPT indices, taxon richness and EPT metrics) under different climatic circumstances (dry and wet periods), and the variation of quality class boundaries between very good and good, and between good and moderate ecological status, according to the WFD requirements.

2. Material and methods

2.1. Study area and sampling sites

A total of 184 sampling sites located in the Catalan Mediterranean basins (NE Spain) (Fig. 1) were analysed in order to find reference sites. The basins analysed have a total area of 16,438 km^2 and an average annual precipitation ranging from 350 mm, in the sites located in semi-arid zones, up to 1400 mm in headwater sites located in mountain zones. The average annual temperature varies from 7 °C to 15 °C, and the flow discharge from a scarce m^3 s^{-1}, or completely dry in some periods, up to 30 m^3 s^{-1} with a high annual variability. All sampling sites were located in the Mediterranean climate region (Illies and Botosaneanu, 1963), and were classified into five different river types: (1b, 2a, 2b, 3a and 3c) out of ten river types defined in the Catalan Mediterranean basins using environmental descriptors according to the WFD requirements (see Munné and Prat, 2004 for details) (Table 1).

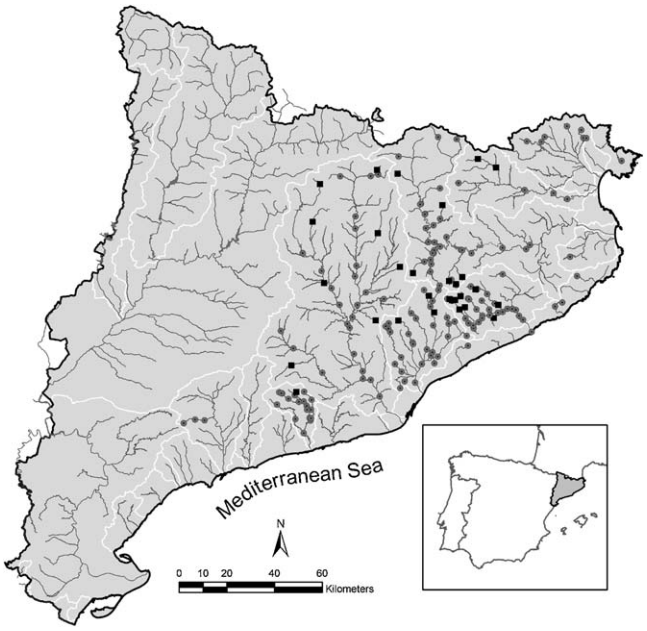

Fig. 1. Sampling sites analysed over a period of nine consecutive years (1996–2004) in Mediterranean Catalan basins are shown using grey circles. The selected reference sites are distinguished by a black squares.

2.2. Selection of reference sites

In selecting reference sites, several works previously carried out in the Spanish Mediterranean rivers were considered (i.e., CHE, 1999; Bonada et al., 2004; Munné and Prat, 2009). Also, the criteria provided by the European Commission (European Commission, 2003; Heiskanen et al., 2004), and the criteria agreed during the intercalibration exercise carried out in Mediterranean river types (Mediterranean Geographic Intercalibration Group–MedGIG) (European Commission, 2007) were taken into account. Using all these documents, and according to the data available, a total of 42 criteria for selecting reference sites were established at three different scales: human pressures at basin, reach (river segment and its floodplain area), and sampling site (Table 2). A Geographic Information System (ARCGIS software) was used to analyse pressures considering aerial photos, maps, and land use layers, together with measured and observed data in the field (ACA-Agència Catalana de l'Aigua, 2005). The nature of river beds and their banks, and the chemical water quality at site scale was considered to be an inviolable reference criterion in order to select reference sites (Bonada et al., 2004; European Commission, 2007), and consequently an assessment *in situ* of the hydromorphological characteristics and water chemical analysis was carried out. Two thresholds were defined in order to select the reference sites, on the one hand the selection threshold at which sites were considered true reference sites and, on the other, an exclusion threshold based on key elements from where sites were rejected (Table 2).

2.3. Characterization of dry and wet periods

The dry and wet periods were determined using the Standardised Precipitation Index (SPI) (McKee et al., 1993). The SPI was developed at Colorado State University, and is widely used to analyse and select drought periods in semi-arid areas (e.g., Edwards and McKee, 1997; Tsakiris and Vangelis, 2004). SPI is basically a representation of rainfall of the period in units of standard deviation. Positive values indicate greater than median rainfall, whereas negative values indicate less than median rainfall. It assumes that the series of precipitations received by a basin follow a normal distri-