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Floodplain capacity to depollute water in relation to the structure of biological communities

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ABSTRACT

Floodplains are complex ecological systems that are mostly regulated by river dynamics and human disturbances that determine the efficiency of the coupling of hydrogeochemical functions and the biological structure to keep floodplains as integrated systems providing regulating services, such as removing pollutants. Biogeochemical indicators related to the structure and functionality of the biological communities were used to show differences of natural depollution capacity of four river floodplains located in the rivers Garonne (France), and Bidasoa, Ebro, and Tagus (Spain) as part of the Interreg IVB SUDOE project ATTENAGUA. Huge differences between these floodplains in river flood dynamics and land-use coverage were observed. While Garonne and Ebro floodplains still kept a relatively intense flood regime and had large areas of their floodplains covered by riparian forests, very low river dynamics and a very narrow riparian forest were observed for Bidasoa and Tagus floodplains, which are dominated by agricultural fields. A multifactorial analysis performed with data of physicochemical variables and biological communities of the water from 12 piezometers in each floodplain showed a high spatial and temporal heterogeneity of the groundwater characteristics of the Garonne and Ebro floodplains compared to the Bidasoa and Tagus floodplains. These differences were associated with a higher capacity to eliminate pollutants in floodplains with river dynamics compared to those with low river–floodplain connectivity. The relatively high depollution capacity of the Garonne and Ebro floodplains was associated with a complex community structure that links riparian forest and groundwater microbial activity through groundwater invertebrates. In contrast, floodplains with low depollution capacity, such as those of the Bidasoa and Tagus floodplains, have narrow belts of riparian forests and much less abundant and diverse microbial and groundwater invertebrate communities. From this comparative approach, an idea emerges to consider

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floodplains as dynamic systems with hydrological and biogeochemical characteristics that fluctuate in space and time in accordance with the balance between river dynamics and impacts from human polluting activities in the floodplain.

1. Introduction

Floodplains are excellent systems to regulate water and nutrient flows if they function in accordance with natural phenomena (Ward et al., 1999; Mitsch and Gosselink, 2015). The interplay between physical, chemical, and biological processes that take place in the floodplain are mostly driven by the floods, and are modulated by the structural components of the floodplains, including the soil layers and the biological populations with metabolic capacity to participate in biogeochemical reactions (Spink et al., 1998; Pinay et al., 2007). However, a floodplain is not a homogeneous environment and they should be more properly considered as heterogeneous environments both in space and time, particularly if surface–groundwater relationships are considered (Poole, 2002). Their environmental characteristics show spatial gradients that change at different timescales in accordance with regulating factors, such as water flows and biological rhythms. In fact, floodplains regulated by natural factors (not human intervention) are dynamic and continuously changing systems, whether or not they are strongly connected with the river. In the first case, the floodplain is far from the equilibrium, such as at the initial or non-structured stage of a succession process. In the second case, the floodplain will follow a typical successional trajectory, reaching advanced terrestrial stages as the lack of river connectivity progresses.

The role of floodplains as systems that are useful to improve the water quality is based on the biogeochemical capacity to assimilate/store or to transform pollutants, including removal or accumulation of micronutrients (Mayer et al., 2007), heavy metals (Csiki and Martin, 2008; Du Laing et al., 2009), pesticides (Everich et al., 2011), and other pollutants (Nairn and Mitsch, 1999; Vidon et al., 2010). Because of the environmental heterogeneity of the floodplains, not all the surface area and/or the subsurface floodplain volume plays this role. In some sites (*hot spots*) and at certain times (*hot moments*), pollutants are removed intensively (McClain et al., 2003). Intense water dynamics and biogeochemical reaction capacity are required for this purpose (Hefting et al., 2003, 2006). However, floodplains differ in their autopurification capacity in relation to the area of their connectivity with the river, which will depend upon the river dynamics and any artificial structures constructed to prevent flooding, and also, in relation to the pollutant discharge, which usually originates in the floodplain catchment but may also be carried out through the river discharge. In this context, groundwater flows through the floodplain stand out because many rivers are strongly regulated and their surface flows restricted after diking their shorelines.

The literature about floodplain hot spots and moments is abundant. Most of it is dedicated to the environmental conditions regulating the removal activity of hot spots, and particularly with respect to carbon and nitrogen, which are of major interest to the ecological functioning of wetland systems (Harms and Grimm, 2008; Vidon et al., 2010). In addition to the biogeochemical conditions that are required for the reactions to take place to remove a pollutant in a hot spot, other environmental conditions are required, such as water flows to feed the site with water as carrier and the pollutant to be removed. In other words, the changing characteristics of a site in a floodplain can change the character of it as a hot spot, and also make the same site later work as an exporter rather than as a pollutant remover, along with geomorphological and environmental changes (Groffman et al., 2009). In order to understand the floodplain characteristics with respect to nutrient and pollutants, it is very important to know the factors that regulate the dynamic changes taking place in the floodplain.

Both synchronic and diachronic approaches can be followed to elucidate the environmental factors that regulate the biogeochemical dynamics of floodplains. Synchronic approaches compare characteristics of different floodplains, or sites in a floodplain that are studied at the same time. Diachronic approaches follow the biogeochemical changes of sites in floodplains over time in relation to environmental factors. Both approaches are required to compare the biogeochemical dynamics of different floodplains. Surface and groundwater studies are required as water flows take place through both layers and play different roles and with markedly different intensities (Cabezas et al., 2008).

It is clear that one of the major regulating factors of the floodplain dynamics is water flow, particularly if associated with flood pulses (Junk et al., 1989). Water is both the carrier of suspended and dissolved compounds, and the agent that changes the environmental conditions at different spatial and time scales (Boulton et al., 2010). Temperature is a boundary condition that also regulates biogeochemical reactions, although it is less variable in ground than in surface waters (Tonolla et al., 2010). The structure and functioning of the biological agents that directly or indirectly influence pollutants are also part of the network of components of the system that determine the character of a floodplain or a site in a floodplain with respect to a pollutant (Triska et al., 1993; Dahm et al., 1998). While most works deal with the environmental and biogeochemical characteristics of the floodplains, less interest has been devoted to the full network of links between structural components and environmental factors that regulate hot spots and moments (Ward et al., 1999; Poff and Zimmerman, 2010).

The objective of this study was to set up an approach to define the biogeochemical role of four floodplains in different rivers of SW Europe and to propose a framework to compare floodplains based on the biological components and their relationships with the interplay between the river dynamics and groundwater flows. This work is based upon the study of four different floodplains located in southern France, and northern, northeastern, and central Spain, *i.e.*, the same study sites as those referred to in other papers of this journal issue.

2. Material and methods

2.1. Study area

Four floodplains in the rivers Garonne (Montbequi), Bidasoa (Lastaola), Ebro (Nis), and Tagus (Redondo) were studied to compare the characteristics of their biological structure, as well as functional aspects related to their pollutant removal efficiency, in relation to environmental characteristics, including river dynamics and land-use. The study sites differ in land coverage and uses, and in their respective river dynamics. The most relevant contrasting macro-characteristics of these four floodplains are: (i) Garonne and Ebro river–floodplain dynamics are relatively frequent and intense; (ii) Bidasoa floodplain has also frequent and intense floods but