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Responses of Mediterranean aquatic and riparian communities to human pressures at different spatial scales

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ABSTRACT

Mediterranean river ecosystems are subjected to intense human pressures and impacts that affect both their aquatic and riparian communities. However, given their stratified position in the river ecosystem and varying ecological requirements, aquatic and riparian communities can respond differently to such pressures. These biological responses could also vary depending on the nature of the disturbances, the spatial scale considered and the indicators used as response variable. Here, we aim to assess the influence of the main human pressures present in Mediterranean rivers (agricultural land use and hydromorphological alteration) on the biodiversity and ecological condition indicators of both riparian and aquatic communities at two spatial scales: reach and basin. For this purpose, a total of 56 sampling sites covering the study area (Segura basin, SE Spain) were surveyed. Water beetles and woody riparian vegetation richness were used respectively as biodiversity surrogates of aquatic and riparian communities, and the Iberian Biomonitoring Working Party (IBMWP) and Riparian Quality Index (RQI) were used to assess the ecological status of both communities. As expected, we found a general decrease in both richness and ecological condition when human pressures increased, regardless of the spatial scale considered. Nonetheless, agricultural land use was the main pressure explaining riparian richness and quality, whereas aquatic communities' responses were highly related to hydromorphological alteration. Contrary to expected, in general, variables at basin scale had a greater effect than those variables operating at local scale. In addition, ecological condition indices responded more clearly to human pressures than biodiversity surrogates. Therefore, land use and hydrological planning at basin scale are essential complements to conservation and restoration efforts, traditionally carried out at reach scale, in order to maintain stream ecosystem integrity and biodiversity.

1. Introduction

The high human pressures on inland aquatic ecosystems have caused these habitats to become recognised as some of the most threatened in the world (Saunders et al., 2002). This is especially evident in the Mediterranean Basin, one of the Earth's biodiversity hotspots (Myers et al., 2000), where the long history of substantial human impacts on the landscape and fluvial systems has been well-documented (Hooke, 2006). These areas provide a wide anthropogenic gradient suitable for studying the influence of human pressures on fluvial communities. Thus, understanding the processes and relationships between human pressures, spatial heterogeneity and riverine communities in Mediterranean areas constitutes a major challenge in freshwater ecology and conservation (Bonada and Resh, 2013; Cooper et al., 2013), particularly in the current context of global change (Sala et al., 2000).

Although frequently overlooked in limnological studies (Ferreira and Aguiar, 2006), riparian areas are an integral part of riverine ecosystems (Ward et al., 2002) that influence both the structure and functioning of aquatic communities (Sabater et al., 2000). Thus, aquatic and riparian communities are mutually interdependent in terms of ecological processes. These large terrestrial-aquatic linkages occur in both directions, existing

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important flows of energy and material between these adjacent systems (Naiman and Décamps, 1997). Conservation and management strategies are usually focussed on aquatic or riparian community but sparsely on both of them. Despite the existing interconnection between both communities, given their stratified position in the river ecosystem and their varying functional traits and ecological requirements, their responses to human pressures could also differ.

Riparian and aquatic communities' responses could also differ depending upon the nature of these pressures and the spatial scale considered (Aguiar et al., 2009; Ferreira and Aguiar, 2006; Richards et al., 1996). The hydromorphological alteration of rivers as a result of flow regulation, and land-use changes can be considered among the main human disturbances modifying freshwater biological communities, especially in Mediterranean areas (Belmar et al., 2013; Bruno et al., 2014; Stella et al., 2013), where they exacerbate the natural stress of river ecosystems (Kroll et al., 2013; Stromberg et al., 2004). Given the scarcity of water resources and the wide agricultural surfaces in these areas, both pressures are highly interconnected, as water supply for irrigation is the main cause for water demands (Zimmer, 2010). Therefore, although agriculture and hydromorphological alteration cause deep modifications in aquatic and riparian communities (Allan, 2004; Ward, 1998), their responses to these pressures can differ depending on the nature of the human pressure. We consider that agricultural land use could be exerting a greater influence on riparian communities, since they are directly impacted by agricultural processes (e.g. occupation of riparian area, greater amount of sediments, modification of river bank profile), whereas strictly aquatic communities could respond more clearly to in-stream disturbances such as hydromorphological alteration (e.g. low ability to persist after the hydropeaking process caused by dam releases, micro and mesohabitat reduction and homogenisation, or bed substrate modification).

Regarding the spatial scale, most previous studies have reported that land-use and hydrological alteration acting at local scale are important for shaping river communities (e.g. Fernandes et al., 2011; Nerbonne and Vondracek, 2001; Nilsson et al., 1991; Sponseller et al., 2001), and some of them have also documented the importance of these pressures at wider scales (Wahl et al., 2013; Yates and Bailey, 2011). Thus, although alteration processes at both scales seem to be important (Johnson et al., 2007; Marzin et al., 2013; Stewart et al., 2001), a greater influence of those operating at reach scale can be detected, as both aquatic and riparian communities are directly exposed to these local impacts, especially in semi-arid rivers (Aguiar and Ferreira, 2005; Boyero, 2003; Monteagudo et al., 2012).

Finally, as results can also vary depending on the indicator used to estimate the biological communities' responses, we decided to use both biodiversity and ecological condition indicators. Firstly, biodiversity indicators are well-surveyed and taxonomically stable groups of organisms whose species richness patterns or rarity can be considered as similar to those of unsurveyed taxa in the same region (Pearson, 1994). Secondly, indicators of ecological condition are widely used to assess river health (Bonada et al., 2006; Karr, 1999). They are complementary integrative and holistic indices that involve a wide range of metrics in order to obtain a measure of quality (Feest et al., 2010). Although it seems evident that ecological condition indices should clearly respond to human pressures, as they are ultimately designed to assess their effects, this assumption has been scarcely tested. Furthermore, many ecological studies regarding the influence of human pressures on biological communities continue using richness as a response variable (Birk et al., 2012).

Many studies have separately tested the influence of diverse human pressures on river communities, the varying biological responses depending on the spatial scale considered, the convergence on the sensitivity of several ecological indicators or the contrasting response of aquatic and riparian communities facing these anthropogenic disturbances. Nevertheless, as far as we know, no holistic studies considering all of these different aspects together (kind of pressure, scale, response variable and target community) have been conducted. Therefore, in this study, we aim to assess the influence of agricultural land use and hydromorphological alteration at basin and reach scales on the biodiversity and ecological condition of both Mediterranean riparian and aquatic communities. Based on the information above, we predict the following: (1) although both types of human pressures are expected to modify riparian and aquatic communities, agricultural land use could have a greater influence on riparian communities, whereas hydromorphological alteration could have a more clear relationship with strictly aquatic communities; (2) human pressures acting at reach and basin scales will modify riparian and aquatic communities, although a greater influence from those operating at reach scale may be found; (3) ecological condition indicators will be more sensitive to human pressures in both communities than biodiversity indicators.

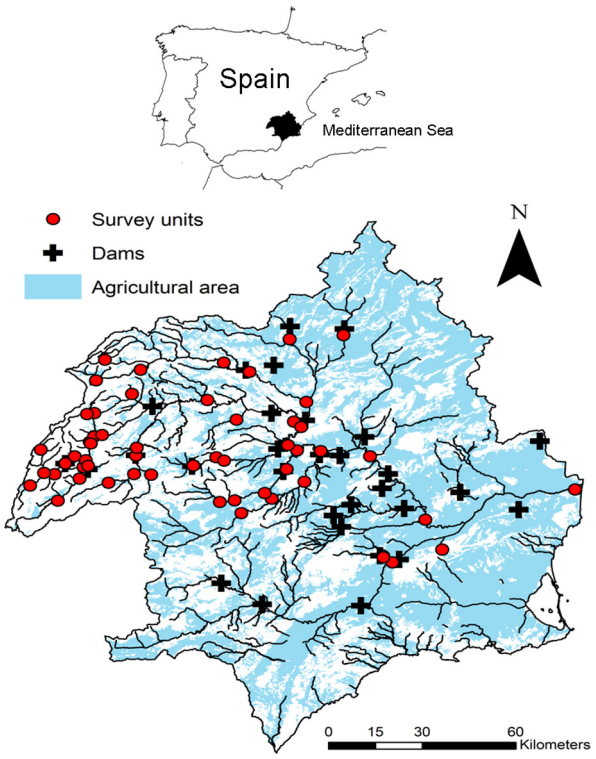

Fig. 1. Geographic location of the study area showing the 56 sampling sites, agricultural area and the main dams.

2. Methods

2.1. Study area

Located in one of the most arid zones in Europe (Fig. 1), the Segura River Basin is an environmentally diverse basin due to human (alteration) and natural (climatic) gradients with a predominately semi-arid climate. These marked gradients make them an ideal candidate to be utilised as a Mediterranean pilot basin, as they involve a wide range of conditions that can be present in most Mediterranean basins. In general, the river network ranges from lowly populated forested headwaters to densely populated lowland cities, with a mostly shrubby landscape. Despite the notable presence of forested or semi-natural areas (45.2%), particularly in