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Fine-scale determinants of conservation value of river reaches in a hotspot of native and non-native species diversity

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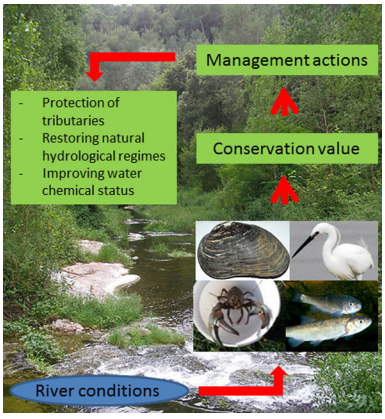
HIGHLIGHTS

- A moderate relationship was observed among indicators of conservation value.
- Protected areas offered limited coverage to imperilled freshwater fauna.
- River tributaries were identified as native fish refugees.
- Restoring water quality and the natural hydrological regime are priority tasks.
- Multiple components of diversity should be examined in resource management.

GRAPHICAL ABSTRACT



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ABSTRACT

Global freshwater biodiversity is declining at unprecedented rates while non-native species are expanding. Examining diversity patterns across variable river conditions can help develop better management strategies. However, many indicators can be used to determine the conservartion value of aquatic communities, and little is known of how well they correlate to each other in making diagnostics, including when testing for the efficacy of protected areas. Using an extensive data set (99,700 km^2, $n = 530$ sites) across protected and unprotected river reaches in 15 catchments of NE Spain, we examine correlations among 20 indicators of conservation value of fish communities, including the benefits they provide to birds and threatened mammals and mussels. Our results showed that total native fish abundance or richness correlated reasonably well with many native indicators. However, the lack of a strong congruence led modelling techniques to identify different river attributes for each indicator of conservation value. Overall, tributaries were identified as native fish refugees, and nutrient pollution, salinization, low water velocity and poor habitat structure as major threats to the native biota. We also

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Threatened taxa
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Environmental degradation

found that protected areas offered limited coverage to major components of biodiversity, including rarity, threat and host-parasite relationships, even though values of non-native indicators were notably reduced. In conclusion, restoring natural hydrological regimes and water chemical status is a priority to stem freshwater biodiversity loss in this region. A complementary action can be the protection of tributaries, but more studies examining multiple components of diversity are necessary to fully test their potential as fluvial reserves in Mediterranean climate areas.

1. Introduction

Biodiversity loss is occurring at unprecedented rates driven by global change (Foley et al., 2005; Halpern et al., 2008; Tittensor et al., 2014). Although global change effects are visible across a wide range of habitats, freshwater ecosystems are particularly affected (Strayer and Dudgeon, 2010). A good example are Mediterranean rivers, where many endemic species live and some of them are at the brink of extinction (Smith and Darwall, 2006; Marr et al., 2010). Human pressure in the Mediterranean area date back to ancient times when humans settled along main rivers and began to exploit water and biological resources, including on the riverbanks (Hooke, 2006). This pressure intensified with modern civilisations that also diversified the type of impacts, including emergent pollutants (Petrovic et al., 2011; Kuzmanović et al., 2015) and the release of non-native species (Leprieur et al., 2008a; Cobo et al., 2010). The situation is expected to worsen due to climate change and human population growth (Vörösmarty et al., 2010); therefore, conservation of freshwater diversity and the goods and services they provide to society requires urgent management actions.

Protected areas are considered as a mainstay of biodiversity conservation as well as contributing to human well-being (Gaston et al., 2008). In rivers, the most effective conservation strategy is proposed to be framed at the basin scale (Allan et al., 1997; Saunders et al., 2002; Linke et al., 2012). This framework considers that basins are biogeographic units (Doadrio, 1988; Reyjol et al., 2007), and that rivers are linear systems through which major threats to freshwater diversity such as pollution can easily propagate (Allan et al., 1997; Nel et al., 2007). Environmental quality standards have been proposed at the basin scale driven by international legislation, such as EU's River Basin Management Plans (Directive 2000/60/EC). At this scale, however, a strict protection is unrealistic. It generates many socio-economic conflicts and is logistically unfeasible for large basins (Saunders et al., 2002); therefore, river reaches need to be prioritised according to their conservation value (Margules and Usher, 1981; Filipe et al., 2004; Hermoso et al., 2015). Nevertheless, this raises the question of which are the best indicators to assess the conservation value of a community.

Traditionally, conservation priorities have been based on indicators such as species richness, rarity, and threatened status (Margules and Usher, 1981). The threatened status is often based on the International Union for the Conservation of Nature (IUCN) Red List (http://www.iucnredlist.org/). However, the conservation status of a species can be unknown or vary across regions due to discrepancies in classifications; for example, the river blenny *Salaria fluviatilis* is listed as least concern in the IUCN Red list and as endangered in the Spanish Red Data Book (Doadrio et al., 2011). Therefore, the focus on international criteria can bias setting conservation priorities at the national level; the target of most conservation actions since they are more politically than biogeographically driven (O'Riordan and Stoll-Kleeman, 2002; Battisti and Fanelli, 2015). Likewise, prioritising rarity to reduce extinction risk may leave unprotected species with a less restricted distribution, including species of major importance for other threatened taxa as food source (e.g. Ruiz-Olmo et al., 2001; Lopes-Lima et al., in press) or for the functioning of the fluvial ecosystem (Winfield and Townsend, 1991; Flecker et al., 2010). Thus, the ideal conservation action would be one that secures threatened species while maximising the protection of species diversity at the basin scale.

Since a major ecological rule is that biodiversity increases with surface area (Lomolino, 2000; but see Allouche et al., 2012), and river size increases downstream (Strahler, 1964), protecting downstream areas could maximise the number of species protected at the basin scale. However, these reaches are usually neighboured by large urban areas and hence the most disturbed, including the presence of non-native species (Marchetti et al., 2004; Closs et al., 2015). As biological invasions pose a significant threat to biodiversity and ecosystem services (Vilà et al., 2009; Simberloff et al., 2013), the presence of non-native species may jeopardise conservation goals in rivers. Studies examining diversity patterns help identify hotspots of high conservation value, but also the mechanisms behind these patterns (Baselga, 2010; Gutiérrez-Cánovas et al., 2013). For instance, if turnover dominates diversity patterns, it suggests that stress generates new communities in which tolerant species may replace those sensitive (Baselga, 2010). In contrast, if species poor sites are a subset of species of those enriched (high degree of nestedness), it suggests that stress causes a progressive loss of sensitive species and that conservation efforts may focus on species rich sites (Baselga, 2010). However, hotspots of native species richness may not be congruent with rarity or threat (Orme et al., 2005; Collen et al., 2014), further increasing the complexity of setting conservation targets.

In this study, we examine indicators that can be used to determine the conservation value of fauna across 15 catchments (99,700 km^2) in the Western Mediterranean area, a world hotspot of biodiversity (Myers et al., 2000) but also highly prone to biological invasions (Leprieur et al., 2008a). The selected basins typify common threats to other Mediterranean-type rivers, including pollution, overharvesting, hydrological alterations, and riparian removal (Moyle et al., 2011). We mainly focus on fish because the distribution of many native species has markedly declined worldwide (Closs et al., 2015), including in the study area (Maceda-Veiga et al., 2010). Firstly, we used pair-wise correlations to test whether one indicator of conservation value could act as surrogate of the others to plan management actions, including measures of fish species diversity, rarity, and nativeness plus indicators of conservation value of fish for other fauna, such as host for freshwater mussels or prey for mammals and birds. Secondly, we tested whether current protected areas meet conservation indicators of the aquatic fauna because they were designed primarily to protect terrestrial taxa (Filipe et al., 2004; Lawrence et al., 2011; Hermoso et al., 2015). Finally, we examined relationships between these indicators of conservation value, and geographical, water and habitat variables to identify the river attributes in which management policies can act to enhance the conservation value of fish communities. These river attributes were further confirmed via a fish community analysis, which also identified the mechanisms behind community variation across rivers and their conditions.

2. Materials and methods

2.1. Study area

We assembled environmental and fish data from our own surveys performed in NE Spain from 2002 to 2009 (Maceda-Veiga et al., 2010; Maceda-Veiga and De Sostoa, 2011; Figuerola et al., 2012, and unpublished data). Briefly, this data set comprised 530 sampling sites that involved all Catalonian catchments from the Muga to Riudecanyes basins, plus the complete River Ebro and part of the Garonne basin (Fig. 1). Our