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Evaluating the use of *Myotis daubentonii* as an ecological indicator in Mediterranean riparian habitats

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ABSTRACT

In recent years, interest and concern regarding biodiversity conservation have grown remarkably not only among conservationists but also amongst a wider public beyond scientific institutions. The monitoring of fauna and flora over long periods of time has been satisfactorily proven to be a viable tool for quantifying how environmental changes affect natural communities. Some bat species are regarded as good bioindicators, mainly due to their longevity and high sensitivity to environmental changes. *Myotis daubentonii* is one of the species most closely associated with riparian habitats in the north-east Iberian Peninsula, and is used as an ecological indicator in specific monitoring programs such as the Waterway Survey (United Kingdom) and the QuiroRius (Spain). Nonetheless, there is still great controversy as to whether *M. daubentonii* is a good biological indicator or not. While some authors accept it as a bioindicator, others point to the studies carried out in the U.K., Poland, Switzerland and Germany that show a remarkable increase in the numbers of this bat when pollution increases in canalized rivers, which suggest that it is in fact a generalist species.

Due to the lack of information regarding habitat-quality requirements in Daubenton's bats in the Mediterranean region and the species' potential as a bioindicator in riparian habitats, we aimed to 1) examine how QuiroRius data match other well-established biological indicators (IBMWP for invertebrates and QBR for riparian forests); 2) analyse how environmental variables at both local and landscape scales affect the presence of *M. daubentonii*; and 3) describe how environmental traits influence the relative abundance of *M. daubentonii*.

A total of 104 streams below 1000 m a.s.l. were simultaneously sampled using bat, macroinvertebrate and vegetation bioindicators. Despite having similar conservation aims, these three bioindicators did not provide consistent images of overall ecosystem quality and thus a multidisciplinary approach is necessary for a full analysis of the health of these riparian ecosystems. *M. daubentonii* were found more frequently in wide rivers with well-structured native riparian forests; on the other hand, landscape composition at broader scales and altitude had no influence on bat presence/abundance.

Thus, we suggest that QuiroRius could be used as a complementary bioindicator for analysing riparian forest quality but cannot be used alone as a tool for evaluating correctly overall riparian ecosystem health. Both relative abundance and/or presence/absence could be used as bioindicator surrogates given that the effect of microhabitat environmental predictors had similar impact on both these measures.

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1. Introduction

Since society became more aware of how human activities affect the natural environment, interest and concern regarding biodiversity conservation have grown remarkably among both conservationists and the general public, far beyond scientific institutions. Concern about how natural resources are being exploited and the impact such activity is having upon the natural environment is now part of everyday life. Thus, quantifying and monitoring ecosystem health has become a priority for conservationists as a way of understanding and minimizing as many environmental impacts as possible. Monitoring fauna and flora over time has been satisfactorily proven to be a viable conservation tool as it is essential to quantify how environmental changes affect natural communities (Castro-Luna et al., 2007; Barlow et al., 2015). In fact, certain species act as ecological or environmental indicators due to their sensitivity to a wide range of environmental stressors and to their predictable reactions to them (Jones et al., 2009). Some species are known to be sensitive to ecosystem changes such as shifts in water quality and increased eutrophication and pollution (Jones et al., 2009; Barlow et al., 2015). Thus, riparian ecosystems are often key habitats in monitoring programs as they are sensitive to the direct and notable effect of surrounding human settlements and to the accumulative effect of catchment areas.

In Europe, a number of bat species are considered to be good bioindicators (Flaquer and Puig-Montserrat, 2012) due to the rich trophic diversity present in this group (highly adapted to different prey such as spiders, moths, beetles, mosquitoes and even vertebrates); in addition, they sometimes provide pest control as a supplementary ecosystem service (Jones et al., 2009; Kasso and Balakrishnan, 2013; Barlow et al., 2015; Puig-Montserrat et al., 2015). Bat populations may be indirectly affected by water pollution, as some metals and organoclorines from contaminated river sediments have been found in Chironomidae flies, a common prey item amongst insectivorous bats (Kalcounis-Rueppell et al., 2007). Certain bats have degrees of response to habitat degradation that correlate closely to responses in other taxa (Jones et al., 2009). However, what makes bats good potential biological indicators for detecting past disturbance events is their slow reproductive rates. This means that population declines can be rapid, but also that take a long time to recover from declines. Bats need a constant healthy environment to rise in population numbers, and thus, past population declines can be easily detected and accurately assessed through a long-term monitoring programs (Jones et al., 2009; Barlow et al., 2015).

Myotis daubentonii and *M. capaccinii* are the only two trawling bat species (both closely associated with riparian habitats) found in the north-east Iberian Peninsula and the only species that are used as ecological indicators in specific monitoring programs such as the Waterway Survey in the UK. Daubenton's bat monitoring began in the UK during the 1990s as part of the National Bat Monitoring Program (NBMP), which was subsequently adapted in 2007 by the Granollers Museum of Natural Sciences and the Galanthus Association in Catalonia (NE Spain) to create a local protocol known as QuiroRius. In general, insectivorous trawling bat species are top predators on riparian insects, which is why they are widely considered to be good species models for understanding the effects of water quality at high trophic levels (Kalcounis-Rueppell et al., 2007). It is commonly assumed that the foraging activity of bats is directly related to insect abundance and also to the quality of riparian zones (Scott et al., 2010). Although both species are protected by current legislation, only *M. capaccinii* is classified as Endangered in Catalonia (*Decret legislatiu* 2/2008) and Spain (*Real Decreto* 139/2011). Thus, given this species' rarity, these monitoring programs use only data on Daubenton's bat (Flaquer and Puig-Montserrat, 2009). Roost segregation is well studied in both species and, whereas *M. capaccinii* mainly roosts in caves or similar underground tunnels, *M. daubentonii* can be found in urban environments such as in buildings or under bridges. Clear sexual elevational segregation has been reported in Daubenton's bat, with females recorded mainly up to around 900 m a.s.l. and males commoner at higher altitudes (Russo, 2002).

Great controversy exists as to whether *M. daubentonii* can be considered to be a good biological indicator. In some countries such as the United Kingdom it is accepted as a bioindicator (Abbott et al., 2009; Lintott et al., 2015), even though certain studies performed in that country, as well as in Poland, Switzerland and Germany, do show that there is a remarkable increase in this bat's numbers when pollution increases in canalized rivers, thereby suggesting that it is a more generalist species (Kokurewicz, 1995; Vaughan et al., 1996; Racey et al., 1998; Downs and Racey, 2006). Studies that show that *M. daubentonii* prefers upstream stretches of river support the hypothesis that this species could be affected by organic pollution accumulated downstream (Abbott et al., 2009). Data from bat monitoring programs in Britain show that *M. daubentonii* is more active in less polluted rivers and is associated with greater insect biodiversity (Abbott et al., 2009). Nevertheless, unlike other bat species in Europe, *M. daubentonii* has recently increased in number (Barlow et al., 2015), a finding attributed by some researchers to the increase in water pollution that leads to more eutrophic surface waters (with the consequent dramatic decrease in guild richness) and an increase in the availability of Chironomidae species (Abbott et al., 2009).

To our knowledge, no articles exist that report habitat quality requirements for Daubenton's bats in the Mediterranean region. In this study we aimed:

1) To compare how data for *M. daubentonii* compares to data generated by other well-established biological indicators (IBMWP and QBR) as a means of evaluating its potential as a biological indicator;
2) To analyse the effect of environmental variables at both local and landscape scales on the presence of *M. daubentonii*;
3) To describe how these environmental traits influence the relative abundance of *M. daubentonii* in the localities in which it is present.

2. Material and methods

The study was conducted in the NE Iberian Peninsula, a Mediterranean coastal region with a climate classified as 'dry-summer' or 'Mediterranean' according to Köppen's classification. This region is thus characterized by hot dry summers and mild rainy winters (www.eoearth.org). Bat sampling localities were homogeneously stratified along the upper, middle and lower reaches of rivers (Fig. 1) on 18 different Mediterranean rivers. Of these localities, 26 (=104 sampling points) were simultaneously and additionally sampled for macroinvertebrate, bat and plant biological indicators in August and September 2014. In order to ensure normal levels for nitrates (5–20 mg/L), pH (7–8), dissolved oxygen (40–80%) and temperature (16–24.1 °C), all these measurements were checked at every monitoring point on every sampling occasion.

2.1. Study species

Myotis daubentonii and *M. capaccinii* hunt almost exclusively over open water by 'trawling', a technique that consists of flying over and very close to the water surface in order to gaff emerging or floating prey, or catch insects just above the water surface (Warren et al., 2000; Abbott et al., 2009; Akasaka et al., 2009). Both are the only bat species that make figure-of-eight turns when