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Human disturbance affects the long-term spatial synchrony of freshwater invertebrate communities

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ABSTRACT

Taxonomic and trait composition of invertebrate communities were investigated for 4 reference and 5 disturbed Mediterranean stream sites over a 18 y period, to test the hypotheses that: 1) human disturbance reduces the resilience of communities to extreme climatic events by affecting their functional structure; 2) and as a result, extreme climatic events could lead to asynchronous responses of communities from streams with similar environmental characteristics but differently affected by human disturbance. In reference sites, trait compositions changed differently (were less similar over time) in response to extreme events and variation was less synchronic than taxonomic compositions in the same sites. Oppositely, in disturbed sites there was a marked synchrony in trait composition indicating a functional homogenization in response to human pressures. This limitation in "functional diversity" may involve a lower ability to respond to climatic extreme events and also a reduced potential in ecosystem services.

1. Introduction

Freshwater communities are shaped by various spatial and temporal environmental characteristics acting at large (e.g., catchment area, altitude, geology, land use, climate) and small scales (e.g., channels morphology, habitat, organic matter content, substrate particle size, water chemistry, flow; Black et al., 2004; Allan, 2004; Brosse et al., 2003). And according to the Habitat Templet theory (Southwood, 1977, 1988; Towsend and Hildrew, 1994), organisms traits found at a given time in a certain habitat (specially life history strategies related to survival and reproduction) are those that confer the highest fitness to individuals. Therefore, similar environmental conditions should lead to a convergence of benthic communities (Finn and Poff, 2005; Feio and Dolédec 2012). Such a relationship is the basis of modern biomonitoring systems, where aquatic community composition is predicted from relevant environmental features (Hawkins et al., 2000; Verdonschot and Nijboer, 2004).

Given this relation between environment and biota, for a given climatic region we would expect similar and synchronic changes in communities under similar environmental conditions. The term synchronism is often applied to microbial aquatic communities (e.g., Crump and Hobbie, 2005; Kent et al., 2007; Crump et al., 2009) and into a lesser extent to freshwater invertebrates (e.g., Bady et al., 2004; Bêche et al., 2009). However, this concept is implicit when addressing the seasonal patterns of communities in the same region due, for example, to insect life cycles (periods of emergence, eggs postures and larval development).

Both floods and droughts can eliminate certain habitat patches and create new ones that are then colonized by biota with the return to stable flow conditions (Lake, 2000). In Mediterranean systems these events are frequent and predictable across seasons: floods occur in autumn–winter and drought develops continuously and gradually over the summer (Gasith and Resh, 1999). Adaptations of communities to such dynamic conditions include the traits: short life spans, mechanisms to resist or avoid desiccation, and high colonization rates (Lytle and Poff, 2004; Bonada et al., 2007). Traits conferring resilience or resistance to hydraulic constraints associated to flooding (e.g. flattened body shape, drift dispersal) or drying (e.g., resistance to desiccation, aerial respiration) have been shown to be more common in wet and dry periods, respectively (Bêche and Resh, 2007).

Unusual climatic events can modify the predictability of floods or drought and may modify the impact of these events on invertebrate communities. Climatic predictions under global warming scenarios for southern Europe include early and longer droughts (Beniston et al., 2007). These events are a challenge to many aquatic

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species, which may not be able to cope with such harsh conditions, leading to a decrease in their abundance or even to their local extinction. Previous, long-term studies of invertebrate communities in Mediterranean streams have shown that extreme events (large deviations from the mean air temperature and precipitation) lead to shifts in invertebrate community evenness and loss of species (Feio et al., 2010). Moreover, frequent droughts may cause the replacement of riffle inhabitants by species from pool conditions (Pace et al., 2013). Thus, we expect that the fauna that survive those extreme events have similar functional characteristics (traits) that allow them to cope with these changes while the other species are eliminated or become significantly reduced in abundance.

Further, here we postulated that human disturbance reduces the resilience of invertebrate communities to extreme climatic events by affecting their functional structure. As a result, extreme climatic events could lead to asynchronous responses of communities between streams with similar environmental characteristics but differently affected by human disturbance. This can have several implications for biodiversity, as alterations in synchronism in insects emergence may alter local recruitment and species colonization capacity (p.e., reduced number of individuals dispersing), among others. Understanding the natural responses of communities to extreme events and their potential synchronism among streams will help establishing more realistic and useful management and restoration practices.

Therefore, in this paper, we test the following hypotheses:

1) Changes in trait composition of communities due to climate change/extreme events are similar in similar reference streams within the same area, regardless of possible differences in taxonomic composition (Statzner et al., 2004);
2) Human disturbance affects the spatial synchrony among communities of similar streams in both taxonomic and trait composition, i.e., impacted sites do not respond similarly to reference sites to extreme climatic events because their pool of species/traits is reduced due to biotic homogenization (e.g. Olden et al., 2004).

To test these hypotheses we compared the trait and taxonomic composition of invertebrates communities of four reference (least impacted) and five human disturbed sites in two Mediterranean streams, selected based on abiotic and biological information gathered at these sites over 18 years, focussing on their spatial synchrony, and the potential effects of the extreme climatic events observed during that period.

2. Material and methods

2.1. *Study area and sites*

Study sites were located in two similar temporary streams in Alentejo, southern Portugal, at low altitudes (<200 m) with sedimentary bottoms (sand and cobbles) and within the Iberian Pyrite band. Four reference sites (R1–R4) and five human-disturbed stream sites (D1–D5) were considered based on previous knowledge on biological and abiotic condition of the streams. This classification results from the long-term monitoring program (>20 years) conducted by the IMAR team and where physical, chemical and biological data are gathered simultaneously at all sites (Coimbra et al., 1996; Feio et al., 2010). The disturbed sites were located downstream from the discharge of the effluent draining mining waters involving increased concentrations of NO_3^-, SO_4^{2-}, and high conductivity (Fig. 1).

Macroinvertebrates were sampled with a kick net (0.5 mm mesh size; 0.25*0.25 opening) covering all representative habitats, by kicking upstream 6 × 1 m distance. The dominant sampled habitats were rifles, macrophyte beds and pool areas. Invertebrates were identified by the same research team to the highest possible

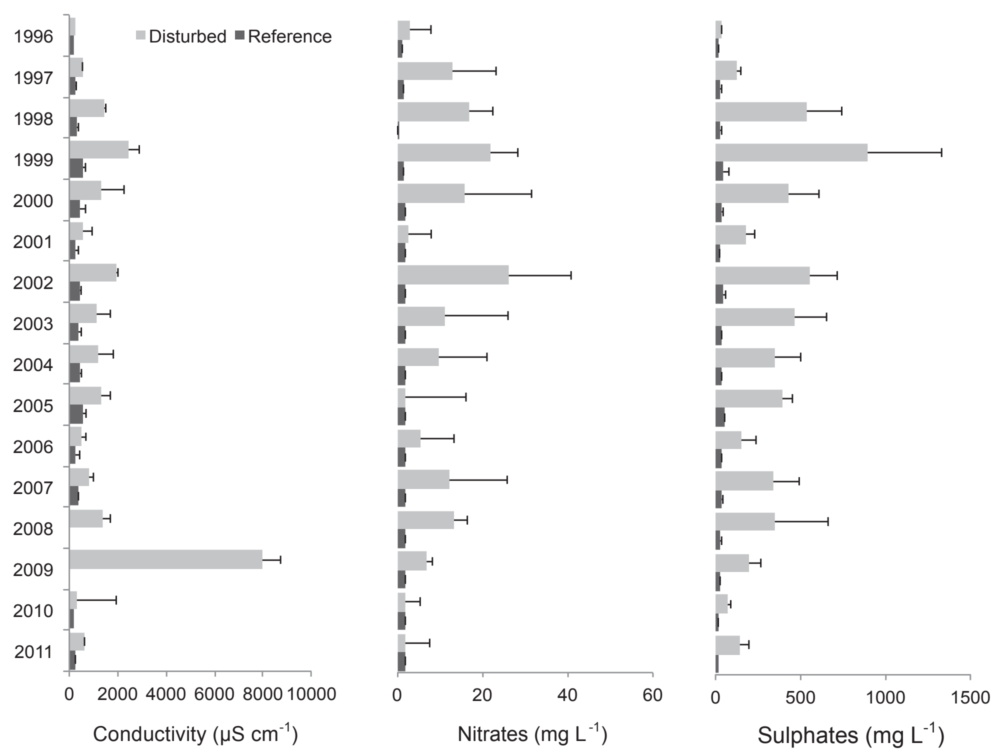

Fig. 1. Average values of conductivity (µS cm^{-1}), nitrates (NO_2^-) and sulphates (SO_4^{2-}) over the study period (except 1993–1995, no abiotic data available) at reference and disturbed sites.