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Research paper

Land cover disturbance homogenizes aquatic insect functional structure in neotropical savanna streams

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ABSTRACT

By modifying local habitat conditions, the alteration of land cover can result in severe faunal impairment, subsequently affecting ecosystem functioning. We analyzed changes in the composition of Ephemeroptera, Plecoptera and Trichoptera (EPT) assemblages along a gradient of human disturbance intensity in 66 neotropical savanna headwater stream sites. Whereas EPT genus richness did not differ among the levels of disturbance, functional richness and diversity significantly decreased from least- to highly disturbed sites. Using a combination of RLQ and fourth-corner analyses, we found that 12 of 28 trait categories were significantly associated with changes in catchment land use and cover intensity, local physical habitat, and water quality. EPT assemblages in least-disturbed sites were characterized by higher proportions of large body size and low body flexibility with < 1 reproductive cycle per year, case building, and climbing functional traits. In addition, disturbed sites demonstrated high assemblage functional homogenization compared with least disturbed sites. To our knowledge, this study is the first that examines the response of invertebrate functional structure along a gradient of human disturbance at a large spatial scale in the Neotropics. In doing so, we demonstrate the applicability of multiple trait-based approaches and the higher reliability of functional structure in comparison to taxonomic composition for assessing the effects of human disturbances in neotropical streams.

1. Introduction

Human pressures related to agriculture and land cover modifications are the main drivers of ecological degradation in stream and river ecosystems, primarily resulting from increases in nutrients and fine sediments and hydromorphological alterations (Carpenter et al., 2011; Dudgeon et al., 2006; Vörösmarty et al., 2010). These changes have often resulted in the simplification of habitats and reduced the diversity of aquatic communities, imperiling the ecological integrity and the sustainability of ecological processes and associated ecosystem services (Cardinale et al., 2012; Hooper et al., 2005). Furthermore, multiple human pressures yield taxonomic and functional losses in assemblages through the reduction of the number of specialized species (i.e., species with narrower niche breadth), leading to biotic homogenization (Devictor et al., 2010; Mondy et al., 2014; Leitão et al., 2016). Olden et al. (2004) identified three components of biotic homogenization: genetic, taxonomic, and functional. Taxonomic homogenization (the most common component) represents the increase in species similarity in space over time whereas functional homogenization stands for the decrease in functional diversity among species in the community (Olden and Rooney, 2006). As a result, functional homogenization at the community level limits the functions provided by the community and its ability to respond to human pressures (Clavel et al., 2011; Gámez-Virués et al., 2015).

Trait-based approaches have been successfully used to assess mechanisms structuring communities and the effects of human pressures on aquatic invertebrate assemblages (e.g., Dolédec et al., 1999; Culp et al., 2011; Gutiérrez-Cánovas et al., 2015; Piló et al., 2016; Kuzmanovic et al., 2017) because of several advantages: (1) Biological trait responses are spatially stable in both natural and human least-disturbed situations (e.g., Statzner et al., 2004; Bonada et al., 2007), which potentially offer a more reliable assessment of ecological integrity compared with the use of taxonomic composition that naturally varies across large spatial scales. (2) Biological traits allow a more mechanistic understanding to identify the causes of changes in assemblages (e.g., Dolédec et al., 2011; Verberk et al., 2013). (3) Biological traits respond to a broad range of stressors in a predictable manner (e.g., Dolédec et al., 1999; Usseglio-Polatera and Beisel 2002; Culp et al., 2011; Mondy et al., 2014; Mouillot et al., 2013).

In the Neotropics, the main human disturbances include habitat

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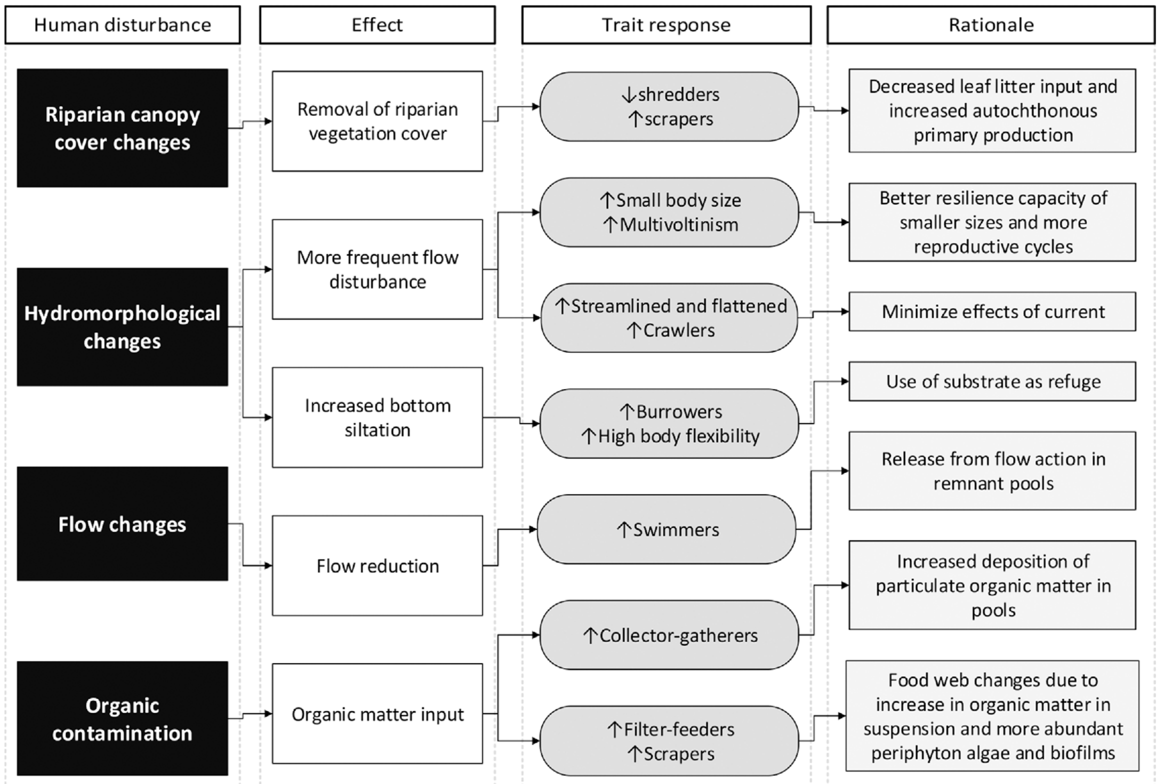

Fig. 1. Graphical framework showing predictions for trait category responses to human impacts. Impacts may decrease (↓) or increase (↑) the relative abundance of a single trait category (after Statzner and Bêche 2010 and Feio and Dolédec 2012).

fragmentation and land cover conversion for agricultural purposes (Overbeck et al., 2015; Hunke et al., 2015). Those disturbances have several consequences for stream environments, such as reduced water quality, excess bottom siltation, altered flow regimes, and changes in stream channel structure (Allan et al., 1997; Leal et al., 2016). In other regions, authors have demonstrated that human disturbances not only affect taxonomic composition and richness but also the functional structure of benthic invertebrate assemblages (e.g., Archaimbault et al., 2010; Mondy et al., 2016; Ding et al., 2017). The neotropical savanna (Cerrado biome), the second largest biome in Brazil and a biodiversity hotspot (Myers et al., 2000), encompasses three of the largest basins in South America (i.e., Paraná, São Francisco, and Tocantins-Araguaia Rivers). Despite its enormous importance for freshwater biodiversity and the provision of ecosystem services (Strassburg et al., 2017), the Cerrado biome has been largely overlooked in terms of human disturbance effects on the functional structure of aquatic invertebrate assemblages. Therefore, assessing changes in functional structure may facilitate disentangling the effects of disturbance on species assemblages (Leitão et al., 2017) and understanding how human disturbances affect aquatic ecosystems in this region.

We designed our study using Ephemeroptera, Plecoptera and Trichoptera (EPT) assemblages to answer two questions: (1) Are potential differences in reliability between taxonomic and functional structure of aquatic insect assemblages to depict human disturbance in the Neotropics similar to those observed elsewhere (e.g., Dolédec et al., 1999)? (2) Do human disturbances also alter assemblage specialization? We had two hypotheses: (1) Because taxa possess traits that confer different sensitivities to land cover alteration intensity and associated hydromorphological degradation, co-adapted traits within benthic assemblages would be selected [life-history strategies include different combinations of traits that represent the solution to a given ecological problem or disturbance (Verberk et al., 2013)]. (2) The more diversified habitat conditions in least-disturbed streams will result in higher taxonomic richness, functional diversity, and assemblage specialization compared with streams affected by anthropogenic stressors. Specifically, we made *a priori* predictions on the potential responses of the functional structure of benthic invertebrate assemblages to land cover alteration (e.g., deforestation) and the associated impairment of the hydromorphology (e.g., sedimentation and flow regime) and stream water quality (e.g., increase in nutrient inputs). Direct effects of riparian vegetation cover removal include the reduction of litter input, which should subsequently limit the proportion of shredders. Indirect effects of riparian vegetation cover removal yield more frequent flow disturbances. Those disturbances should select organisms with traits conferring resilience, such as small size, several reproduction cycles per year (multivoltinism), and resistance capabilities (streamlined/flattened shape and crawling locomotion) (Townsend and Hildrew, 1994). In addition, changing land cover for agricultural purposes may directly involve an increase in fine sediment deposition, which should favor burrowers and potentially lead to flow reduction (because of water abstraction), which should favor swimmers (e.g., Statzner et al., 2010). Finally, changes in water quality associated with organic contamination should favor filter feeders and collector gatherers, and the associated expansion of biofilms should favor scrapers (Fig. 1). Although we made individual predictions, we are aware that traits correlate in organisms (Verberk et al., 2013).

2. Methods

2.1. Study area

We conducted our study in wadeable streams located in the neotropical savanna (Cerrado biome) of southeastern Brazil. A total of 160 sites (1st- to 3rd-order streams sensu Strahler (1957), defined at a 1:100,000 scale) were randomly selected and sampled in four hydrological units (defined as the contributing drainage areas within 35 km