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Research paper

Biological indicators of diversity in tropical streams: Congruence in the similarity of invertebrate assemblages

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ABSTRACT

Surrogate indicators are important alternatives to overcome the shortage of total biodiversity data for planning and implementing conservation measures. The most important premise of this approach is congruence among surrogate candidates and among different assemblages. The aim of this study was to evaluate abundance and incidence congruence between invertebrate assemblages at two taxonomic resolutions (genus and family), and between invertebrate assemblage (genus) and three groups of taxa (EPT, Odonata, and Trichoptera). We also evaluated the congruence between functional groups of EPT and the taxonomic groups listed above. Data were collected from 51 stream sites distributed along a disturbance gradient in the rural area of the Paragominas municipality of the state of Pará, Brazil. We used Procrustes analysis to test congruence between invertebrate assemblages at the multiple taxonomic resolutions listed previously. Family taxonomic level was a good substitute for similarity patterns measured at the genera level. EPT genus also were highly congruent with whole invertebrate assemblage (genus level) variation. Trichoptera had greater congruence with all macroinvertebrate genera than did Odonata. The congruence between EPT functional groups and groups of taxa was greater than r = 0.70. In general, taxonomic and functional metrics responded similarly to environmental conditions (water quality, channel morphology, substrate, riparian vegetation cover). Trichoptera (abundance), EPT (genera and functional groups), or invertebrate families appear to be reasonable surrogates for Amazon stream invertebrate assemblage as biological indicators for assessing and conserving streams influenced by agriculture.

1. Introduction

Predictions about global change effects on biodiversity patterns indicate land use has a major impact on aquatic systems (Sala et al., 2000), principally resulting from reduced habitat availability and removal of riparian vegetation (With and King, 1999). Agricultural and urban landscapes represent ~43% of the planet's land surface (Barnosky et al., 2011). Tropical forests and their aquatic environments are among the most altered biomes (Macedo et al., 2013; Laurance et al., 2014). In the Brazilian Amazonia, agricultural activities have removed ~18% of the forest (Ferreira et al., 2012). This scenario has prompted conservationists to protect the remaining biodiversity by preserving focal areas, better managing remaining forests, and by rehabilitating altered ecosystems (e.g., Howard et al., 1998; Palmer et al., 2009).

For biodiversity conservation it is necessary to know the distribution patterns of the biota via comprehensive floristic and faunal surveys. However, such surveys are very costly and time consuming because of the need for rigorous field sampling and laboratory sample processing by highly skilled professionals (Lovell et al., 2007). In tropical biomes, the costs and time required for the surveys are greater than in temperate regions because of limited taxonomic knowledge, high biodiversity, and difficulties in accessing the study area (Lund and Rahbek, 2002). Because of the continued global economic crisis, resources for biodiversity research and conservation are increasingly scarce. For example, in Brazil, the research budget over the last two years (2015–2016) has been reduced by approximately 36%, affecting both project funding and the training of professionals (Angelo, 2016). To counter a perfect storm of economic crisis and pressure to expand agricultural frontiers over the Amazon forest, it is increasingly

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necessary to find shortcuts for biodiversity conservation strategies through sensitive, accurate, and economical approaches to survey biota.

An important alternative for addressing the scarcity of biodiversity data is the use of surrogates, such as environmental characteristics or indicator taxa instead of the entire biotic community (Heino et al., 2005). Similarly, the focus can be on higher taxonomic levels (e.g., family) versus genera or species (Heino and Soininen, 2007; Whittier and Van Sickle, 2010). However, efficient use of this approach requires a high level of congruence between candidate biodiversity indicators and the whole community or environment variables (Lovell et al., 2007; Heino, 2010). For example, two assemblages are congruent when values of metrics used to describe them are highly correlated. Studies testing applicability of the surrogates approach have found contradictory results (Su et al., 2004; Heino, 2010; Landeiro et al., 2012; Westgate et al., 2014). Uncertainties about the efficiency of this approach have stimulated an increased number of studies assessing the congruence of various community descriptors (e.g., Landeiro et al., 2012).

Functional descriptors using organism traits can also be an important tool for explaining community patterns (Lange et al., 2014; Serra et al., 2016; Floury et al., 2017). An advantage of this approach is the greater understanding of the mechanisms determining the function of ecological systems (Poff, 1997). Thus, functional traits should be explicitly linked to ecosystem processes. However, most congruence studies have prioritized a purely taxonomic approach (Guareschi et al., 2015; Valente-Neto et al., 2016; Vilmi et al., 2016). For example in aquatic ecosystem studies, comparisons between taxonomic levels (e.g., species, genera, families, orders) and taxonomic groups (e.g., macrophytes, invertebrates, and vertebrates) have predominated. A purely taxonomic approach may result in loss of valuable information.

Aquatic invertebrates have several characteristics that favor their use as biological indicators, which is why they are widely used in biomonitoring freshwater environments (see Bonada et al., 2006). Ephemeroptera, Plecoptera and Trichoptera (EPT) and Odonata are promising candidates for assemblage surrogates because they are sensitive to environmental changes, relatively easy to identify, have a relatively high number of taxa, and are widely distributed in low-order tropical streams (Martins et al., 2017; Siegloch et al., 2017). Moreover, Odonata are charismatic animals (Luke et al., 2017), have strong appeal for biodiversity conservation (Monteiro Jr. et al., 2015), and are sensitive to riparian disturbance (Oliveira-Junior et al., 2017).

Thus, we had four objectives in our study. 1) Determine the congruence between similarity patterns of entire aquatic invertebrate assemblages in eastern Amazon streams and three assemblage subgroups (EPT, Odonata and Trichoptera). 2) Evaluate the use of the family taxonomic level as a substitute for similarity patterns measured at the genus level. 3) Assess the congruence between EPT functional groups and the taxonomic groups listed above. 4) Examine the relationship between the preceding biological metrics and environmental variables (water quality, channel morphology, substrate, riparian vegetation cover).

2. Material and methods

2.1. Study area

We sampled 51 low-order streams located in the rural area of the municipality of Paragominas (02°59′45″S, 47°21′10″W), Pará state, Brazil (Fig. 1). We selected the sites along an anthropogenic disturbance gradient, principally riparian vegetation loss, which changed from 0% (11 sites) to 100% (5 sites). This region is one of the largest agricultural areas in the state of Pará (El-Husny et al., 2003). Livestock farming was the first large-scale land-use activity established in Paragominas, and was driven by the arrival of farmers from southern Brazil (1950–1960). Between 1980 and 1990, the timber industry expanded rapidly and, since 2000, mechanized agriculture has been expanding into the pasture and secondary forest areas of the region. Another important activity is plantation forestry, mainly *Eucalyptus* spp. and *Schizolobium amazonicum* (Gardner et al., 2013). In a previous study of these sites, the negative effect of agricultural activities on fish and invertebrate (EPT and, Odonata) assemblages was observed (Chen et al., 2017).

2.2. Invertebrate sampling

We sampled stream sites during the 2011 dry season (June to August). In each site, we collected a 0.09 m^2 sample of bed substrate

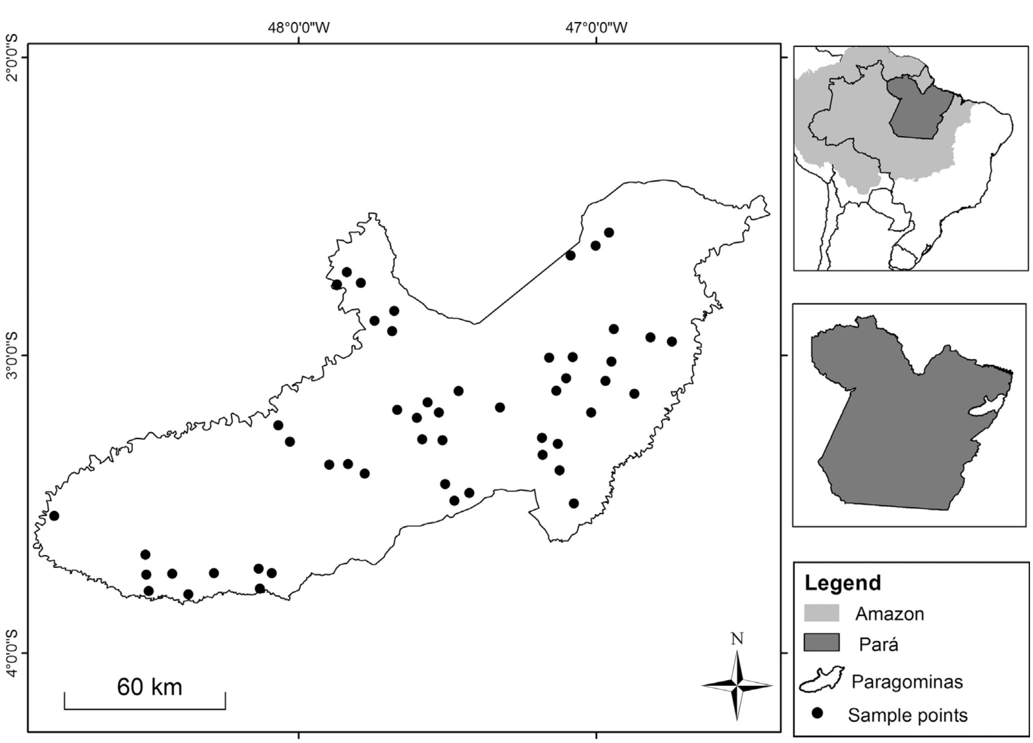

Fig. 1. Stream site locations (n = 51) in Paragominas municipality, Pará state, Brazil.