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Assessment of biotic condition of Atlantic Rain Forest streams: A fish-based multimetric approach

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ABSTRACT

We developed a preliminary fish-based multimetric index (MMI) to assess biotic condition of Atlantic Rain Forest streams in Southeastern Brazil. We used least-disturbed sites as proxies of reference conditions for metric development. To determine the disturbance gradient we used an Integrated Disturbance Index (IDI) that summarized the multiple disturbances measured at local/regional catchment scales in a single index, describing the totality of exposure of the streams to human pressures. For our 48 sites, nine were least-disturbed (IDI < 0.25), five were most-disturbed (IDI > 1.35) and 34 were intermediate. Initially, we considered 41 candidate metrics selected primarily from previous studies. We screened this pool of candidate metrics using a series of tests: range test, signal-to-noise test, correlation with natural gradients, responsiveness test, and redundancy test. After screening, we selected six metrics for the MMI: % Characiform individuals, % water column native individuals, % benthic invertivorous individuals, % tolerant species, % intolerant species, and % detritivorous individuals. Metrics such as diversity, dominance, species richness and biomass that have been historically used for assessing ecosystem condition failed one or more screening tests. We conclude that an IDI and rigorous metric screening are critical to the MMI development process and for meaningful assessments of stream condition.

1. Introduction

Multimetric indices (MMIs) have been applied as an integral part of water quality monitoring programs worldwide (Furse et al., 2006; Yagow et al., 2006; Marchant et al., 2006; Borja et al., 2008). First proposed by Karr (1981), many countries have adopted one or more fish MMIs as official tools for monitoring aquatic systems (Hughes and Oberdorff, 1999; Roset et al., 2007). In the United States, MMIs have been widely adopted by water management agencies as the primary tool for assessing the biological condition of streams and lakes (Karr and Chu, 1999; USEPA, 2002) and for making national stream and river assessments (USEPA, 2013). In Europe, following the Water Framework Directive (European Commission, 2000), implementation of biological monitoring became mandatory and MMIs help guide restoration activities and management of aquatic ecosystems (Hering et al., 2006; Pont et al., 2006). However, in developing countries such as Brazil, the use of MMIs are not required in monitoring programs, although several studies aiming to develop such tools have been conducted in recent years (Ferreira and Casatti, 2006a; Pinto et al., 2006; Pinto and Araújo, 2007; Baptista et al., 2007; Mugnai et al., 2008; Casatti et al., 2009; Oliveira et al., 2011; Terra and Araújo, 2011).

The lack of a biomonitoring program reflects the absence of an integrated view of the ecological condition of the water bodies, which hinders creation of rational recovery and protection plans (Hughes et al., 2000). On the other hand, high tropical taxonomic diversity and the lack of reliable information about physical and chemical disturbance thresholds hinder MMI development. It is important to overcome these challenges in countries such as Brazil by developing an MMI that efficiently uses available biological information, as well as known disturbance gradients. For example, using an Integrated Disturbance Index (IDI; Ligeiro et al., 2013) for the identifying reference sites is feasible because it does not depend on previous classifications based on physical or chemical thresholds. The IDI combines disturbance at local and regional scales in a single index describing the total disturbance of the sites by human pressures.

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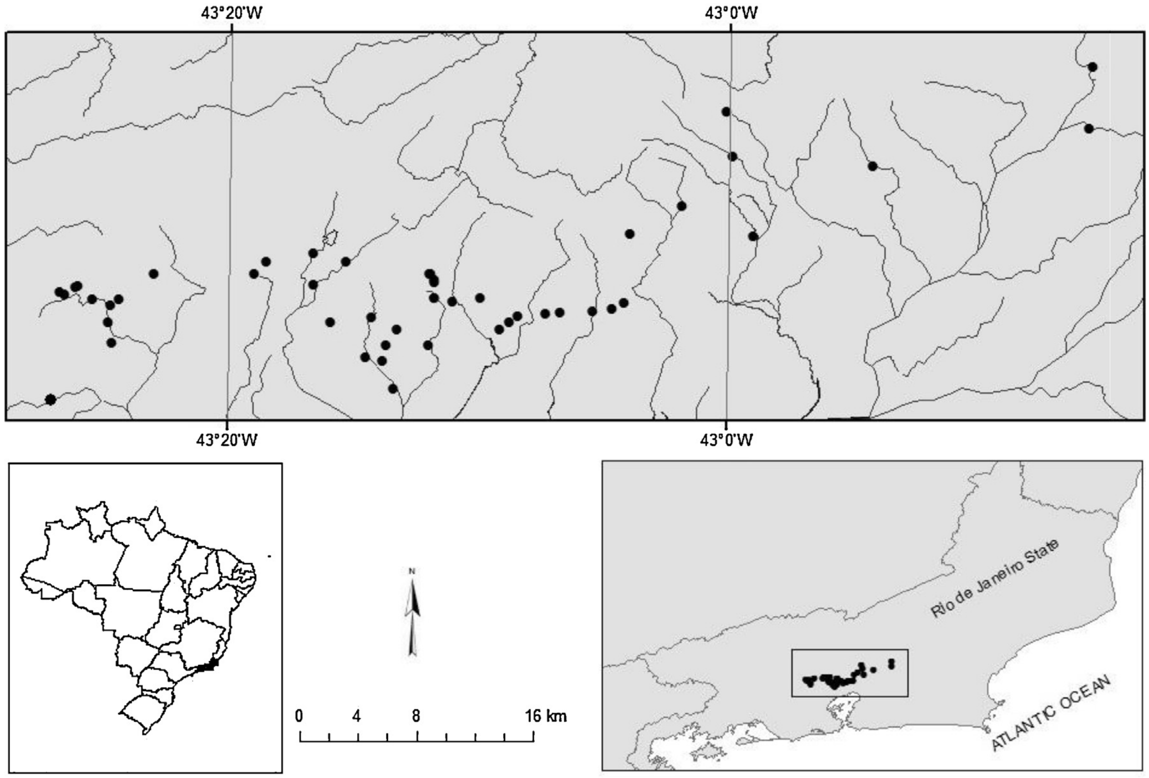

Fig. 1. Locations and distribution of the 48 sites sampled in five basins that drain to Guanabara Bay, Rio de Janeiro, Brazil.

The Atlantic Rain Forest is one of the most threatened biomes of the world, with an estimated 11.4–16% remaining of the 150 million ha originally in Brazil (Ribeiro et al., 2009). The remaining biome covers approximately 157,000 km^2 along the Brazilian coast (Ribeiro et al., 2009), and its rivers and streams support a highly diverse and endemic fish fauna (Bizerril, 1994). The most important reason for that diversity and endemicity is the great number of independent coastal drainages (or groups of basins), and the isolating effect of mountain ranges and seawater among coastal rivers (Bizerril, 1994; Menezes et al., 2007). According to Abilhoa et al. (2011), 70% of the freshwater fishes in the Atlantic Forest can be considered exclusive to the coastal drainages of this biome. However, the high water demands, untreated wastewater disposal, and intensive land uses conflict with conservation policies for Atlantic Rain Forest streams. Consequently, these systems need to be monitored and assessed, and biotic indices have been shown to be useful tools for doing so elsewhere in Brazil (e.g., Bozzetti and Schulz, 2004; Ferreira and Casatti, 2006a; Casatti et al., 2009).

In this study, our goal was to assess the ecological quality of Atlantic Rain Forest streams through use of an MMI. To do so we (a) determined a disturbance gradient, (b) selected fish-based ecological indicators (metrics) capable of distinguishing fish assemblages along that gradient, (c) combined those metrics into an MMI, and (d) assessed the performance of that MMI statistically.

2. Materials and methods

2.1. Study area

We conducted this study in five basins, all of which drain to Guanabara Bay in the Atlantic Rain Forest biome, in the State of Rio de Janeiro, southeastern Brazil. The study area included four Conservation Units (Tinguá Biological Reserve, Petrópolis Environmental Protection Area, Serra dos Órgãos National Park, and Três Picos State Park). This area is bounded by the Serra do Mar, with altitudes between 800 and 1800 m a.s.l. The climate is warm and humid, with two well-defined seasons: a wet season from October to March, and a dry season from April to September, an average annual temperature of 22 °C, and mean annual precipitation near 1700 mm (SEMADS, 2001).

2.2. Site selection

We studied 48 sites distributed in five river basins: Estrela (23 sites), Suruí (5), Roncador (2), Iguaçu (12) and Guapimirim (6). The sites were randomly chosen within first to fourth-order streams, with mean stream width ranging from 1.0 to 16.0 m (Fig. 1; Table 1). We also ensured that the sites had distinctly different channel slopes, substrates, and anthropogenic pressures (urbanization, sewage discharges, deforestation).

2.3. Sampling design

We sampled fish during the dry season from May to October (2010 and 2011) to standardize the seasonal context. Although our goal was to assess the influence of human actions, not natural assemblage variation through time, we re-sampled seven of the sites during the wet season from February 2010 to March 2011 (Table 1) to measure the repeatability or precision of the candidate metrics.

Following the USEPA's national protocol (Peck et al., 2006), at each random point, a site was extended upstream for 40 times the mean wetted channel width, or a minimum of 100 m. In each stream site, 11 equidistant cross-section transects were marked, defining 10 sections of the same length. In the middle of each section another