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Research Letters

Longitudinal gradient effects on the stream fish metacommunity

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ABSTRACT

Understanding the influence of local and regional factors that structure biological communities can be useful in environmental conservation. Our objective was to verify whether a fish metacommunity in the Brazilian Atlantic Forest has a nonrandom structure along the longitudinal stream gradient. To do so, we applied the elements of metacommunity structure to examine fish distribution patterns at the micro-basin extent for 20 stream fish assemblages. Stream fish species were independently distributed following the Gleasonian pattern. The Gleasonian pattern suggested that the communities varied continuously over space, potentially reflecting the degree to which species tolerances overlap. The metacommunity structure may have resulted from the environmental gradient and has a high beta diversity. The upstream reaches have higher values from regional variables (confluence distance and declivity) and slower values on variables representing a local scale (temperature, conductivity, depth, and width). Knowing the type of structure and the drivers that shape a metacommunity, we suggested that ensuring the connectivity of streams is a good conservation strategy as the species move from one to another, being very dependent on the colonization source. This environmental management can affect biodiversity at local and regional scales, thus we would require devoting local conservation efforts to a large number of different reaches of streams and in a micro-basin regional scale.

Introduction

A central theme in community ecology is the relative importance of local and regional processes on the structuring of local biological communities (Ricklefs, 1987). Local processes, such as competition, predation, resource limitation, disturbance, and stochastic events, are known to influence local diversity. Regional processes, such as lifetime of the habitat, differences in speciation and immigration rates, and differences in extinction history (Ricklefs and Schluter, 1993), are more difficult to be incorporated into ecological studies. These processes act

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on a larger spatial and temporal scale. The metacommunity concept has been applied to understand the direct influence of local processes and indirect influence of regional processes in community structure (Ricklefs, 2008; Leibold et al., 2004; Holyoak et al., 2005). A metacommunity is considered a set of local communities that are linked by dispersal and that potentially interact with one another (Hanski and Gilpin, 1991; Wilson, 1992; Holyoak et al., 2005).

The elements of metacommunity structure (EMS) (Leibold and Mikkelson, 2002) constitute a pattern-based approach to examine the metacommunity. EMS identify which idealized metacommunity structure best reflects the species distribution along the latent gradient. The idealized patterns of species distribution include checkerboard, nestedness, evenly spaced, Gleasonian, Clementsian, and random distributions (Leibold and Mikkelson, 2002; Presley et al., 2010).

The checkerboard pattern occurs when pairs of species co-occurrence is less than expected by chance, demonstrating the existence of competitive exclusion (Stone and Roberts, 1990). The nestedness pattern is found if poor communities that occupy a smaller portion of the environmental gradient are subsets of those that occupy a larger portion of the gradient (Patterson and Atmar, 1986). If species distributions exhibits turnover along the environmental gradient, three patterns can be identified. Evenly spaced distributions occur if the boundaries are hyperdispersed, indicating maximal differences in environmental tolerances among species (Tilman, 1982). If the boundaries of the species distributions are idiosyncratic, the pattern is Gleasonian, with individualistic responses to the underlying environmental gradients and overlapping ranges (Gleason, 1926). The Clementsian pattern occurs if the boundaries are clumped in reference of distinctive "communities" in which the boundaries of species ranges are coincident (Clements, 1916).

Stream systems are characterized by branched and hierarchically organized dendritic networks (Grant et al., 2007) in which the upstream water course is smaller and tend to become larger in the downstream due to the connections between them. The mobility pattern of species is influenced by this structure (Brown and Swan, 2010). In dendritic networks, it is expected that communities of macroinvertebrates and fish assume distinct metacommunity patterns because these organisms respond differently to local and regional effects along the longitudinal gradient (Grant et al., 2007; Brown et al., 2011; Henriques-Silva et al., 2013; Fernandes et al., 2014). The environmental heterogeneity along the upstream-downstream gradient influences the community composition, creating species zonation and addition (Balon and Stewart, 1983; Rahel and Hubert, 1991; Petry and Schulz, 2006; Ferreira and Petrere, 2009).

The longitudinal gradient is central to stream hydraulics, depth, and substrate type and act as a filter on functional species traits (Lamouroux et al., 2002). The upstream-downstream gradient may affect the extinction-colonization events, shaping ecological community and facilitating the identification of the metacommunity pattern (Datry et al., 2016). Motivated by these ideas, we expect that stream fish community will exhibit turnover along the environmental gradient (Clementisian or Gleasonian metacommunity pattern), because both the environmental harshness in the downstream-upstream gradient and local environmental conditions determine the species occurrence in a transition of high to intermediate dispersal and within a instream to across streams gradient (Heino et al., 2015). Our objective was to verify whether a fish metacommunity in the Brazilian Atlantic Forest has a nonrandom structure along the longitudinal stream gradient. To do so, we applied the elements of metacommunity structure (EMS) to examine fish composition patterns at the micro-basin extent for 20 stream fish assemblages.

Material and methods

Study area

The network of streams selected is located in the southeastern of São Paulo state, in the Alto Paranapanema River Basin. The headwater streams originate in Serra de Paranapiacaba, at an elevation of 1100 m. In this part of the basin, the vegetation is characterized by Atlantic Forest, with a rainfall of 1700 to 2400 mm and an annual temperature ranging from 18 °C to 20 °C (CBRN, 2009). We selected twenty wadeable streams stretches targeting 2nd to 4th order (Strahler, 1952). Eleven were from Claro River micro-basin (C1–C8 and CL1–CL3), six from Pinhal River micro-basin (P1–P6), and three from Alegre River micro-basin (A1–A3) (Fig. 1 and Table S1). For each stream stretch, geographic coordinates (UTM) were recorded with a GPS (Garmin eTrex Legend H) and the distance (km) between each stream stretch and the main confluence in the subbasin and declivity (m/km) were measured.

Fish sampling and environmental data

Fish were collected during the dry season in August–November 2011/12 during daytime hours by electrofishing using a portable gasoline generator (Yamaha EF2600 model, 2.3 kVA, 60 Hz) linked to a current rectifier. In each stretch, a single downstream-upstream sweep was performed, without contention nets at the upper and lower limits. We selected streams stretches of 70 m in length presenting at least one pool-and-riffle sequence that provides a heterogeneous physical environment that is utilized by many different types of organisms (Fryirs and Brierley, 2013). In the dry season, the relationship between fish assemblages and water conditions in the streams were expected to be more robust, since flows are lower and fish can be captured more efficiently (Pinto et al., 2006; Pease et al., 2012). Furthermore, this ensured only direct dispersal interactions between sites, with no confounding in the data through multiple dispersal events, which occurs in the rainy season (Cottenie, 2005).

We used 29 variables to characterize the stream stretch environment (Table 1). Bank composition was visually estimated as the percentage of rocks, tree roots, tree trunks, steep slopes, and exposed soil in both banks at three transects positioned perpendicular to the 70-m reach. Transects were separated by 20–25 m and selected to represent upper, middle, and low sections of the reach. Shading was estimated as the percentage of shaded and lighted areas within the 70-m stream reach.