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Research Letters

Where matrix quality most matters? Using connectivity models to assess effectiveness of matrix conversion in the Atlantic Forest

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ABSTRACT

Great interest has been devoted to understand how agricultural matrix managements affect species flux in the patchy landscapes and agroforestry systems are known to enhance connectivity for forest dwelling species. In the Brazilian Atlantic Forest, high degree of fragmentation makes the implementation or the conservation of the existing agroforestry systems keystone to connectivity conservation. We located places in the Atlantic Forest where agroforestry restoration is more effective in terms of connectivity conservation using a multi-scale approach. We conducted a large scale regional analysis to identify regions in which matrix conversion has larger effect on bird functional connectivity. Furthermore, we conducted two separate local analyses in the landscape which accounted for high restoration effectiveness in the regional analysis. One was the overlap with the Forest Code debt map to assess where and how much land-owners must restore as obligated by law. The second local analyses consisted in locating areas which least cost path trajectories density is larger within the selected landscape. Matrix restoration effort would be largely maximized by acting on specific places, and multi-scale and interdisciplinary models that account for the biological response of biodiversity and contextualizes under environmental laws will foster effective conservation policies.

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Introduction

Connectivity concerns the capability of the landscape in facilitating species flux and is vital for conserving biodiversity in patchy environments (Taylor et al., 1993). Through landscape connectivity, recolonization can balance local extinction, a process called "rescue effect" (Brown and Kodric-Brown, 1977) maintaining populations in space and time. Because, around one third of the terrestrial ice-free surface of the world is covered by some kind of agricultural system (Ramankutty et al., 2008; Foley et al., 2011), great interest has been devoted to understanding how different agricultural managements influence landscape connectivity (Perfecto and Vandermeer, 2008). Agriculture is also considered the single greatest cause of biodiversity loss (Green et al., 2005). Furthermore, the footprint of agriculture is predicted to increase in the near future, increasing the cultivated area, degrading soil and water and negatively affecting ecosystems services (Laurance et al., 2014). According to the classical definition, matrix is the largest land-use type in a given landscape (Forman, 1995). In degraded and fragmented regions the matrix is often composed by anthropogenic habitat, and generally agricultural managements (Perfecto and Vandermeer, 2008). Therefore, in many landscapes, habitat patches are embedded in agricultural matrices, and organisms inhabiting such patches often present metapopulation dynamics (Perfecto and Vandermeer, 2008). These agricultural matrixes may serve as a conduit or a barrier to species dispersal depending on the type of management they are subjected to (Perfecto and Vandermeer, 2008). Agroforestry systems are known to facilitate flux of species in the matrix (Perfecto and Vandermeer, 2008; Asare et al., 2014). On the other hand, intensive agricultural systems such as pasture and other monocultures act as barriers to dispersal of forest species (Robertson and Radford, 2009).

Connectivity is composed by two elements: structural and functional (Uezu et al., 2005). Structural connectivity concerns the proximity among habitat patches, the presence of corridors and matrix permeability. On the other hand, functional connectivity refers to the species-specific response to this structure (Uezu et al., 2005). In the Brazilian Atlantic Forest region, both structural and functional connectivity are important for species conservation (e.g. Uezu et al., 2005).

The Atlantic Forest biome occurs in Brazil, Argentina, Uruguay and Paraguay and it has being considered global priority site for conservation (Myers et al., 2000). Between 11 and 16% of the original cover remains and most of the forest patches smaller than 50 ha which increases the risk of extinction for many forest species (Ribeiro et al., 2009). Because of this extremely high species richness and high degree of fragmentation, it is expected that local and global extinction events take place among Atlantic forest birds in a near future (Metzger et al., 2009). Therefore policies that act implementing agroforestry systems in anthropogenic matrices are keystone to biodiversity conservation in the biome. Financial resources for conservation are scarce, hence conservationists must define areas in which conservation policies are optimized, identifying where conservation actions intensively affects more species (Sarkar and Illoldi-Rangel, 2010; Jenkins et al., 2010). Finally, conservation actions must be contextualized in the legislation and policy issues in order to move from theory to practice. Concerning this aspect, any restoration management in the Atlantic Forest, as well as in other Brazilian biomes, must be rooted on the New Forest Code (Soares-Filho et al., 2014).

We assessed the response of bird connectivity to agricultural matrix conversion in assess priorities sites for matrix conservation in the Atlantic Forest of Minas Gerais State using a cross-scale framework. We hypothesize that connectivity increment caused by matrix restoration will affect preferably certain landscape configurations, as well as affect species differently according to their dispersal abilities.

Methods

This framework uses a regional and a local analysis for matrix restoration. In the regional analyses we used binary forest and non-forest map of the Atlantic Forest, located places where four endemic bird species occur, simulated the conversion of the matrix into three different land-use (low, medium and high quality) and calculated the increase in functional connectivity caused these conversions (Fig. 1). We selected the following passerine birds, all of them endemic to the Atlantic Forest: *Chiroxiphia caudata* (Blue Manakin), *Xiphorhynchus fuscus* (Lesser Woodcreeper), *Pyriglena leucoptera* (White shouldered fire eye) and *Sclerurus scansor* (Rufous-brested Leaftosser). For further information about these species and why they were selected, see supplementary material. We then identified places where matrix restoration is most effective in terms of functional connectivity conservation for these species assuming homogeneous matrixes types. In the local analyses, we assess areas in which matrix restoration would be recommended at small scale within the region that accounted for highest levels of restoration effectiveness in the regional analyses. To do this we used land-use maps to account for matrix heterogeneity and identify least cost paths trajectories, and the density of trajectories among the largest forest patches. Furthermore, we made a separate analysis which takes into account the Forest Code offset balance to locate where restoration is obligatory by law at local scale.

Regional analyses

The regional analysis consisted in selecting 40,000 ha landscape cells in which the four endemic bird species occur in the State of the Minas Gerais using a binary of forest and non-forest habitat (S.O.S. Mata Atlântica, available at http://www.sosmatatlantica.org.br). Using these maps, we assumed three hypothetical matrix quality scenarios. The matrix quality was assumed to be low (pasture and monoculture), medium (polyculture and home gardens) and high (rustic agroforestry). We used literature records to defy dispersal thresholds for the species in these different matrices and used these values to model functional connectivity (see supplementary material). We calculated functional connectivity (IIC) of the species using Conefor Sensinode 2.2 (Saura and Torné, 2009). Than we subtracted the IIC produced after treatments (matrix permeability scenarios), so that for each grid and for each species, we calculated: