



Effects of habitat loss on taxonomic and phylogenetic diversity of understory Rubiaceae in Atlantic forest landscapes



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ABSTRACT

Habitat loss has been long recognized as a major driver of the current species extinction crisis, but to date few studies have estimated deforestation thresholds above which biodiversity negatively respond to the changes in landscape configuration. In this study, we used a very representative understory plant family (Rubiaceae) to evaluate the effects of forest cover reduction in the landscape on taxonomic and phylogenetic alpha and beta diversity, species originality, and composition. We selected nine Atlantic forest sites in southern Bahia, Brazil, immersed in landscapes ranging from 9% to 71% of remaining forest cover. We established a 50 × 100 m plot in each site and identified all the Rubiaceae individuals. Forest cover reduction at the landscape scale is strongly and negatively related to the number of individuals, species, and genera of Rubiaceae. Our model predicts that every 10% decreasing in landscape forest cover results in the loss of about three species and 74 individuals of understory Rubiaceae. Canopy openness at the plot level increased linearly with the decrease of forest cover in the landscape. A trend of linear decrease of the phylogenetic diversity with the loss of forest cover was also observed, increasing the co-occurrence of close relatives in more deforested landscapes. Furthermore, we found a reduction in the presence of species with higher values of originality along the gradient of forest cover, as a consequence of species richness reduction. Regardless of the geographical distances, areas with similar values of forest cover were different in composition (β -diversity) and phylogenetic relationship (phylogenetic β -diversity), indicating that even highly deforested landscapes contribute to the regional diversity. We concluded that less forested areas are losing species richness and diversity, and as a consequence species originality, and presenting a general trend of phylogenetic impoverishment at the landscape scale. However, regional conservation initiatives should take all landscapes into account, because they all contribute to taxonomic and phylogenetic beta diversity, to ensure the long-term protection of the irreplaceable evolutionary history of Rubiaceae and the numerous organisms it supports.

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1. Introduction

Habitat loss is a major driver of the current rates of species extinction, considered the main global threat to biodiversity, especially in ecosystems with high endemism such as the Atlantic Forest in South America (Tabarelli et al., 2005). The Atlantic Forest from South America leads the world statistics of habitat loss, with over 93% of the original area lost (Galindo-Leal and Câmara, 2005). In Brazil, 11.4–16.0% of the Atlantic Forest still remains,

including secondary forest areas and small fragments (Ribeiro et al., 2009), but only 3.5% of natural intact forest (Sloan et al., 2014). This high level of forest conversion results mainly from the accelerated population growth and the consequent increase of anthropogenic actions harmful to the environment.

In this context, habitat loss and the synergistic effects of habitat fragmentation adversely affect biodiversity patterns and population persistence in anthropogenic landscapes (Andrén, 1994; Fahrig, 2003). These landscapes are usually represented by few and small remaining patches (Andrén, 1994), which are subjected to a myriad of modifications due to increasing forest area exposed to edge effects (Laurance et al., 2001; Murcia, 1995; Oliveira et al.,

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2004; Saunders et al., 1991). As a consequence the microclimatic conditions are modified (Murcia, 1995). Besides, habitat loss might also change the canopy structure, which in turn modifies the amount of light that reaches the understory (Nicotra et al., 1999), influencing the distribution and persistence of many species mainly in this stratum. In Atlantic Forest fragments, there is little information about the understory flora, as most studies focus only the tree stratum (Kozera, 2001). Understory species have been highly neglected despite the fact that they represent almost two-thirds of the woody plant diversity in tropical forests, playing specific functions in the plant community (Poulsen and Balslev, 1991). In tropical forests, understory plants are also of key importance to the maintenance of many animal pollinators and seed dispersers (de Souza et al., 2009).

Among the plants in the Neotropics, Rubiaceae is an outstanding family, with the fourth highest number of individuals among all angiosperms (Chiquieri et al., 2004). The family is represented by approximately 13,100 species distributed in 611 genera (Govaerts et al., 2007). Brazil, is one of the numerous hotspots of the family diversity in the tropics (Govaerts et al., 2007), harboring approximately 1396 species in 120 genera (Barbosa et al., 2014). In addition, the Rubiaceae family is distinguish in the forest understory (Guaratini et al., 2008; de Lima et al., 2012; Martini et al., 2008; de Souza et al., 2009), exerting a strong influence on vegetation structure. Several species are important resources for animals that feed on pollen and nectar (Castro and Oliveira, 2002; Lopes and Buzato, 2005), and Rubiaceae is appointed as one the main sources of fleshy fruits to frugivores (Poulin et al., 1999; Snow, 1981; Tabarelli et al., 1999). Thus, this family is one of the most well-suited to be used in ecological analyses in tropical vegetation due to its representativeness, fewer taxonomical problems, and representation in all kinds of growth habits (Delprete and Jardim, 2012).

Identifying species that are being lost is undoubtedly very important for conservation. However, species identities *per se* often bring little information regarding their function or evolutionary history, which are also components of biodiversity (Cianciaruso et al., 2009; Swenson, 2011). Diversity measures such as phylogenetic information are increasingly being used to assess biological communities responses to environmental changes (Helmus et al., 2010). Important advances in this field are helping us to understand the effects of fires on community assembly (Cavender-Bares and Reich, 2012; Cianciaruso et al., 2012; Verdú and Pausas, 2007), the processes involved in community organization during forest regeneration (Letcher, 2010; Letcher et al., 2012), and the outcome of species loss and gain on community phylogenetic diversity (Arroyo-Rodríguez et al., 2012; Cadotte and Strauss, 2011; Santos et al., 2010, 2014).

Species susceptibility to habitat modifications might reduce phylogenetic diversity if traits associated to those modifications are evolutionarily conserved along particular lineages (Cavender-Bares et al., 2004; Webb et al., 2002). A recent study has demonstrated such a phylogenetic trait conservatism in *Psychotria*, the most common Rubiaceae genus, especially in hydraulic traits related to tolerance to changes in soil moisture (Sedio et al., 2012). If this evolutionary pattern also holds for other traits associated to vulnerability to deforestation, it is likely that remaining communities in more deforested areas are formed by closer relatives, being more phylogenetically clustered and poorer than those inhabiting less deforested areas (see also Arroyo-Rodríguez et al., 2012; Santos et al., 2010, 2014). Given that the extinction of highly distinct species from old and species-poor clades results in greater loss of evolutionary information (Redding et al., 2008; Winter et al., 2013), we also evaluated how forest loss affects the most original species.

Our goal was to evaluate how habitat loss at the landscape scale can affect species diversity of the understory Rubiaceae family. To accomplish this goal, we sampled nine forest fragments located within 16 km² landscapes ranging from 9% to 71% of remaining forest cover, a proxy for habitat amount, and assessed not only common descriptors of diversity – such as species composition, richness, and abundance – but also measures of species originality, alpha and beta phylogenetic diversity. We predicted that the reduction of forest cover at the landscape scale would have a detectable negative impact on species diversity, with greater impact of rare species in more deforested landscapes. We also expected that forest cover reduction will favor the coexistence of closely related species, resulting in decreased phylogenetic diversity at both local (alpha) and regional (beta) scales.

2. Material and methods

2.1. Study sites

We conducted this study in Atlantic forest remnants from the south of the state of Bahia, northeastern Brazil, in the surroundings of Una, Mascote, and Belmonte municipalities, where we could identify representative patches of the original forests. These municipalities are located between the Jequitinhonha and the Contas rivers, where forest fragments have similar soil types, topography, and floristic composition (Thomas et al., 1998; Thomas, 2003), although human occupation has led to land use differences among these municipalities.

The Una region contains some of the last remnants of Atlantic forest in northeastern Brazil (Faria et al., 2009). In this region, there is a Federal Protected Area – the Una Biological Reserve (Rebio UNA) – established in 1980. After the incorporation of additional forest fragments in 2007, it covers an area of 18,500 ha, being one of the largest blocks of forest in southern Bahia (Schroth et al., 2011). Most Una landscapes comprise a mosaic of different physiognomies including mature and secondary forests, rubber and shade cocoa plantations (Faria et al., 2006).

By contrast, the region including Belmonte and Mascote municipalities suffered a different and more pronounced deforestation process. In the 1990s, extensive areas of dense rainforest were burned, yielding a large loss of forest cover due to the expansion of areas for grazing followed by *Eucalyptus* plantations (Nascimento et al., 2009). Nowadays, most of the regional matrix comprises mainly open areas of pastures and patches of *Eucalyptus* crops.

2.2. Sampled landscapes

We used Landsat TM images, obtained on 07/14/2011 in orbits 215/70 and 215/71 to map the forest cover in the study area. The mapping focused on these two regions, encompassing 1728 km² of Una and 2018 km² of Belmonte region. Due to the difficulties to accurately map the different components of this mosaic from Landsat images, and after an intensive field validation process, we considered the landscape forest cover as the sum of all forest categories, including native forests in different stages of forest succession and also those areas of shade cocoa plantations. We constructed grids with cells of 16 km² (hereafter landscapes) to estimate the amount of forest cover. One grid was located in Una and proximities and another in Belmonte region. The proportion of forest habitats was obtained by manual classification using Idrisi and ArcGis 9.3.

To ensure rainforest representativeness in our sampling, we excluded those grid cells dominated by sand vegetation. We also

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