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Translating plant community responses to habitat loss into conservation practices: Forest cover matters

Maíra Benchimol[a,*], Eduardo Mariano-Neto[a,b], Deborah Faria[a], Larissa Rocha-Santos[a], Michaele de Souza Pessoa[a], Francisco Sanches Gomes[b], Daniela Custodio Talora[a], Eliana Cazetta[a]

[a] PPG Ecologia e Conservação da Biodiversidade, Laboratório de Ecologia Aplicada à Conservação, Universidade Estadual de Santa Cruz, Rodovia Jorge Amado km 16, 45662-900 Ilhéus, BA, Brazil

[b] Departamento de Botânica, Instituto de Biologia, Universidade Federal da Bahia, Rua Barão de Geremoabo, 147, Campus Universitário de Ondina, 40170-290 Salvador, BA, Brazil

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ABSTRACT

Unveiling the minimum amount of habitat required for different taxa represents a great contribution of ecologists to conservation management actions at the landscape-scale. However, groups from different life-stages are likely to exhibit divergent shifts in species diversity and community composition, yet greatly neglected in ecological studies. We sampled adult and juvenile tree assemblages at twenty sites of Brazilian Atlantic Forest surrounded by different percentages of forest cover remaining at the landscape-level (3–93%) to compare patterns of species richness and community composition between both life-stages in response to habitat amount. We also investigated distinct functional guild responses (proportion of species and stems of shade-intolerant, biotically-dispersed and large-seeded species) among adult and juvenile trees to forest cover reduction. We hypothesize that juveniles will exhibit dissimilar community composition, faster responses, and higher vulnerability of functional guilds to forest loss than adults. Our results indicate that community composition was markedly different among life-stages and strongly correlated with forest cover. Additionally, the number of species of both life-stages was negatively affected by landscape-scale forest loss, exhibiting a greater decline of species richness when forest cover was reduced to < 19.5% and 34.6% of forest cover, for adults and juveniles, respectively. Forest loss might led to non-random floristic shifts, characterized by an increased proportional representation of shade-intolerant species and stems from both life-stages, a severe decline of biotically-dispersed adult species, and reduction in large-seeded juvenile species in severely deforested landscapes. Of uppermost importance, our results show that young assemblages are not mirroring the preceding generation, indicating that future woody plant communities are likely to exhibit an impoverished sample of the original biota with subsequent loss of functionality in deforested landscapes. Given that 20% of native vegetation at the property-scale is the legal minimum amount required by the current Brazilian Forest Code in the Atlantic Forest, we reveal that this amount is not enough to safeguard diverse plant communities − particularly juveniles, an essential group of population dynamics, which require greater forest cover amount at the landscape-scale. We strongly recommend the implementation of restoration projects within severely fragmented landscapes.

1. Introduction

Habitat loss and fragmentation have so far been recognized as major drivers of biodiversity loss (Fahrig, 2013; Hanski, 2015), with subsequent environmental perturbations leading species to local extinction and/or population reduction (Foley et al., 2005). Nevertheless, biological groups differ in the amount of time taken to become extinct according to their competitive dominance, resulting in distinct extinction debts – *i.e.*, differences on the number of extant species predicted to disappear following habitat change (Tilman et al., 1994). Especially in deforested and fragmented landscapes, the minimum amount of suitable habitat required for the persistence of a species (known as extinction thresholds) considerably differ among taxa, in which species exhibiting long generation times and populations near their extinction threshold are prone to have an extinction debt (Kuussaari et al., 2009). The knowledge of the species, population or community-specific extinction thresholds becomes an extremely useful approach to implement conservation measures, such as the amount of habitat expansion

* Corresponding author.
E-mail address: mairabs02@gmail.com (M. Benchimol).

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needed in restoration programs to maximize species conservation and ensure biodiversity maintenance (Tambosi et al., 2014).

In neotropical fragmented forest landscapes, studies examining the extinction thresholds for different biological groups have substantially increased over the last decade (Martensen et al., 2012; Lima & Mariano-Neto, 2014; Morante-Filho et al., 2015, Ochoa-Quintero et al., 2015). Most of these studies considered the percentage of forest cover within the landscape as a proxy of habitat loss (Fahrig, 2003), and commonly identified a breakpoint on the relationship between habitat loss and species richness for a specific taxa. For instance, a threshold response between forest cover at the landscape-scale and species richness of medium and large-bodied sized birds and mammals were identified at contrasting fragmented landscapes in the Brazilian Amazonia, with landscapes showing < 30% of forest cover retaining less species (Ochoa-Quintero et al., 2015). Yet few studies investigated how extinction threshold values vary within different life stages from a single taxon, which could enhance our understanding on the true minimum amount of habitat required to safeguard overall assemblages.

Woody plants are key components of tropical forests, providing essential food and shelter resources for a wide range of organisms, storing a great amount of carbon, and are also responsible for interior microclimatic regulation (Richards, 1998; Laurance et al., 1998). Although several studies have examined the effects of forest fragmentation on trees, seedling and sapling assemblages in deforested landscapes, including some along the Brazilian Atlantic Forest (Metzger, 2000; Tabarelli et al., 2010; Santo-Silva et al., 2015), a comprehensive study contrasting shifts in species diversity and community composition between different life-stages within entire tree assemblages is still missing. Given the differences of group dynamics, distinct time delays are expected among species or life-stage groups, which in turn will exhibit divergent responses to environmental modifications (Ernoult et al., 2006; Rigueira et al., 2013). In this context, while the structure of those long-lived, standing adult trees may reflect the accumulated responses to historical changes, the earlier life stages are more sensitive to recent shifts in landscape structure (Metzger et al., 2009). As a result, adult individuals are prone to remain in the landscape for a longer time (Metzger et al., 2009; Rigueira et al., 2013), including estimates of more than a century after fragmentation for slow-growing plant species (Vellend et al., 2006). Conversely, juveniles are better at reflecting the footprint of dispersal and stochastic events, as well as niche differences (Hubbell, 2001; Norden et al., 2009). Therefore, it is expected that groups recently established exhibit a higher sensitivity to habitat loss compared to adults due to disruption in reproductive, dispersal and establishment processes influenced by habitat cover at a landscape scale (Rigueira et al., 2013).

Tropical tree assemblages stranded in forest patches are likely to experience a collapse in both taxonomic and functional diversity, with some studies evidencing a 'fragmentation-driven' homogenization of forest floras (Laurance et al., 2006; Lôbo et al., 2011; Solar et al., 2015). This floristic homogenization (*i.e.*, increasing levels of similarity or lower beta-diversity) has been described by the replacement of mature-forest species to light demanding counterparts, leading to major shifts in local floras including the proliferation of pioneers, small-seeded and abiotic-dispersed species, especially in the edges and/or small patches (Laurance et al., 2006; Santos et al., 2008). Alternatively, a process of floristic differentiation (*i.e.*, decreasing levels of similarity or higher beta-diversity) can emerge in fragmented tropical landscapes, given that dispersal among fragments is impaired within severely deforested landscapes (Arroyo-Rodriguez et al., 2013). It seems that the spatial scale analysis and the landscape configuration could determine if plant assemblages in forest patches are experiencing floristic homogenization or differentiation (Arroyo-Rodriguez et al., 2013). Yet, further studies are required to extend our understanding on the plant responses to land-use changes and consequently assess the conservation value of contrasted landscapes in tropical forests. Accounting for different life-stages responses within a single study can enhance even more our knowledge on the mechanisms driving patterns of species composition in tropical fragmented forest landscapes.

In this study, we gathered a robust dataset on adult and juvenile tree species from twenty sites of Brazilian Atlantic Forest surrounded by a wide range of forest cover remaining at the landscape level (3–93%) and compared shifts in species diversity and community composition between both life-stages of woody plants to examine their responses to forest cover. Specifically, we: (*i*) examined how different life stage groups respond to forest cover gradient at the landscape-scale; (*ii*) compared species composition patterns between adult and juvenile trees and tested whether compositional dissimilarity among communities is driven by forest cover; (*iii*) examined if remaining forest cover could predict the occurrence rates of each individual tree species; and (*iv*) investigated the responses of distinct functional guilds (the proportion of species and stems of shade-intolerant, biotically-dispersed and large-seeded species) to forest cover between both life stages. For each of our aims, we expected that: (*i*) juveniles will exhibit a more intense response to habitat loss than adults, with species loss occurring faster for younger groups (Rigueira et al., 2013); (*ii*) species similarity between adult and juvenile trees will increase in deforested landscapes due to dispersal limitation processes, but both life-stages will converge to floristic differentiation (*i.e.*, decreasing levels of similarity) among severely deforested landscapes (Arroyo-Rodriguez et al., 2013); (*iii*) species sensitive to forest disturbance will exhibit lower occupancy in severely deforested landscapes (Fischer & Lindenmayer, 2007); (*iv*) sites within smaller amount of forest cover at the landscape-scale will tend towards greater representation of shade-intolerant species, with severe declines in the proportion of species and stems of large-seeded and animal-dispersed species (Magnago et al., 2014; Benchimol & Peres, 2015).

2. Material and methods

2.1. Study area

We conducted this study in a set of twenty forest landscapes of the Atlantic Forest in southern Bahia state, Brazil (15°0′–16°0′ S and 39°0′–39°30′ W). The Brazilian Atlantic Forest comprises one of the world's 35 biodiversity hotspots, housing > 8000 endemic species of vascular plants and vertebrates distributed along the vast Brazilian coast and extending south to northeastern Argentina (Myers et al., 2000; Tabarelli et al., 2005). The entire biome had once covered about 150 million hectares of pristine forests, but after the European colonization and subsequent deforestation, only 11–16% of this original forest remains to date (Ribeiro et al., 2009). Indeed, forest loss and fragmentation still comprise major threats to biodiversity conservation of this unique biome, with 80% of the total forest remaining consisting of forest fragments smaller than 50 ha (Ribeiro et al., 2009). The southern Bahia Atlantic Forest shelters one of the most diverse flora worldwide, exhibiting high levels of plant endemism (Thomas et al., 1998).

We adopted a hybrid patch-landscape approach (Tischendorf & Fahrig, 2000) by sampling 20 single sites in non-overlapping landscapes with a 1-km buffer from the centers of each site (*i.e.*, a sampled site is no closer than 1 km to any other). We selected forest sites using high-resolution cloudless satellite images taken from 2009 to 2011 (RapidEye®, QuickBird®, and WorldView®) on the basis of the amount of native forest cover (hereafter, FC) at the landscape-scale, *i.e.*, the percentage of mature and successional FC within a radius of 2 km surrounding forest sites, or ~13 km^2 landscapes. By analyzing the images, we thus identified 58 potential sampling sites spanning a study area of 3500 km^2 from four municipalities of southern Bahia (Mascote, Canavieiras, Una, and Belmonte), excluding demanding access, indigenous lands and highly mountainous forest sites. From these, we performed a stratified sampling and selected 20 forest sites covering a wide variation of FC at the landscape-scale, in which we established our study forest plots (see Fig. S1 in Supplementary Material). Given that