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Positive forestry: The effect of rubber tree plantations on fruit feeding butterfly assemblages in the Brazilian Atlantic forest

Elaine Cristina Barbosa Cambui [a], Rodrigo Nogueira de Vasconcelos [b], Eduardo Mariano-Neto [c], Blandina Felipe Viana [d], Márcio Zikán Cardoso [e,*]

[a] PPG Multi-Institucional e Multidisciplinar em Difusão do Conhecimento, Universidade Federal da Bahia, Salvador, BA 40110-100, Brazil
[b] PPG em Modelagem e Ciências da Terra e do Ambiente, Universidade Estadual de Feira de Santana, Feira de Santana, BA 44036-900, Brazil
[c] Departamento de Botânica, Instituto de Biologia, Universidade Federal da Bahia, Salvador, BA 40170-290, Brazil
[d] Departamento de Zoologia, Instituto de Biologia, Universidade Federal da Bahia, Salvador, BA 40170-290, Brazil
[e] Departamento de Ecologia, Universidade Federal do Rio Grande do Norte, Natal, RN 59078-900, Brazil

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ABSTRACT

Agroforestry systems have increased in area in tropical regions in recent decades and many studies have sought to evaluate their impact on native biodiversity. Yet, few have assessed the impact of perennial plantations such as rubber-tree harvesting on native biodiversity. The goal of our study was to assess the effect of rubber tree plantations on fruit-feeding butterflies of the endangered Brazilian Atlantic Forest in Brazil. To do so, we sampled fruit- feeding butterfly species in a landscape mosaic composed of primary forest, rubber tree plantations under two management regimes (active production with intense management and undergrowth suppression and low management plantations with no undergrowth suppression), and forest fragments immersed in rubber tree plantation matrix. By trap-baiting butterflies for a year, we captured 5800 individuals of 85 butterfly species. Species richness was higher in unmanaged (no growth suppression) plantation and forest fragments (57–60 species) and lower in managed plantation (with growth suppression) (47) and primary forest (43). Ordination analysis suggests three main community groups formed by primary forest samples, a cluster combining unmanaged plantation and fragments, and managed plantation. There was substantial variation in butterfly abundance in the landscape, but our data suggest that several forest specialists species are able to occur along the mosaic on the landscape, and despite differences in management the entire landscape can contribute for a rich biota. Loss of understory vegetation led to simplified communities, with skewed dominance of a few species. By allowing understory development, a low impact management can provide adequate habitat for native butterflies. Yet, current rubber tree plantation technology does not normally use this method, opting to use the high management approach instead. We hypothesize that these minimally benign plantations may serve as conduits for butterflies in forest patches. Thus, we suggest that rubber tree plantations near Atlantic forest fragments should encourage understory development and establish a landscape mosaic, allowing forest fragments immersed in plantation matrix to be able to exchange individuals and colonize more complex plantation habitat. Intensive suppression of undergrowth should be avoided, except for trail maintenance, and isolation of fragments in this matrix should be kept to a minimum. If undergrowth suppression cannot be avoided, then establishment of stepping stones in plantation matrix should be encouraged to reduce isolation of fragments.

1. Introduction

The loss of natural environments throughout the tropics calls for practical solutions that reconcile human needs with biodiversity conservation (Kaimowitz et al., 2007). In this context, there is great need not only to conserve natural habitats but also to reconcile habitat modification caused by agricultural systems with biodiversity conservation (Harvey et al., 2006; Power, 1996). The ability of native species to persist in agricultural mosaics depends not only on the biological needs of these species but also on the structural aspects of the landscape (Di Giulio et al., 2001), such as the percentage and distribution of native forest and the quality of the matrix (Faria et al., 2006). Encouraging results show that

* Corresponding author.
E-mail addresses: elainecambui@gmail.com (E. Cristina Barbosa Cambui), rodrigodevasconcelos@yahoo.com.br (R. Nogueira de Vasconcelos), marianon@gmail.com (E. Mariano-Neto), bfviana@ufba.br (B. Felipe Viana), mzc@cb.ufrn.br (M. Zikán Cardoso).

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structural similarity of plantation forests to native forest may minimize fragmentation effects (Lindenmayer et al., 2006), reduce edge effects (Perfecto and Vandermeer, 2002), increase functional connectivity (Taylor et al., 1993), and turn forested plantations into suitable habitats for native species (Antongiovanni and Metzger, 2005; Ewers and Didham, 2006; Faria et al., 2007; Gaston, 2003; Perfecto and Snelling, 1995; Perfecto and Vandermeer, 2002; Pineda et al., 2005).

Studies that relate planted forests and species conservation are greatly needed, notably due to the increase in forested plantations in tropical regions (ABRAF, 2010; Fearnside, 1998), which corresponds to over 140 million hectares of cultivated areas in the world (Fao, 2006). In large tropical countries such as Brazil, the spread of commercial plantations of *Eucalyptus*, *Pinus*, *Araucaria* and *Hevea*, notably in the Atlantic forest biome, has made them an important research topic aimed at evaluating their impact on biodiversity (da Rocha et al., 2013; Faria et al., 2006, 2007; Fonseca et al., 2009; Marsden et al., 2001; Pardini et al., 2009; Zurita et al., 2006). In rubber tree (*Hevea*) plantations, latex harvest depends on standing trees and is arguably less disturbing for plant and animal colonists than other types of planted forests that rely on timber (or processed timber) extraction.

Rubber trees (*Hevea brasiliensis*) are native to the Amazon basin and rank fourth among planted tree crops in Brazil (ABRAF, 2010). To reduce dependency on foreign markets currently based on Asia which holds 72% of the 9.7 million hectares planted worldwide (Fao, 2006), Brazil has expanded plantations to areas outside the Amazon, mainly in the Atlantic Forest in the eastern coast, a biodiversity hotspot (Metzger, 2009; Myers et al., 2000). From a conservation standpoint, there is concern that rubber plantations will expand at the cost of native forest cover and will create habitats that are not adequate for native species, exacerbating the historical process of conversion of native Atlantic forest into small isolated forest patches in an agricultural/urban matrix (Pardini et al., 2009; Ribeiro et al., 2009). Given the socioeconomic arguments for the expansion of rubber plantations, it is important to evaluate the impact of this increasingly important landscape element on the imperiled Atlantic Forest biome.

Fruit-feeding butterflies have been widely used as models for characterization of disturbance levels in fragmented landscapes (Brown and Freitas, 1997; DeVries and Walla, 2001; Kremen, 1992; Ramos, 2000) and several studies have sought to understand the dynamics of butterfly diversity in landscapes influenced by agricultural plantations (Bergman et al., 2004; Cunningham et al., 2005; Perfecto and Snelling, 1995). In Brazil, studies have tried to assess the influence of silvicultures as *Eucalyptus* plantations (Barlow et al., 2007a,b; da Rocha et al., 2013; Ramos, 2000), but no study with butterflies has been conducted in rubber tree plantations. To evaluate the value of rubber tree plantation for the survival of butterfly species we studied a plantation system with different management regimens and asked whether the structure of fruit feeding butterfly communities was affected by these procedures and whether the assemblage structure differed between plantation and neighboring forest patches.

2. Material and methods

2.1. Study site

We carried our study in a landscape mosaic located in the state of Bahia, Brazil (13°50′S, 39°10′W). The mosaic consisted of a mixture of mature Atlantic forest, forest fragments, and two large blocks of planted rubber trees that differed in management practices for understory-removal (Fig. 1). We sampled butterflies in a 1000 ha high-intensity management rubber plantation containing wetlands and small (<10 ha) forest fragments, and in the 3096-ha Michelin Ecological Reserve, which contained a patch of low-intensity management rubber grove mixed with forest fragments and wetlands, and a 2000 ha patch of mature forest. The mature forest itself consisted of three blocks with 140, 550, and 625 ha (Fig. 1). The local climate is rainy, warm and humid without a dry season, with annual temperature at 25 °C and average annual rainfall of 2000 mm, concentrated between February and July (Michelin Ecological Reserve, unpublished data).

2.2. Landscape units

We sampled fruit-feeding butterflies in five distinct landscape units (Fig. 1), with four replicates in each landscape type, totaling 20 sampling sites. Locations of replicates were chosen randomly, with the condition that each sampling unit was located at least 100 m away from the border with other habitat types to avoid potential edge effects. The landscape units were categorized in the following manner: (i) mature forest (coded as For) - three blocks of mature forest located within the ecological reserve; (ii) forest fragments associated with low intensity management plantation (FragL) – small forest patches (<10 ha), mostly growing on rocky outcrops unsuitable for growing trees; (iii) forest fragments associated with high intensity management plantation (FragH) - forest patches with the same characteristics of the previous group (FragL), except that they were located within the high intensity management plantation. Both types of forest fragments contained several species of pioneer plants such as *Cecropia*, *Schefflera*, *Tapirira*, *Miconia*, *Henrietta*, *Inga*, *Byrsonima*, *Stryphnodendron*, *Solanum* and *Piper*; (iv) low intensity management plantation (PlantL) - plantation consisting of rubber tree groves where inter-row vegetation was left undisturbed for the past 10–20 years. Pioneer vegetation (similar to the one in the fragments) grows in dense thickets with a canopy height between 2–8 m. Management practice consists of herbicide application on rubber tapping paths (once a year or less) to facilitate harvester movement; (v) high intensity management plantation (PlantH) - rubber groves with the same planting characteristics as PlantL, except that the inter-rows are cleared once a year or so to maintain the understory open. The inter- row vegetation is dominated by herbaceous species (*Cyperus* spp., grasses, *Heliconia*) and young pioneer bushes, shrubs, and trees, mostly from the family Melastomataceae, but also *Cecropia* and *Schefflera*.

2.3. Sampling protocol

In each sampling area, we set 10 butterfly traps (DeVries, 1987) in two parallel lines 25 m apart, each line containing 5 traps installed at every 25 m. We trap-baited butterflies at every third month between July 2007 and June 2008. Traps remained open for 10 days during each sampling period and were monitored every other day. Baits were replaced during each visit. All trapped individuals were collected and deposited in the entomological collection of the Universidade Federal da Bahia (MZUFBA). Species were identified by consulting the literature and butterfly taxonomists listed in the acknowledgements.

2.4. Data analysis

To compare estimates of species richness among sampling sites, we generated species accumulation curves using the command *specaccum* with rarefaction as a method in the package *vegan* (Oksanen et al., 2016). We estimated species richness using the model employed by Dorazio et al. (2006). This method controls for issues associates with detection error when estimating species richness by using variance between samples. To do so, we ran five