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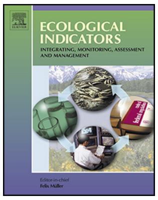

Biotic congruence in humid tropical forests: A multi-taxa examination of spatial distribution and responses to forest disturbance

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ABSTRACT

Biodiversity is vital for fully functional natural habitats, and the maintenance of biodiversity through effective conservation planning depends on reliable information on its spatial distribution and response to anthropogenic disturbance. However, gathering extensive data on multiple species is a difficult task, due to logistical and financial constraints and the lack of taxonomic expertise. A common resource to address this hurdle is the use of surrogate taxa: focusing on a limited set of species that provide information that can be extrapolated to wider patterns of biodiversity and ecological integrity. We examine this by (1) testing if species richness proportions among different taxa/methodology employed (ants, birds sampled with point counts, birds sampled with mist nets, dung beetles, trees and saplings) will be similar across different undisturbed Amazonian forests, and (2) if patterns of local congruence in richness and community composition are consistent in undisturbed forest and gradients of forest disturbed by forest fires. Our results indicate that species richness, across field sites, was positively associated at a regional scale. At a local scale, richness and community composition in unburned forest showed virtually no correlation between the taxa, but the inclusion of samples from burned forest increased the number of significant correlations. Vegetation (trees ≥10 cm diameter at breast height) composition was the best indicator of overall community composition of all other taxa. The congruence of regional patterns of richness is likely a consequence of macro variables such as climate and biogeographical history, and should not be extrapolated to local scales. Although the use of community composition metrics increased congruence at a local scale, we highlight the importance of using a broad ecological gradient.

1. Introduction

Effective conservation planning depends on reliable information on the spatial distribution of biodiversity (Margules and Pressey, 2000), and information on how species respond to environmental changes, especially human induced disturbance (Mace et al., 2005; Wright, 2005). However, gathering extensive data on multiple species in natural habitats is usually a difficult task due to logistical and financial constraints and a lack of taxonomic expertise (Gardner et al., 2008; Gaston, 1996; Howard et al., 1998). Surrogate or indicator taxa are frequently used to overcome these challenges. These approaches consist of focusing on a limited set of species that, ideally, provide information that can be extrapolated to other taxa, wider patterns of biodiversity and ecological integrity (Caro, 2010; Caro and O'Doherty, 1999; Lewandowski et al., 2010; Margules and Pressey, 2000).

Many studies show cross taxon congruence in geographical patterns of species richness (e.g. Fattorini et al., 2011, 2012; Gaston, 1996; Qian and Ricklefs, 2008; Wolters et al., 2006) or along local gradients of disturbance and habitat alteration (e.g. Barlow et al., 2007; Lawton et al., 1998). However, the use of surrogate taxa also presents a number of disadvantages and complications. In particular, the power of a taxon for predicting the diversity of one or more other taxa may not be consistent across geographic regions and/or at different spatial scales, and a number of studies found contrasting results in surrogacy effectiveness (e.g. Araujo et al., 2001; Gaspar et al., 2010; Heino et al., 2009; Lovell et al., 2007).

The use of indicator taxon to predict the richness of other taxa at regional scales can be useful for planning broad conservation

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initiatives, such as the identification of important biomes and habitats. However, regional patterns of species richness provide little or no information at a local scale, where most conservation decisions, such as establishment of reserves, are made (Ricketts et al., 2002). Locally, different taxa usually show little congruence when simple biodiversity measurements are employed, such as species richness (Lawton et al., 1998; Lovell et al., 2007; Ricketts et al., 2002). Different species and taxa depend on a variety of resources and can experience habitat changes at idiosyncratic spatial and temporal scales. Additionally, in some cases indicator groups are chosen based on inadequate selection criteria and limited by feasibility issues, resulting in weak relationships between the indicators and the indicated pattern (Gardner et al., 2008; Heink and Kowarik, 2010). Finally, differences in sampling protocols for each taxon, such as area surveyed by each method, can make comparisons difficult (Howard et al., 1998).

A variety of species have been chosen as surrogates, based on characteristics such as their ecological function, distribution, threat status and charismatic value (Bonn et al., 2002; Ozaki et al., 2006). But the use of well-defined taxonomic groups seems to be the most usual application of surrogates, mainly because it requires less taxonomic expertise than using species from many different taxa. Studies have shown the efficiency of butterflies (Lovell et al., 2007; Mac Nally and Fleishman, 2004), beetles (Azeria et al., 2009; Baldi, 2003; Lovell et al., 2007), vertebrates (Lund and Rahbek, 2002) and vascular plants (Anand et al., 2005; Kati et al., 2004; Norden et al., 2007) as surrogates in many different ecological settings.

The use of surrogate taxa can be particularly useful in tropical forests, since most of them are located in developing countries where conservation initiatives and studies are especially underfunded (Balmford and Whitten, 2003). These forests hold an immense biodiversity (Dirzo and Raven, 2003) and are facing high levels of deforestation and habitat modification (Gardner et al., 2009; Wright, 2005). Forest fires are an increasing threat to these habitats (Aragão et al., 2008; Aragão and Shimabukuro, 2010; Cochrane and Barber, 2009), affecting vegetation structure, local biodiversity and forest dynamics (Barlow and Peres, 2004, 2006; Cochrane, 2003; Lindenmayer et al., 2009). Although studies show the effects of fire on tree mortality and forest structure (see Cochrane, 2003, for a review), understory avian communities (Barlow and Peres, 2004), fruit production and large vertebrates (Barlow and Peres, 2006) and invertebrates (Andrade et al., 2011; Silveira et al., 2010), overall biodiversity responses to this type of disturbance are not fully understood.

In the present study, we use standardized sampling protocols in four distinct regions of the Brazilian Amazon affected by different fire events to examine whether the congruence between different taxa is context-specific, or whether results from one region can be used to predict congruence in other regions. To do so, we used six different approaches to sampling four taxonomic groups: (1) dung beetles and (2) birds, both known to be cost-effective indicators of disturbance and habitat integrity (Bibby, 1999; Gardner et al., 2008; Nichols et al., 2007; Spector, 2006); (3) plants, also frequently used as surrogates due to their role as primary producers and in shaping habitat heterogeneity (Gaston, 2000); and (4) ants, known to be sensitive to fire disturbance in tropical forests (Silveira et al., 2010, 2012). We examine patterns of congruence in species both at regional and local scales. In addition, we evaluate communities in the context of fire disturbance. We address the following hypotheses:

1. At a regional scale, species richness proportions among different taxa/methodology employed (ants, birds sampled with point counts, birds sampled with mist nets, dung beetles, trees and saplings) will be similar across different undisturbed Amazonian forests. Even though total species richness is expected to vary in such distinct regions of the Brazilian Amazon, we expect the richness of one taxon to be a good surrogate of species richness in other taxa (e.g. a higher species richness in birds in one fieldsite is likely coupled with a higher richness of trees or other taxa).
2. Patterns of local congruence in richness and community composition are consistent along (a) spatially discrete samples in undisturbed forest and (b) gradients of forest disturbance (including unburned and burned sites) in different regions of the Brazilian Amazon. We hypothesize that the inclusion of a broader ecological gradient (i.e. samples from forests comprising both undisturbed and burned habitat) will influence surrogacy capabilities between taxa.

2. Methods

2.1. Study sites

The study was conducted at four field sites across the Brazilian Amazon: (1) The Roraima site (RR), in the northern Amazon is at the Maracá ecological reserve (3°25′ N, 61°6′ W). The local vegetation is composed of a mix between tropical semi-evergreen rain forest, and dense lowland *terra firme* forest (Fragoso et al., 2003; Furley et al., 1994). Some areas of the reserve were affected by a forest fire during the severe dry season associated with the 1997/1998 El Niño Southern Oscillation, and sampling for the present study was taken 11 years after burning. (2) The Pará site (PA), in central Amazonia, is within the Tapajós-Arapiúns Extractive Reserve (2°44′ S, 55°41′ W), a forest composed of dense lowland ombrophilous forest (Radam, 1988) and small enclaves of edaphic savannas (campinarana) (Barlow and Peres, 2006). Fires affected the site in the same dry season as the fires described for Roraima, and sampling also took place 11 years after burning. (3) The Acre site (AC), in the western Brazilian Amazon, is at the Chico Mendes Extractive Reserve (10°50′ S, 69°00′ W), a forest occurring in a predominantly clay soil, with vegetation containing a high density of two species of semi-scandent woody bamboos, *Guadua sarcocarpa* Londoño and P.M. Peterson and *G. weberbaueri* Pilg. (Smith and Nelson, 2011). The area was affected by a fire that occurred during a severe drought in 2005 and sampling took place three years after burning. Lastly, (4) the Mato Grosso site (MT), at the private farm Fazenda São Luiz (12°39′ S, 52°22′ W) in a seasonally-dry forest in the southern Amazon. Local vegetation is characterized by closed canopy-forest (Ivanauskas et al., 2003) that are close to open Cerrado vegetation. Climate is characterized by a pronounced dry season from May to September and mean annual rainfall is around 1500 mm. Although some parts of one fragment had been affected by severe recurrent forest fires, for comparative purposes, we restricted sampling to areas affected by a single wildfire that occurred during the same 1997/1998 dry season, and sampling also took place 11 years after burning. Sampling was carried out in the beginning of the rainy season at each field site (which varied according to the region). Fieldwork in Acre was conducted in October 2008, in Pará during December 2008, in Mato Grosso during February 2009, and Roraima during March 2009.

2.2. Transect and sampling point design

Several 500 m transects were used in each field site and four sampling points were placed at 50 m, 200 m, 350 m and 500 m along each transect. In Roraima and Acre, six transects were placed in burned forest and six in control unburned forest. In Pará, four transects were located in each treatment (burned and unburned). In Mato Grosso, due to the smaller size of the forest fragment, only two transects were located in burned forest and four in unburned forest.