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Changes in seed rain across Atlantic Forest fragments in Northeast Brazil

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ABSTRACT

The objectives of this study were to characterize the distribution of seeds in remnant fragments of the Atlantic Coastal Forest and to determine whether the species diversity, seed weight, and species composition of plant communities are altered by forest fragmentation. A transect of 100 m was established in the core of each of nine fragments of Atlantic Coastal Forest in a private sugarcane plantation in the state of Alagoas, NE Brazil, and ten seed-traps were distributed at intervals of 10 m each along the transects. For 12 consecutive months seeds were collected, dried, counted, weighed, and identified to species. Seeds were assigned to categories according to their size, dispersal mode, and shade tolerance. Multiple regression models and Mantel correlation tests were used to detect the effects of fragment size, percent forest cover nearby, distance from the source area, and distance from the nearest fragment on species diversity, mean seed weight, and species similarity. Analyses were carried out for all species and for subsets corresponding to each seed category. A total of 21,985 diaspores of 190 species were collected. Most seeds were small, shade-intolerant, and zoochoric, which corroborates other studies of fragmented forest landscapes and reflects the high disturbance levels in isolated forest remnants. Our data indicate that fragmentation processes such as habitat loss can alter species diversity and species composition by reducing habitat availability and increasing fragment isolation. We also found that large-seeded species are more affected by fragment isolation, possibly because their seed dispersers rarely cross non-forested areas between fragments, while zoochoric species are more strongly affected by fragment size and apparently more strongly associated with local edaphic conditions than with distance from seed sources.

1. Introduction

Forest fragmentation is a landscape process in which a once-extensive continuous forest is converted into smaller remnants surrounded by non-forested habitats, resulting in habitat loss and isolation (Fahrig, 2003). At the patch scale, fragmentation is a pattern whose underlying processes affect biodiversity through habitat loss, edge effects, the geographical isolation of fragments in a landscape, and the potential interruption of gene flow among populations (Fahrig, 2003). Together, these processes represent serious threats for biodiversity conservation. They are especially critical threats for the Brazilian Atlantic Coastal Forest, which is both one of the most diverse ecosystems and one of the most endangered tropical forests in the world (Galindo-Leal and Câmara, 2003).

Fruit and seed availability may decline with decreasing fragment size (Terborgh, 1986), leading to changes in seed rain composition. Such changes ultimately cause a shift in plant community structure (Laurance et al., 2006) and lower diversity (Fahrig, 2003) and are strongly associated with habitat loss. Other processes associated with forest fragmentation, such as the degree of isolation or connectivity among fragments, can also affect the movements of dispersers and, consequently, the seed flow of most zoochoric species. Many authors treat distance to the nearest fragment (Fahrig, 2003) and percent forest cover as measures of landscape connectivity. In addition to the effects of area and isolation, edge effects also alter tree survival and influence changes

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in microclimate and forest structure (Camargo and Kapos, 1995), seedling richness (Benitez-Malvido and Martinez-Ramos, 2003), and juvenile recruitment, driving the final floristic composition in edges and small fragments to a pioneer (Laurance et al., 2006) (hereafter referred to as shade-intolerant), zoochoric (mainly avian), and small-seeded flora (Tabarelli and Peres, 2002; Oliveira et al., 2004a; Grillo et al., 2006; Melo et al., 2006; Santos et al., 2008).

Brazilian Atlantic Coastal Forest originally covered 1.3 million km^2, from which 84–89.6% is lost (Ribeiro et al., 2009) as consequence of logging and intensive land use (Galindo-Leal and Câmara, 2003). In especial critical situation is the area in the northern São Francisco River valley (hereafter called the Pernambuco Center of Endemism, *sensu* Santos et al., 2007), where only 2% of the original forest is estimated to remain (Pôrto et al., 2006). This tiny remnant of the original forest cover consists of small patches of forest scattered through a matrix of agricultural fields and urban areas, lacking legal protection and facing pressures from fire, hunting, and logging (Ranta et al., 1998; Silva and Tabarelli, 2000).

Recent studies in the region have documented declines in the number of species of frugivorous birds (Roda, 2006), frugivorous mammals (Mendes-Pontes et al., 2006), large-seeded trees (Melo et al., 2006), and shade-tolerant seedlings along forest edges (Melo et al., 2007). These studies have also found that plant recruitment processes in the Pernambuco Center of Endemism have been affected by habitat loss. For example, Costa et al. (2012) assessed changes in seed rain across a chronosequence of secondary forest in the same area. They found that the reduced availability of large-seeded late-successional species may prevent the regeneration of late-successional stages and suggested that the effect may be stronger in smaller and more isolated fragments. However, they did not evaluate the full disturbance gradient, which is critical for assessing changes in diversity since most forest fragments in Brazilian Atlantic forest are small (<50 ha) and isolated (more than 1500 m apart) (Ribeiro et al., 2009).

In this study we evaluated changes in species diversity, as expressed in seed rain, along a broad disturbance gradient of fragment size and isolation. More specifically, we studied the effects of habitat loss on seed rain by evaluating the impact of forest fragmentation on species diversity, species composition, and average seed weight. We focused on three of the four main effects of fragmentation on forest seed diversity cited by Fahrig (2003): reduction of habitat patch size (area), reduction in habitat quantity (surrounding forest cover), and the increasing isolation of fragments (distance to the source area (DSA) and to the nearest fragment (DNF)). Our expectation was that reductions in patch size, reductions in the amount of surrounding habitat, and increasing isolation of fragments would lead to changes in seed rain diversity that were strongest in small, isolated patches.

2. Materials and methods

2.1. Study site

The study was carried out at the Usina Serra Grande, a private sugarcane plantation of 22,000 ha in the state of Alagoas, northeastern Brazil (9° S, 35° 52′ W). The area includes 9000 ha of forest consisting of dozens of fragments embedded in a matrix of sugarcane fields. The largest fragment, named Coimbra, covers 3500 ha and is considered the single largest remnant of the northeastern Atlantic Forest (Oliveira et al., 2004a; Grillo et al., 2006). Coimbra was isolated as a fragment at least 60 years ago. The fragment is currently protected from large-scale human disturbances and harbors species considered indicators of well-preserved and mature forest (Oliveira et al., 2004a; Grillo et al., 2006). For those reasons, we consider Coimbra to be the best source of mature forest seeds in the region. Eight other fragments were also surveyed in this study, varying in size, distance to Coimbra, and distance to other fragments (Fig. 1; Table 1).

These fragments are located on the low-elevation plains (500–600 m a.s.l.) of the Borborema Plateau, a mountain chain that extends down Brazil's northeastern coast along a north–south axis. The prevailing soils at the study site are latosols and podzols (IBGE, 1985). Annual rainfall is *ca.* 2000 mm (data collected by Usina Serra Grande staff), with a three-month dry season (<60 mm per month) lasting from October to December. Vegetation in the fragments consists largely of well-preserved old-growth or mature forest and has been classified as lower montane rain forest (IBGE, 1985). Forest composition is typical of tropical rainforest: communities are highly diverse and 40% of species can be considered rare (Grillo

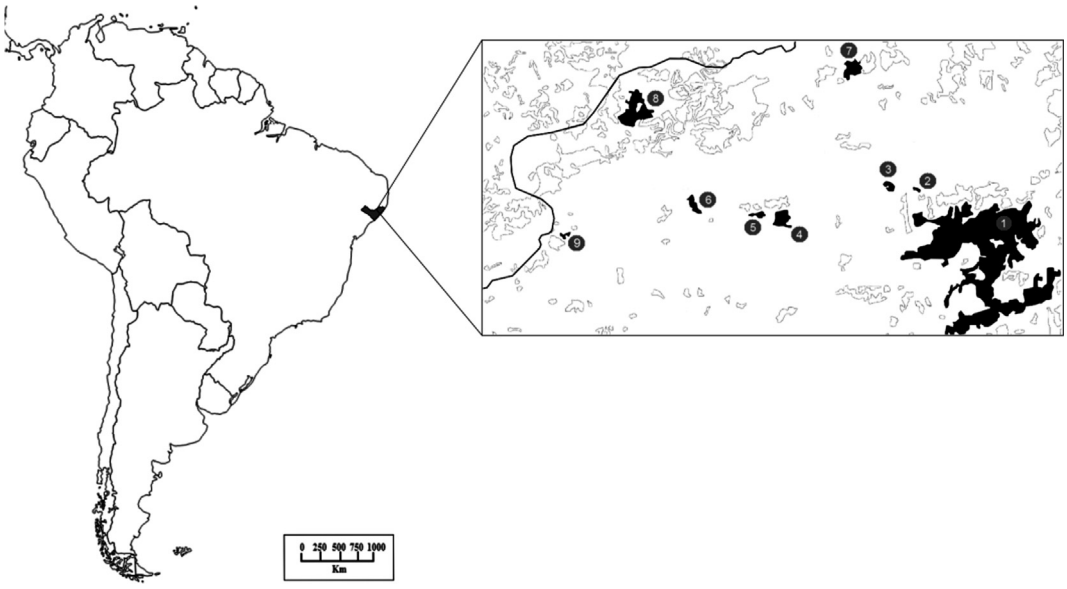

Fig. 1. Map showing the location of nine forest fragments distributed across the study site landscape and in relation to South America. The base map for the fragments location and shape is a satellite image.