



Forest fragmentation and selective logging affect the seed survival and recruitment of a relictual conifer



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ABSTRACT

Defaunation, invasive species and forest fragmentation are considered to be the major drivers for the disruption of key ecological processes, particularly those related to plant animal-interactions such as seed dispersal and predation. The disruption of critical phases in the plant life cycle may ultimately have negative impacts on plant recruitment and the survival of plant populations. Here, for the first time we compared the seed removal and recruitment of *Araucaria angustifolia*, a critically endangered and relictual gymnosperm species, in multiple sites, including continuous and fragmented forest areas in the Brazilian Atlantic subtropical forest. Our sampling included seed removal experiment monitored by camera traps and surveys of *A. angustifolia* recruitment. We found that seed survival and recruitment were related to the density of adult *A. angustifolia*. Therefore the formation of large and dense groves, which is a characteristic of pristine *Araucaria* moist forests endangered by forest fragmentation and selective logging, may be an attempt to satiate seed predator communities. Additionally, forest fragmentation and the introduction of wild boar decreased seed survival to very low, and forest fragmentation decreased recruitment by fourfold on average. Increase protection and recuperation of *Araucaria* moist forests and the eradication of the invasive wild boar where possible are necessary measures for increasing seed survival rates and the recruitment of this relictual conifer.

1. Introduction

Seed survival and seedling recruitment represent a bottleneck in the life cycle of most vascular plants, therefore, for zoochoric species, the presence of dispersers is indispensable to their success (Nathan and Muller-Landau, 2000; Schupp et al., 2010; Galetti et al., 2013; Neuschulz et al., 2016). In fact, both seed dispersal and seed predation have been suggested to regulate plant dominance and thereby maintain forest diversity (Janzen, 1971; Connell, 1978). As a result these ecological interactions play major roles in determining the composition of forests (Kurten et al., 2015).

However, ecosystems suffer globally with human interference altering biological communities and consequently leading to breaks and changes in ecological processes (Sanderson et al., 2002; Tylianakis et al., 2008; Butchart et al., 2010; Estes et al., 2011; Galetti and Dirzo, 2013; Dirzo et al., 2014; Young et al., 2016). Forest fragmentation (Galetti et al., 2006; Cordeiro et al., 2009), the loss of seed dispersers (Wright et al., 2000; Galetti et al., 2006), and changes in the seed predator community (Galetti et al., 2015; Tella et al., 2016b) are among the Anthropocene's effects that may negatively affect plant populations and recruitment dynamics, posing

real risks to the future survival of some plant species (Pérez-Méndez et al., 2016). Understanding these impacts on plant recruitment are fundamental to guiding conservation efforts (Kurten, 2013).

In this study, we aimed to investigate the effects of forest fragmentation, selective logging and changes in the animal community on seed predation and the recruitment of Paraná-pine (*Araucaria angustifolia*), a relictual conifer from a genus originating in the Jurassic period (Kershaw and Wagstaff, 2001). The use of this species as a model is interesting because its presence characterizes a global ecoregion, the *Araucaria* moist forest. In its absence this ecosystem becomes uncharacterized, a rare case, in which the loss of a single species may change the main attribute of an ecosystem. Additionally, Paraná-pine has been considered a key-stone species for fauna, because it produces a large quantity of resources (seeds) in a period of food scarcity (Autumn-Winter) (Iob and Vieira, 2008), being used by a large number of vertebrate species. However, despite its ecology importance, *Araucaria* moist forests have experienced strong fragmentation and timber exploitation (Castella and de Brites, 2004; Ribeiro et al., 2009), and the Paraná-pine is Critically Endangered (Thomas, 2013) and has shown recruitment failures in forest fragments (Souza, 2007; Paludo et al., 2016).

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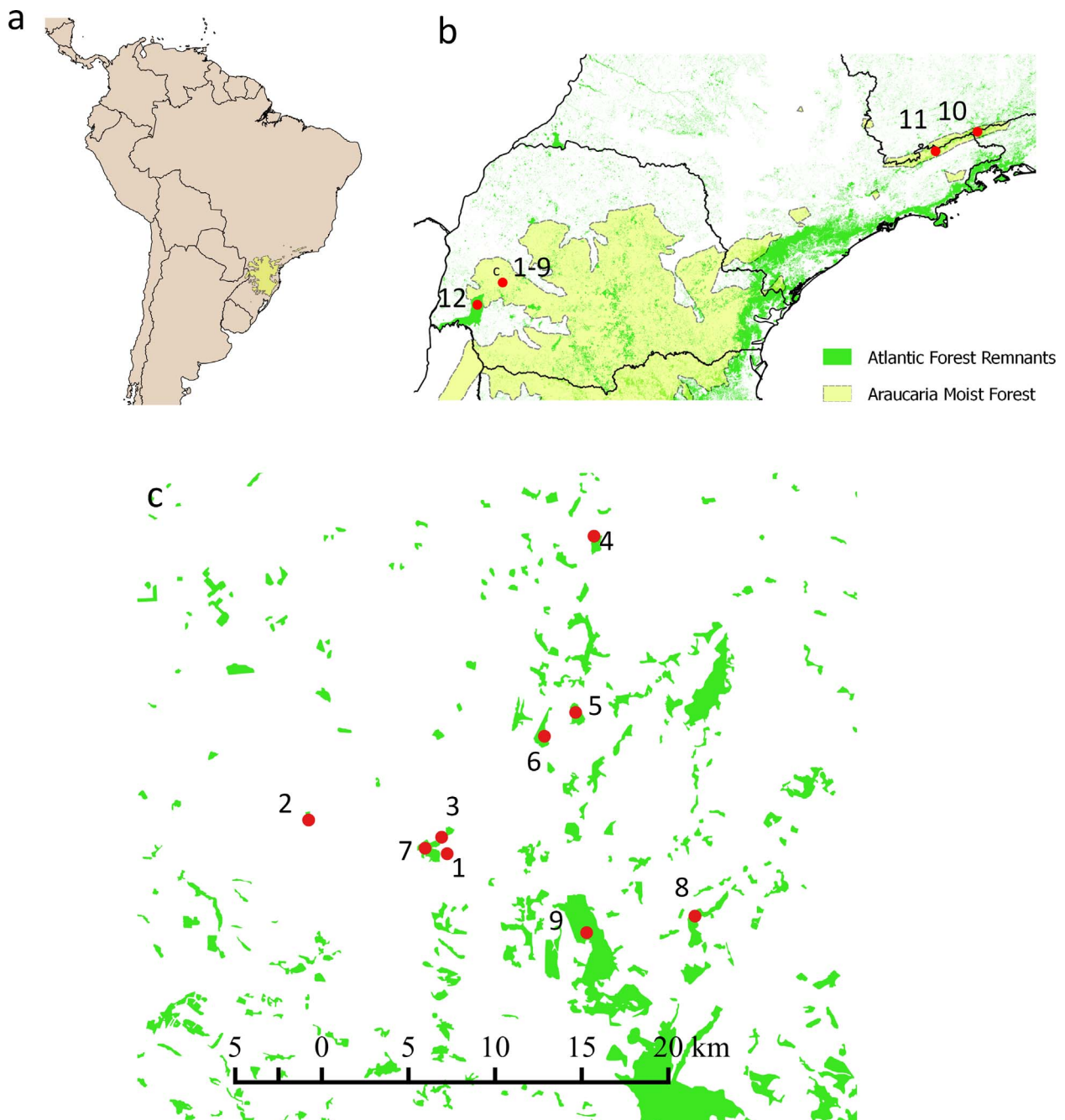


Fig. 1. (a) *Araucaria* moist forest in South America; (b) sampled sites, and; (c) highlights to 1–8 sampled forest fragments. Site names are presented in Table S1.

Since Paraná-pine seeds rely on animals for dispersal and encounter high rates of seed predation (Job and Vieira, 2008; Brum et al., 2010; Vieira et al., 2011), we tested the hypotheses that: (I) seed removal will be negatively related to Paraná-pine dominance; (II) high recruitment will be related to high adult female numbers as a result of higher seed abundance (satiation hypothesis); (III) fragmentation will increase seed removal; (IV) in fragments seed removal will be dominated by small rodents due to the release of competition with large mammals; (V) fragments will present low recruitment than control site; (VI) interactions with the largest seed disperser (agouti) will be negatively affected by forest fragmentation; and (VII) buried seeds will have a greater chance of surviving than non-buried seeds, independent of their distance from adult tree, demonstrating the importance of scatter-hoarders for the recruitment of this plant.

2. Materials and methods

2.1. Study areas

To measure the effects of forest fragmentation and changes in the animal community on seed removal and the recruitment of *A. angustifolia* we studied ten forest fragments and three continuous areas (Fig. 1). Study areas varied from 8 to 181,000 ha (more details about study sites see Supplemental Material). *Araucaria* moist forest fragments, in general, experienced timber extraction and reduction in seed predator and disperser communities (Brocardo and Cândido-Jr, 2012), while two of our continuous areas represented more intact seed predator community (Iguaçu National Park and Campos do Jordão State Park) (Brocardo et al., 2017), and a third continuous area (Alto-

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