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Changes to anuran diversity following forest replacement by tree plantations in the southern Atlantic forest of Argentina

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ABSTRACT

The replacement of native forests by high-density tree plantations affects the richness and composition of animal communities through the modification of the resource availability, hydrological regimes, nutrient cycles and soil structure. Previous studies have been conducted mainly on birds and mammals, whereas few have explored the response of anurans, a taxon considered at risk and in steep decline. With this study we aimed to evaluate changes in anuran diversity associated with native forest replacement by pine plantations (*Pinus taeda*) in the southern Atlantic forest of Argentina, a highly diverse and threatened ecosystem. Additionally, we intended to explore the role of the micro-habitat (terrestrial, aquatic) in the response. We characterized vegetation and habitat structure and sampled anurans in terrestrial and aquatic micro-habitats in the native forest and pine plantations monthly over two consecutive years (2012–2014), using three complementary techniques (pitfall traps, audio strip transects and larval sampling). A total of 964 individuals of 21 species were captured: *Physalaemus cuvieri*, *Odontophrynus americanus* and *Elachistocleis bicolor* were the most abundant species. Replacement of the structurally complex native forest by extremely simplified monoculture tree plantations influenced the patterns of anuran alpha and beta diversity. However, these changes were micro-habitat-dependent: changes in anuran diversity in the terrestrial habitat were explained by species loss, while those in the aquatic habitat were explained by both species loss and turnover. The arboreal species of the family Hylidae (eight) were found absent from tree plantations. Both the hydroperiod instability of the water bodies and the simplified vegetation structure of the tree plantations are probably limiting the suitability for both reproduction and larval development of some specialist species. The native vegetation surrounding the water bodies in the tree plantations constitutes a central element to maintain anuran diversity, through increasing the hydroperiod and providing a habitat for species reproduction in the southern Atlantic forest and to facilitate the movement of individuals among native forest remnants.

1. Introduction

The replacement of tropical and subtropical forests by fast-growing tree plantations (mainly *Pinus* and *Eucalyptus*) has become an emergent global activity (FAO, 2007). After South Africa and Australia, South America presents the highest rate of development of this activity (Baldi et al., 2008), being Argentina, Brazil and Chile the countries with the largest extensions of this land use (Simberloff et al., 2010). Native forest replacement by high-density tree plantations affects the richness and composition of animal communities through the modification of the resource availability (Richardson et al.1994; Richardson and Higgins, 1998), hydrological regimes (Le Maitre et al., 2000), nutrient cycles (Vitousek, 1990; Jackson et al., 2002) and soil structure (Schmitz et al., 1997). At large scales, tree plantations reduce landscape heterogeneity and the number and diversity of habitats available for species (Lindenmayer and Franklin, 2002; Magura et al., 2000; Raman, 2006). However, in contrast to other intensive land uses (such as livestock, annual crops, and urbanization), tree plantations provide a suitable habitat for many animal species through the preservation of certain components of the native forest, such as canopy cover, microclimate conditions and some trophic resources (Barbaro et al., 2005; Carnus et al., 2006; Klomp and Grabham, 2002; Pawson et al., 2008; Lantschner et al., 2008; Zurita and Bellocq, 2012).

Anurans are considered the most threatened group of vertebrates globally (Wake and Vredenburg, 2008). For the Atlantic Forest anuran community, 3.4% of species are categorized as at risk of extinction

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(Silvano and Segalla, 2005), mainly due to habitat loss and degradation (Blaustein et al., 1994; Eterovick et al., 2005; Collins and Storfer, 2003, Beebee and Griffiths, 2005) and 20% are listed as Data Deficient (IUCN, 2017). Also, because of their ecology and physiology, anurans are considered indicators of disturbance in both terrestrial and aquatic ecosystems (US EPA, 2002). Although forest plantations strongly modify habitat structure and hydrological regimes for anurans, and thus potentially their reproduction and survival, globally only few studies have focused on the effects of forest replacement by tree plantations on this taxon (Pineda et al., 2005; Urbina-Cardona and Londoño-Murcia, 2003; Faruk et al., 2013; Behm et al., 2013; Ernst and Rodel, 2005; Ernst et al., 2006). Specifically, the only two studies performed with *Pinus spp*. in Australia (Parris, 2004) and Brazil (Machado et al., 2012) have shown that monoculture tree plantations reduce anuran richness.

The Semideciduous Atlantic forest of Brazil, Argentina and Paraguay is one of the most diverse areas with the highest number of endemic species worldwide (ICPB, 1992; Laclau, 1994; Stotz et al., 1996). The high levels of humidity and micro-habitat diversity in this ecoregion promote the evolution of specialized reproductive modes in some anuran species (Brown and Brown, 1992; Haddad and Prado, 2005). However, despite the high anuran diversity and specialization and the extent of monoculture tree plantations in the southern Atlantic forest, no studies have evaluated the suitability of tree plantations for this taxon. Previous studies with vertebrates have focused mainly on birds and mammals (Marsden et al., 2001; Pardini et al., 2005; Cockle et al., 2005; Faria et al., 2006; Zurita et al., 2006; Pardini et al., 2009). In this context, our main objective was to quantify the consequences of native forest replacement by monoculture plantations (*Pinus taeda*) on the anuran diversity (both richness and the composition of species) of the southern Atlantic forest of Argentina and study the role of the micro-habitat (terrestrial, aquatic) in these changes.

2. Materials and methods

2.1. Study area and experimental design

The study was performed in the Semideciduous Atlantic forest of Argentina, which retains one of the most continuous and least degraded remnants of Atlantic forest (Giraudo et al., 2005) (Fig. 1). The climate is subtropical without dry season; the average annual air temperature is 21 °C with monthly means of 25 °C in summer and 15 °C in winter, the annual precipitation ranges between 1600 and 2100 mm, evenly distributed throughout the year (Ligier, 2000). Landscapes in the study area are composed of large continuous native forest remnants in protected areas (Iguazú National Park and Urugua-í Provincial Park in Misiones province), forest fragments of variable size, and a productive matrix of tree plantations, mostly of *Pinus taeda* (Zurita and Bellocq, 2010).

Within the study area, we selected three areas of continuous native forest (control, NF hereafter) and three of *Pinus taeda* monoculture tree plantations (replicates, TP hereafter). The selected TP were between 13 and 16 years old and in the third harvest cycle. Each sampling site (NF and TP) included two micro-habitats: a temporary water body (aquatic habitat) and the surrounding terrestrial habitat. Aquatic habitat referred to lentic water bodies, in all cases including TP sites, surrounded by native vegetation composed of trees in different strata and a diverse understory with grasses and lianas (*Cyperus sp*. and *Hiraea fagifolia*). All water bodies were filled through rainfall and have similar size when full (NF water bodies area $\overline{X} = 6.352\ m^2$ (SD = 8.095)/TP water bodies area $\overline{X} = 11.007\ m^2$ (SD = 9.114)). Sampling sites were located at an average distance of 25.8 km to avoid spatial autocorrelation. Anuran samplings were carried out monthly in every site for two consecutive years (from August 2012 to August 2014).

2.2. Anuran sampling

To obtain a more complete measurement of anuran diversity (both richness and composition) in both the aquatic and the terrestrial micro-habitats, we used three complementary methodologies:

1. Pitfall traps (Corn, 1994; Ribeiro-Junior et al., 2008): in each sampling site (NF and TP), we placed 16 traps, which were active for 72 h each month and checked daily (1728 sampling hours). In each site, they were grouped in four groups of four traps near the water bodies, forming a Y and connected by a shading mesh to maximize capture efficiency (2 habitats × 3 replicates × 4 groups × 4 traps = 96 traps). Groups of traps were separated between 50 and

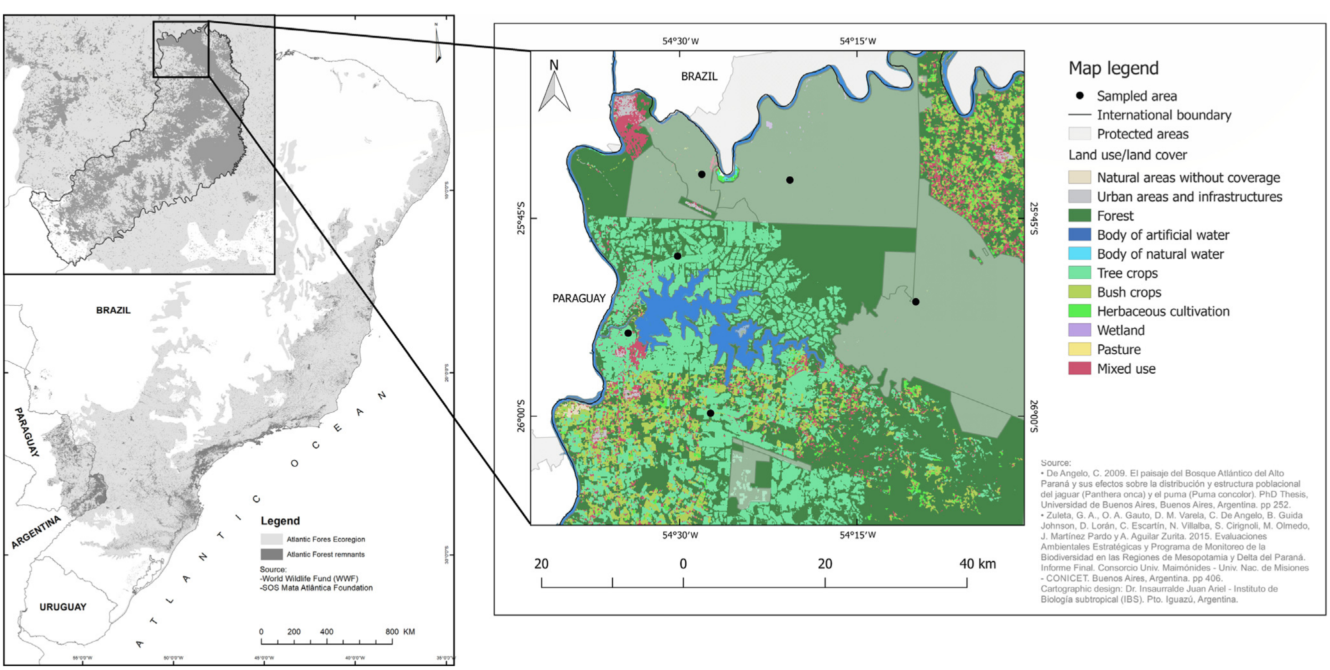

Fig. 1. Study area in the southern Atlantic forest of Argentina. Black circles represent sampling locations.