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The exotic palm *Roystonea oleracea* (Jacq.) O. F. Cook (Arecaceae) on an island within the Atlantic Forest Biome: naturalization and influence on seedling recruitment

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ABSTRACT

Here, we investigated the population structure of the exotic palm *Roystonea oleracea* in a swamp on an island within the Atlantic Forest Biome, evaluating its influence on the seedling recruitment of other plant species. The population structure was analyzed in six 4 × 30 m plots, within which we categorized all individuals by ontogenetic stage. The influence of *R. oleracea* on the seedling recruitment of other plant species was evaluated in 2 × 2 m plots established beneath palm crowns and in adjacent areas without palms. We recorded 53 *R. oleracea* individuals. The majority (56.6%) of the *R. oleracea* population was composed of immature adults, followed by mature adults. The density, richness and diversity of seedling species differed significantly between areas beneath and away from palms, the values being lower beneath *R. oleracea* crowns. Our results indicate that *R. oleracea* recruitment does not require human intervention, the number of reproductive individuals characterizing successful naturalization. This underscores the need for management policies aimed at palm eradication in order to avoid reductions in biodiversity.

Key words: Biodiversity loss, biological invasion, exotic species, seedling mortality

Introduction

Exotic species are those that have been introduced into habitats where they do not naturally occur (IUCN 2000; CBD 2012). Several factors can contribute to species invasiveness. Among such factors are species traits such as fertility and dispersal effectiveness, as well as the characteristics of invaded sites, including the presence of interacting species and the degree of disturbance (Rejmánek & Richardson 1996; Williamson & Fitter 1996; Londsdale 1999; Davis *et al.* 2000). The absence of natural enemies can also promote a rapid increase in exotic species abundance, favoring their dissemination to new areas (Keane & Crawley 2002; Dewalt *et al.* 2004). For the consolidation of invasive process, however, it is necessary that the species become established in these new areas, through the survival and reproduction of their descendants (Richardson *et al.* 2000; Ziller & Zalba 2007; CBD 2012).

When an invasive species is established outside its natural distribution range, it can threaten the new environment or the species occurring within it (Vitousek *et al.* 1996). Exotic species can affect the structure of the invaded communities through various processes (Parker *et al.* 1999; Levine *et al.* 2003), including disruption of community assembly through competitive exclusion of native plant species (Sundaram & Hiremath 2012), changes in the composition of the understory and litter layer (Mack & D'Antonio 1998; Parker *et al.* 1999), and changes in the genetic structure of native populations through hybridization (Richardson *et al.* 2000; Nyoka 2003). In addition, ecosystem functioning can be affected by alterations in nutrient cycling and hydrological regimes (Ehrenfeld 2003; Levine *et al.* 2003). Therefore, invasive species have been considered important drivers of ecosystem changes (Macdougall & Turkington 2005).

Various plants can become invasive, and one example is the palm tree. Most likely because of their great ornamental value, many palms are often introduced into areas outside their natural ranges (Lorenzi *et al.* 2004). Some palms can invade natural vegetation and become a threat to local native species. Among the characteristics that contribute to the higher invasive potential of palms are their aggregated distribution (Beck & Terborgh 2002), which favors high population densities at local scale, and the wide range of frugivorous fauna (Zona & Henderson 1989; Andreazzi *et al.* 2009), which increases the probability of colonizing new habitats. In addition, some palms are also favored at disturbed sites, where they can flourish (Aguiar & Tabarelli 2010; Andreazzi *et al.* 2012). In view of these factors, problems

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with invasive palm species are to be expected (Svenning 2002) and have been reported by several authors (Dislich *et al.* 2002; Svenning 2002; Christianini 2006; Meyer *et al.* 2008).

Since the 16th century, *Roystonea oleracea* (royal palm) has been widely cultivated worldwide because of its ornamental characteristics (Oliveira *et al.* 2009). This palm has been reported to be invasive, especially in the swamps of Guiana (Henderson *et al.* 1995), in Panama (Svenning 2002), and in the Atlantic Forest of Brazil (Nascimento *et al.* 2013). Arboreal palms can have negative effects on the seedling recruitment of other plant species due to the fact that their vegetative structures drop to the ground (Peters *et al.* 2004). Palm leaves and reproductive structures typically decompose slowly, forming a deep litter layer. Litter accumulation modifies microhabitat conditions and affects the recruitment of other plant species, as has been observed by Farris-Lopez *et al.* (2004) for the palm *Oenocarpus mapora*, in Panama, and by Aguiar & Tabarelli (2010) for the palm *Attalea oleifera*, in Brazil, both of whom reported reductions in the abundance and richness of seedling species beneath palm crowns. Because *R. oleracea* is a tall palm with large, heavy leaves, negative effects on seedling recruitment beneath their crowns are also to be expected.

Predicting the impact of exotic species on native populations has become a major goal of ecological research (Svenning 2002). These effects are in fact more severe in insular habitats than in continental habitats (Loope & Mueller-Dombois 1989). In this study, we investigated a population of the exotic palm *Roystonea oleracea* in a swamp on an island within the Atlantic Forest Biome, aiming to characterize their population structure and its possible effects on local biodiversity. More specifically, we address the questions of whether this palm species is recruiting naturally in the area and whether introduced mature adult palms are affecting the recruitment of other plant species.

Material and methods

Studied species and area

Roystonea oleracea is native to Trinidad and Tobago, as well as to the Lesser Antilles, northern Venezuela, and northeastern Colombia (Henderson *et al.* 1995), forming dense stands in swamps (Bonadie 1998). In Brazil, the species was first introduced by the Portuguese court in the 19th century, when it was widely used on coffee plantations because it was considered a status symbol (Oliveira *et al.* 2009). This palm is among the tallest in the world, reaching a height of 40 m. The trunks are solitary, either columnar or slightly swollen, measure 46-66 cm in diameter, and are swollen at the base when young. Leaves are pinnate, 2-4 m long. Fruiting occurs from December to March, and a single individual can produce thousands of fruits. Fruits are purple-black, ellipsoid, 1.3-1.7 cm long and 0.8-1.0 cm in diameter. Germination occurs 70 days after fruit fall, and germination rates are high (Henderson *et al.* 1995; Lorenzi *et al.* 2004).

The study was carried out in the community of Vila de Dois Rios, within Ilha Grande State Park, in the state of Rio de Janeiro, Brazil. The island is located off the southeastern coast of the state (23°15'S; 44°15'W), within the municipality of Angra dos Reis, and covers an area of 12,052 ha (INEA 2012). The vegetation is typical of the Atlantic Forest Biome, albeit in different successional stages because of the use of some areas for agriculture, especially during the 19th century (Alho *et al.* 2002). Although a portion of the island is covered by dense rain forest, most of the area consists of vast stretches of secondary formations, with trees reaching 20 m in height, and there are some species characteristic of advanced ecological stages, such as *Vochysia bifalcata*, *Tabebuia stenocalyx* and *Lecythis pisonis* (Alho *et al.* 2002; Oliveira 2002). The sampling was carried out in a secondary area where a row of palms was planted in the past. The climate is tropical humid with an average temperature of 21°C and an annual precipitation exceeding 2200 mm (INEA 2012).

Sampling and data analysis

Field sampling was carried out in November 2011. Palm recruitment was indirectly assessed through analysis of the population structure in an area where the row of palms had been planted. Six 4 × 30 m plots were established, 10 m apart. In each plot, all *R. oleracea* individuals were recorded and classified into one of following ontogenetic stages, based on a morphological analysis: seedling—individuals without visible stems and with non-pinnate leaves; (2) juvenile—individuals without visible stems and exhibiting leaves with incipient division; (3) immature adult—individuals with visible trunks, fully pinnate leaves, and no reproductive structures; or (4) mature adult—individuals with visible trunks, fully pinnate leaves, and signs of current or past reproduction. The diameter at ground level (DGL) was measured whenever possible.

The effects of *Roystonea oleracea* on the seedling recruitment of other species were evaluated beneath 10 selected mature adult individuals of the species within the study area. We established two 2 × 2 m plots, 5 m apart: one near the trunk and beneath the crown; and a control plot not beneath any palm crown. The positioning of the two plots in relation to each other was defined at random. In each plot, the seedlings of all species except *R. oleracea* ones were quantified and assigned to morphotypes. Seedlings > 0.5 m in height were excluded. Morphotypes were classified on the basis of the leaf characteristics commonly used in taxonomic identification.

Statistical analysis

Data are presented as means ± standard deviations or as proportions. After checking the data for normality and homoscedasticity, we use paired t-tests to analyze differences between the areas with and without the influence of palm crowns with respect to seedling abundance. Seedling diversity, beneath and away from the palm crowns, was assessed with rarefaction curves (Magurran 2011). Values of $p < 0.05$ were considered statistically significant.

Results and discussion

We found 53 individuals of *Roystonea oleracea* in the sampled area, corresponding to a density of 736 individuals/ha. Within that population, all ontogenetic stages were represented, primarily the immature adult stage (n = 30; corresponding to a density of 417 individuals/ha), followed by the mature adult stage (n = 11; 152 individuals/ha), collectively corresponding to approximately 77% of the total population (Fig. 1). Seedlings accounted for 17% of the population (n = 9; 125 individuals/ha), whereas juveniles accounted for 6% (n = 3; 42 individuals/ha). For immature adults, the mean DGL was 54.4 ± 20.0 cm (range, 14-80 cm), compared with 93.5 ± 4.5 cm (range, 90-97 cm) for mature adults.

The abundance, richness, and diversity of seedling species were lower in areas beneath palm crowns. We identified 152 seedlings, of which only 27 (17.8%) occurred beneath *Roystonea oleracea* palm crowns (t = 4.96, $p = 0.001$, Fig. 2a). Seedlings belonged to 43 morphotypes; 14 were found beneath palm crowns and 34 recruited away from palms - six in common between areas. In addition, seedling species richness was lower beneath palm crowns than away from palms (t = 5.78, $p < 0.001$, Fig. 2b). As a consequence, seedling diversity was also significantly lower beneath *R. oleracea* palms (Fig. 3).

This study showed that new individuals of *Roystonea oleracea* are establishing in the wild without human assistance. The high proportion of immature adult individuals indicates that the species has a high dissemination potential if those individuals reproduce successfully. Seeds of *R. oleracea* can be dispersed by frugivorous vertebrates, which favors its recruitment to areas not previously colonized by the species. Bats and birds, which are able to carry seeds over long distances, are among the main dispersers of *R. oleracea* (Oliveira *et al.* 2009). In other localities, bats of the genus *Artibeus* have been observed consuming *R. oleracea* fruits, as have parrots (Bonadie & Bacon 2000; Bredt *et al.* 2012), and both of those frugivores occur in our study area (Ésberard *et al.* 2006; Alves & Vecchi 2009). Even though a large part of those seeds become unviable, a few can be dispersed to sites that are favorable for germination and recruitment.

The higher proportions of immature adult and mature adult individuals differ from those generally described for palm populations, in which most individuals are typically in the initial ontogenetic stages (e.g. Giroldo *et al.* 2012). However, population structures similar to that observed in the present study have been described for a natural *Roystonea oleracea* population in a swamp in Trinidad (Bonadie 1998). This structure is promoted only in certain years, when there are optimal conditions of soil moisture, microtopography, flooding and drying, which allow seedling establishment (Bonadie 1998). Because our study site is also subject to flooding, the same could be true for our population. Nevertheless, the influence of factors not investigated here, such as reproduction in alternate years, dispersal rates, and seedling mortality, cannot be discarded.

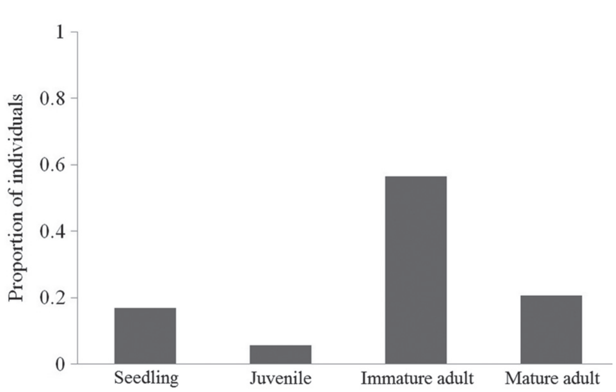

Figure 1. Proportion of individuals of *Roystonea oleracea*, by ontogenetic stage, in a swamp on an island within the Atlantic Forest Biome. Ilha Grande State Park, state of Rio de Janeiro, Brazil.

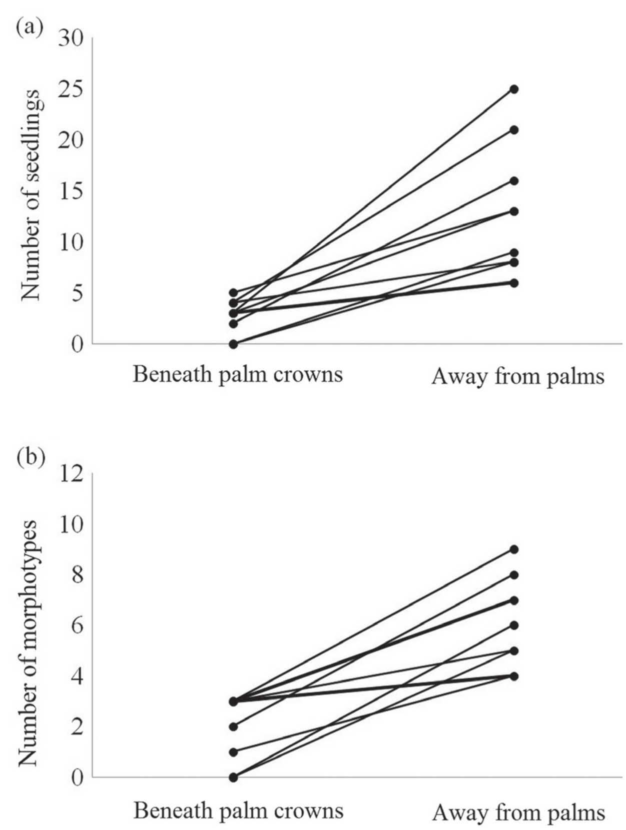

Figure 2. Abundance (a) and richness (b) of seedling species in areas beneath and away from *Roystonea oleracea* crowns, in a swamp on an island within the Atlantic Forest Biome. Ilha Grande State Park, state of Rio de Janeiro, Brazil.

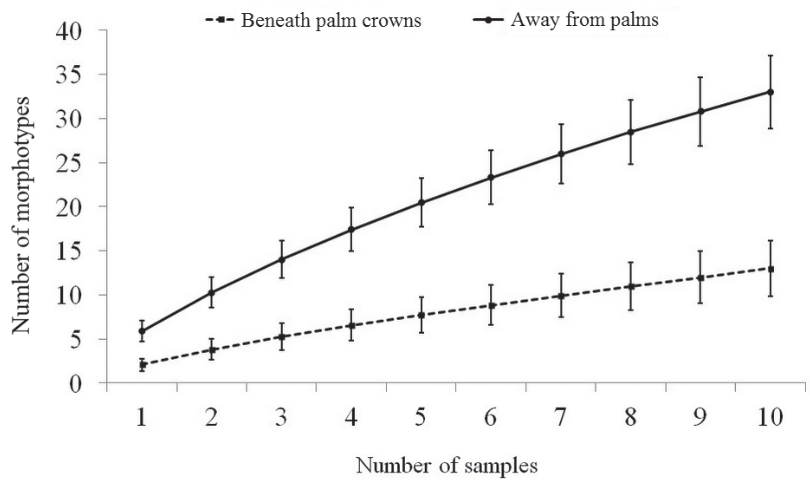

Figure 3. Rarefaction curves based on individuals (samples), expressed as the expected number of species found in function of the number of plots, for areas beneath and away from *Roystonea oleracea* crowns, in a swamp on an island within the Atlantic Forest Biome. Ilha Grande State Park, state of Rio de Janeiro, Brazil. Bars represent confidence intervals.

Because the abundance, richness and diversity of seedling species were significantly lower beneath palm crowns, the spread of this palm could imply in a reduction of plant diversity in the areas it comes to dominate. The lower seedling abundance and diversity beneath palm crowns could have resulted from the fact that *Roystonea oleracea* individuals drop large leaves and reproductive parts (Peters *et al*. 2004). The accumulation of leaves on the ground can inhibit the establishment of some species by altering light intensity and humidity (Farris-Lopez *et al.* 2004; Aguiar & Tabarelli 2010). Future studies should focus on the mechanisms responsible for seedling recruitment failure, as well as on identifying the most vulnerable species.

Our results demonstrate that the studied population of *Roystonea oleracea* met two of the three criteria that characterize an invasion process (Richardson *et al.* 2000). After a successful introduction by humans, through the establishment of a few individuals for ornamental purposes, the species was able to colonize the area through the establishment of reproductive individuals. Although we did not evaluate the final, decisive criterion - the invasion itself (defined as the spread into areas away from the introduction sites) - some traits of *R. oleracea* indicated that invasion is likely to occur in the short-term. In fact, Nascimento *et al.* (2013) showed that this palm is dispersing naturally over long distances (up to 440 m) in wetland areas of a protected area within the Atlantic Forest, where it was introduced around 1930. The combination of high productivity, high germination rates, and seed dispersal by animals, as has previously been reported for *R. oleracea* (Henderson *et al.* 1995; Lorenzi *et al.* 2004), is common in exotic invaders (Van Kleunen *et al.* 2010; Richardson & Pyšek 2012). This demand calls for management efforts to address the fact that dozens of *R. oleracea* individuals will soon be able to reproduce in the study area. Future studies should focus on identifying other areas into which this palm invades, in order to avoid reductions in biodiversity, especially in wetland areas, which constitute the most endangered subclass within the Atlantic Forest Biome.

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