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Impact of rain forest fragmentation on the population size of a structurally important palm species: *Astrocaryum mexicanum* at Los Tuxtlas, Mexico

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ARTICLE INFO

Article history:
Received 11 October 2006
Received in revised form
6 April 2007
Accepted 11 April 2007
Available online 29 May 2007

Keywords:
Arecaceae
Common species
Edge effect
Forest fragmentation
Isolation
Landscapes

ABSTRACT

Forest fragmentation changes the structure of natural landscapes causing shifts on the distribution and abundance of plant species that could lead to population extinctions. The tree palm *Astrocaryum mexicanum* is one of the most abundant plant species in the Los Tuxtlas region, Mexico. Nevertheless, 95% of the original rain forest in this region has disappeared, and remaining palm populations are present within landscapes that differ in their conservation status. To identify the landscape (e.g., amount of forest cover, fragment size, fragment shape and isolation) and vegetation (e.g., plant species richness, density and basal area) attributes that could influence the adult population size of *A. mexicanum*, we analyzed 45 forest fragments (<1–266 ha) distributed in three landscapes that encompassed different levels of fragmentation, and compared with the population inhabiting the Los Tuxtlas Field Station (700 ha). Fragmentation affected the population size of *A. mexicanum*, with the smaller, most isolated and irregular forest fragments showing the lower number of individuals. The importance value index of *A. mexicanum* was greater in the most conserved landscape. Furthermore, palm density was positively correlated with species richness, density and basal area of old-growth forest species, but negatively correlated with richness of secondary forest species. Overall, the strong decline in population size of adult reproductive palms may affect the regeneration and genetic diversity of this species increasing its probability of extinction. The loss of this species from the remaining fragments may have dramatic consequence for the ecological functioning of this system.

1. Introduction

Deforestation and fragmentation of natural ecosystems are some of the most pervasive global environmental changes, particularly affecting old-growth forests in tropical regions (Achard et al., 2002). Tropical rain forests are characterized by the presence of many tree species with low population densities, and very rarely one or two tree species are much

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0006-3207/$ - see front matter
doi:10.1016/j.biocon.2007.04.016

more abundant than the rest (Richards, 1952; Hubbell and Foster, 1986). Such as in the case of the legume tree *Pentaclethra macroloba* at La Selva, Costa Rica (Hammel, 1990), the laurel tree *Nectandra ambigens* and the palm *Astrocaryum mexicanum* in the canopy and in the understory of Los Tuxtlas, Mexico, respectively (Sarukhán, 1978; Bongers et al., 1988), or the tree Family Dipterocarpaceae in South East Asia, that has a particularly large number of species and individuals (Whitmore, 1984). These abundant species are important constituents of these rain forests as many of their other features may be directly dependent on them. Because their importance on tropical rain forest structure and function it is relevant to study the effect of human disturbances such as forest fragmentation on abundant tree species.

The reduction of forest cover, coupled with shifts in landscape patterns (e.g., increase number of forest fragments, reduction in fragment size, increase of fragment isolation; Fahrig, 2003) can directly affect vegetation related ecological processes such as pollination, seed dispersal, seed predation, forest regeneration, and competition (Kearns et al., 1998; Wright and Duber, 2001; Aizen et al., 2002; Benítez-Malvido and Martínez-Ramos, 2003; Dupuy and Chazdon, 2006; Fleury and Galetti, 2006; Galetti et al., 2006), which in turn influence the distribution and abundance of several plant species (Turner et al., 1996; Hill and Curran, 2003; Arroyo-Rodríguez and Mandujano, 2006) that could lead to the loss of genetic diversity (Young et al., 1996) and extinction of numerous populations within the remaining forest patches (Turner et al., 1996; Hughes et al., 1997; Pimm and Brooks, 2000; Ferraz et al., 2003).

The forest edge is the most drastically altered zone of a fragment (Laurance and Yensen, 1991; Saunders et al., 1991; Murcia, 1995). Increments in the incidence of light and wind near edges may cause high tree mortality (Laurance et al., 1998, 2000), with the most damage suffered by large and emergent old-growth forest species (Benítez-Malvido, 1998; Hill and Curran, 2003; Arroyo-Rodríguez and Mandujano, 2006). However, our understanding of the impacts of forest fragmentation on plant populations is still rudimentary (Fahrig, 2003), and largely focused on woody trees, leaving aside other plant growth forms that are important components of forest structure and biodiversity (Laurance et al., 1998, 2000; Scariot, 1999; Zhu et al., 2004).

Palm species are important components of tropical rain forests being present at all forest strata (canopy, subcanopy and understorey). Furthermore, palms are important food resource for many animal species and have an important economic value for human populations (Scariot, 1999; Vormisto, 2002; Henderson, 2006). Despite of their abundance, because many palm species are obligate outcrossing (Murcia, 1996), and pollination frequently depends on highly specialized insect species (Henderson, 1986; Listabarth, 2001) their populations are extremely susceptible to fragmentation. However, research on the effect of fragmentation on palms have reported contrasting results with some species and ontogenetic stages such as seedlings being particularly susceptible to forest fragmentation (Svenning, 1998; Scariot, 2001; Souza and Martins, 2002; Benítez-Malvido and Martínez-Ramos, 2003).

In this paper, we present data on the palm *A. mexicanum* Liebm. (Arecaceae) inhabiting rain forest fragments in the Los Tuxtlas Biosphere Reserve, Mexico. This species is very representative of the forest understorey of Los Tuxtlas, with around >1000 adult palms per hectare (Piñero et al., 1977). Although there is a lot of information concerning different aspects of its demography (Sarukhán, 1978; Piñero et al., 1984; Martínez-Ramos et al., 1988b), gap dynamics (Martínez-Ramos, 1985; Martínez-Ramos et al., 1988a,b; Martínez-Ramos et al., 1989), and population genetics (Eguiarte et al., 1992, 1993), all studies have been conducted within the Los Tuxtlas Field Station (LTFS, 700 ha), and little is known about the effects of forest fragmentation on the abundance of this important palm species across the landscapes integrating the Biosphere Reserve.

We analyzed adult populations of *A. mexicanum* within 45 rain forest fragments distributed in three landscapes that encompassed different levels of fragmentation and addressed following questions: (1) What are the density patterns of *A. mexicanum* within the three landscapes?; and (2) What are the habitat attributes (i.e., fragment size, shape and isolation) with stronger influence on the density patterns of *A. mexicanum*.

In the Los Tuxtlas region 95% of the original tropical rain forest has already disappeared (Castillo-Campos and Laborde, 2004; Guevara et al., 2004). Therefore, our study is relevant for the conservation of this palm species because Los Tuxtlas holds the northern most *A. mexicanum* populations of the Neotropics, this species is very representative of this rain forest region and is involved in many ecological processes (Martínez-Ramos, 1997).

2. Methods

2.1. Study site

Los Tuxtlas is located in the southeast of the Veracruz State, Mexico (18° 8′–18°45′ N, 94° 37′–95° 22′ W; Fig. 1). The climate is warm, with a mean annual temperature of 25 °C, and annual rainfall between 3000 and 4600 mm; elevation ranges from 0 to 1780 m a.s.l. (Guevara et al., 2004). The region was heavily deforested and fragmented between 1972 and 1993 (Guevara et al., 2004), but Los Tuxtlas was decreed a Special Biosphere Reserve in 1998 (Diario Oficial de la Federación, 1998), as it represents the northern limit of tropical rain forest distribution in the Neotropics with high and unique biodiversity (Dirzo and García, 1992; Castillo-Campos and Laborde, 2004). The Reserve covers an area of 155,122 ha, and it is naturally divided in three regions: the northern San Martin Tuxtla Volcano landscape; the central Sierra de Santa Marta landscape; and the southern San Martin Pajapan Volcano landscape (Guevara et al., 2004). The original dominant vegetation type (below 700 m a.s.l.) was tropical rain forest, but it is actually highly fragmented and surrounded by a matrix of pastures and croplands (Castillo-Campos and Laborde, 2004).

2.2. The study species

The tree palm *A. mexicanum* is the only species of the genus in Mexico (Henderson, 1986). In Los Tuxtlas it is distributed between 0 and 700 m a.s.l. (Martínez-Ramos, 1997). Its