Acta Oecologica 91 (2018) 1–6

Contents lists available at ScienceDirect

Acta Oecologica

journal homepage: www.elsevier.com/locate/actoec

Edge, area and anthropization effects on mangrove-dwelling ant communities

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ARTICLE INFO

Keywords:
Multiple edges
Edge influence
Coastal ecosystem
Formicidae
Functional groups

ABSTRACT

In mangroves the habitat fragmentation has contributed to area reduction and increased edge extension, as well as other anthropogenic consequences that can change abiotic conditions, interfere with ecosystem functioning and lead to the loss of biodiversity. These impacts may affect terrestrial and marine invertebrates living in this coastal system. This study investigated the effects of fragment characteristics (size and matrix type) and distance to edge on ant richness, occurrence of functional groups and of the most frequent species in mangroves in North-Eastern Brazil. Our research covered ten mangrove fragments. We used sardine and honey baits in twelve randomly selected points per area. Twenty-five species of ants were recorded, with *Camponotus arboreus*, *Crematogaster erecta*, *Azteca* sp. and *Neoponera villosa* being the most frequent. Only four functional groups were found, the most representative of which were the Arboreal Omnivores with Massive Recruitment and the Generalist Predators. No relationship was found between the response variables and the environmental characteristics. Mangroves ants are mostly arboreal; thus, the pattern of competition between ant species or even tree architecture elements may have stronger effects than those related to anthropization, loss of area and fragmentation in this environment. Furthermore, the harsh physical conditions in the mangrove serve as barriers for most exotic species and to some functional groups of ants. This study highlights the natural restrictive nesting and foraging conditions in mangrove areas as the powerful forces in ant community structuring, possibly even more than anthropization itself.

1. Introduction

Historically human population growth and urban development have been the main causes of mangrove habitat loss (Valiela et al., 2001). The rate of areas loss of this environment, due to activities such as vegetation clearing, grounding or conversion into developed land, is estimated between 1 and 2% per year, with the Americas as the most affected regions (3.6% loss per year) (Urbas et al., 2007). This percentage exceeds the suppression rate of tropical forests, which is about 0.8% per year, and makes mangroves one of the World's most fragile ecosystems (FAO, 2007).

Studies on this ecosystem have focused mainly on quantifying area losses (Martins et al., 2008; FAO, 2010), and few have addressed how the use or degradation of the environment by anthropic practices affect the species that mangroves shelter. Nevertheless, the continuous loss of habitat in the mangroves, as well as their fragmentation, lead to an increase of their perimeters: area ratio, which may result in increased edge effects in the fragments. In general, anthropogenic edges are responsible to changes in abiotic condition, interfere in the functioning of the ecosystem and cause biodiversity loss (Murcia, 1995; Harper et al., 2005). Studies about edge effects in mangroves resulting from their anthropization indicate higher rates of tree mortality (Zamprogno et al., 2016) and changes in abiotic variables, including rising pH and substrate temperature and lower stability of air temperature (Medellu and Berhimpon, 2012; Amortegui-Torres et al., 2013). Some invertebrates living in this coastal system are directly affected by the quality of their microhabitat and, therefore, they are susceptible to the changes caused by human actions (Medellu and Berhimpon, 2012; Amortegui-Torres et al., 2013).

Among the terrestrial species, ants are the predominant group of insects that inhabit this system (Delabie et al., 2006). Ants are considered excellent bioindicators because of their high sensitivity to environmental changes, numerical representativeness, easy sampling, wide geographic distribution and they play an important role in

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https://doi.org/10.1016/j.actao.2018.05.004
Received 29 January 2018; Received in revised form 26 April 2018; Accepted 13 May 2018

ecosystem dynamics (Alonso and Agosti, 2000; Toro et al., 2015). Thus, it is increasingly common to use this group of organisms to assess the anthropic impacts on any terrestrial environment (Sobrinho et al., 2003; Wirth et al., 2007; Gomes et al., 2010; Costa-Milanez et al., 2014). Although these insects are widely used as indicators of disturbance, only a single study was carried out in mangroves, where a lower diversity of ants was linked to the human impact degree (Delabie et al., 2006). Hence, the lack of investigations that seek to understand how the effects generated by natural and anthropic edges affect the ants in this system is worthy of note.

The present study aims to fill this knowledge gap by characterizing the ant fauna living in this system and answering the following questions: Do natural and anthropogenic edges, as well as fragment attributes (size and conservation status), affect the ant richness and the occurrence of different species and functional groups in mangrove areas? If the answer is positive, which of these variables are the most important? What ant species could be considered as indicator of anthropization in mangrove areas?

2. Material and methods

2.1. Sampling sites

This study was carried out in 10 mangrove fragments distributed along 44 kilometers of coast and located in the extreme south of the State of Bahia (Brazil), in the municipalities of Caravelas, Prado and Alcobaça (Fig. 1). The climate of the region is tropical humid, categorized as Afi according Köppen's classification (Köppen, 1936) with average precipitation always above 60 mm per month and average temperature in the coldest month above 18 °C.

The areas of the sampled fragments ranged between 1.81 ha and 103.0 ha (Table 1); the fragments were chosen because they have similar human occupation, based on the anthropogenic impact classification in mangrove areas proposed by Delabie et al. (2006). This classification divides anthropization in mangroves into six levels, based on parameters such as the occurrence of garbage, deforestation and landfilling for real estate. Based on this information, five areas with a maximum impact level, assessed as anthropic, and five areas with a zero level, considered as conserved, were selected.

2.2. Ants sampling and predictor variables

Sampling was carried out from February to April 2016. As our region lacks marked seasonality due to the buffering effects of the Atlantic coast, mangrove ant community in the study sites is expected to be stable along time. For this reason, we collected only a single time. In each area, we randomly selected the geographic coordinates of twelve sample points, at least 30 m apart, totaling 120 samples. At each sampling point (located in the field with a GPS device), a tree was randomly selected to place the bait containing a mixture of honey and sardine (Bestelmeyer et al., 2000). Due to the flood regime, the use of the bait method is common in studies that describe the ant fauna in mangroves (Clay and Andersen, 1996; Lopes and Santos, 1996), and previous studies obtained similar results for baits and other methods (Simberloff and Wilson, 1970; Nielsen, 2000; Flanders et al., 2013). A single bait per tree always was placed at the same position. The bait was put on a branch at about 1.5 m from the ground, owing to the wet or swampy ground (see Lopes and Santos, 1996). The baits were exposed for 1h30min. After this time, baits and specimens attracted to the bait were stored in appropriate plastic bags, fixed in 90% alcohol and taken to Myrmecology Laboratory of the Cacao Research Center (Centro de Pesquisas do Cacau – CEPEC; Ilheus, BA, Brazil) for identification. Observing the baits after shorter periods was not possible because of logistic constraints related to movement difficulties in the mangrove and time available for sampling. All ants were identified whenever possible at the species level, the nomenclature follows Bolton (2003, 2016). Vouchers are deposited in the Collection of the CEPEC Myrmecology Laboratory.

Each species was classified into one of the following functional groups, following a classification adapted from Delabie et al. (2000) and Silvestre and Silva (2001): 1) predatory specialists; 2) generalist predators; 3) fungus cultivators; 4) army ants; 5) arboreal opportunists with massive recruitment; and 6) pollen cultivators.

The following attributes of the fragments and the sampling points were analyzed: i) conservation level: anthropic or conserved (Delabie et al., 2006); ii) distance of sample from water (river edge); iii) distance of sample from the land edge (for areas with human encroachment the land edge was between the encroachment and the mangrove; for conserved areas the edge is that between the mangrove and the adjacent non-mangrove vegetation); iv) Total area of each fragment. The distance to the edges and the size of each mangrove were obtained using Google Earth (2015).

2.3. Data analysis

The analyses were run separately at the sampling point level (testing the relationship with edge distance and interactions with the conservation level) and at the fragment level (testing the relation with fragment area, conservation level and interactions). Ant richness, presence/absence of the functional groups and presence/absence of the

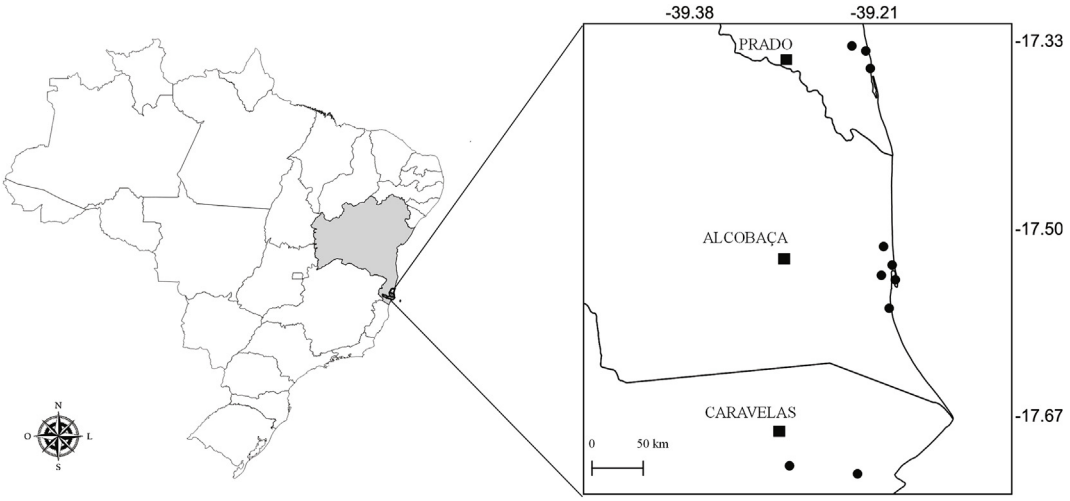

Fig. 1. Sampling areas in Bahia/Brazil. Dots represent sampled areas and squares represent bigger metropolis.