Rodriguésia 75: e01322022. 2024
http://rodriguesia.jbrj.gov.br
DOI: http://dx.doi.org/10.1590/2175-7860202475026

Short Communications

Visiting dynamics in tank-bromeliads after enrichment of a reforested urban patch of the Atlantic Forest

Juvenal Damasceno Amaral-Filho[1,2] & *Jefferson Rodrigues Maciel*[2,3,4]

Abstract
Many species of Bromeliaceae store water among their leaves creating microhabitats for several biological groups. Using bromeliads in enrichment of reforestation offers an opportunity to understand the occupation of tank habitat, and the impacts of these plants in increasing biodiversity. We translocated 20 rescued individuals of tank-bromeliad *Hohenbergia ramageana* to enrich a reforested area in Atlantic Forest. Then, we recorded the visiting dynamics of animals in the tank habitat of *H. ramageana*. Ten orders of vertebrates and invertebrates visited nine terrestrial and eight epiphyte tank-habitats just one month after the translocation. Richness and composition were similar between epiphyte and terrestrial translocations. We found that precipitation explained a significant proportion of variation of the number of visited plants and richness of animal orders. Our results confirm the importance of using tank-bromeliads in reforested ecosystems and bring novelty that reintroduced bromeliads in alternative habitats also play the same role for animal groups as in their original habitat. This knowledge will orientate future plans of conservation of bromeliads and of ecosystem restoration.
Key words: bromeliads, conservation, enrichment, translocation.

Resumo
Muitas espécies de Bromeliaceae armazenam água entre suas folhas criando microhabitats para diversos grupos biológicos. O uso de bromélias no enriquecimento de reflorestamentos oferece uma oportunidade para entender a ocupação do habitat tanque e os impactos dessas plantas no aumento da biodiversidade. Foram translocados 20 indivíduos resgatados da bromélia-tanque *Hohenbergia ramageana* para enriquecimento de uma área reflorestada de Mata Atlântica. Em seguida, foi gravada a dinâmica de visitação de animais no habitat tanque de *H. ramageana*. Dez ordens de vertebrados e invertebrados visitaram nove habitats tanques terrícolas e oito epífitos apenas um mês após a translocação. A riqueza e a composição foram semelhantes entre as translocações epífitas e terrícolas. Descobrimos que a precipitação explicou uma proporção significativa de variação do número de plantas visitadas e da riqueza de ordens de animais. Nossos resultados confirmam a importância do uso de bromélias-tanque em ecossistemas reflorestados e trazem novas evidências de que as bromélias reintroduzidas em habitats alternativos também desempenham o mesmo papel para grupos de animais que em seu habitat original. Esse conhecimento orientará planos futuros de conservação de bromélias e de restauração de ecossistemas.
Palavras-chave: bromélias, conservação, enriquecimento, translocação.

Habitat loss is one of the main threats to biodiversity (Pimm *et al.* 1995). Five centuries of deforestation have reduced the Atlantic Forest to archipelagos of small remnants that represent 11.4 to 16% of its original cover (Ribeiro *et al.* 2009; Rezende *et al.* 2018). This process has caused loss of habitat quality and availability for a large number of endemic species (Myers *et al.* 2000; Lindenmayer & Fischer 2006). For example, the reduction of richness and diversity of large trees affects species that depend on the habitat provided by them, such as epiphytes of the Bromeliaceae family (Oliveira *et al.* 2008; Siqueira-Filho & Tabarelli 2006).

[1] Faculdade Frassinetti do Recife, Recife, PE, Brasil. ORCID: <https://orcid.org/0000-0002-7008-2967>.
[2] Prefeitura da Cidade do Recife, Jardim Botânico do Recife, Recife, PE, Brasil.
[3] Universidade Federal Rural de Pernambuco, Prog. Pós-graduação em Biodiversidade, Recife, PE, Brasil. ORCID: <https://orcid.org/0000-0003-1472-1274>.
[4] Author for correspondence: jeffersonmaciel@recife.pe.gov.br

Many of the 3,500 species of Bromeliaceae store water in their rosettes creating habitat conditions for several biological groups (Benzing 2000; Fernandez-Barrancos *et al.* 2016; Zizka *et al.* 2019). Studies confirm that bromeliads are indispensable for restoring ecosystems, because tank-habitats of bromeliads increase richness and density of many animal groups when introduced in restored areas (Benzing 2000; Duarte & Gandolfi 2013; Fernandez-Barrancos *et al.* 2016; Melo *et al.* 2016; Rocha *et al.* 2004). Thus, tank-bromeliad species play an indispensable role in ecosystems where they occur (Cogliatti-Carvalho *et al.* 2010).

Translocation of bromeliad plants offers an opportunity to test the importance of tank-habitat for fauna in restored ecosystems. Because the terrestrial habitat is the most available in recently restored ecosystems, reintroducing bromeliad in these places also offers opportunities to understand whether bromeliad play the same ecological role in alternative habitats. Therefore, we aimed to evaluate the impact of using bromeliad in reforested ecosystems and to test whether there is difference in visiting dynamics of fauna associated with tank-habitats in typical epiphytes and alternative terrestrial habitats of a bromeliad species.

We selected a reforested area placed between two old Atlantic Forest remnants and surrounded by a densely urbanized matrix in Recife, Pernambuco, Brazil (08°04’40.9”S, 34°57’53.0”W; Fig. 1). The reforested area was a pasture field of elephant grass and brachiaria until 2010, when the Recife Environmental Office (Prefeitura da Cidade do Recife) started several programs of reforestation (Nascimento *et al.* 2017). The climate of the region is tropical rainy (AS’); the dry season is from October to December and the rainiest season is between May and July; the average annual rainfall is 1,651 mm/year and the average temperature is 25 °C (77 °F); and the soil of the region is classified as dystrophic red argisols (Nascimento *et al.* 2017).

For this study, we used plants of *Hohenbergia ramageana* Mez (Bromeliaceae: Bromelioideae), an epiphyte and terrestrial tank-bromeliad endemic to the Atlantic Forest of the states of Alagoas, Pernambuco, Paraíba and Rio Grande do Norte (Siqueira-Filho & Leme 2006). In 2015, an outbreak of dengue disease in Recife caused panic, bringing about many people to remove bromeliads from urban trees. The team of Recife Botanic Garden rescued these plants and brought them to be cultivated in the plant nursery of the institution.

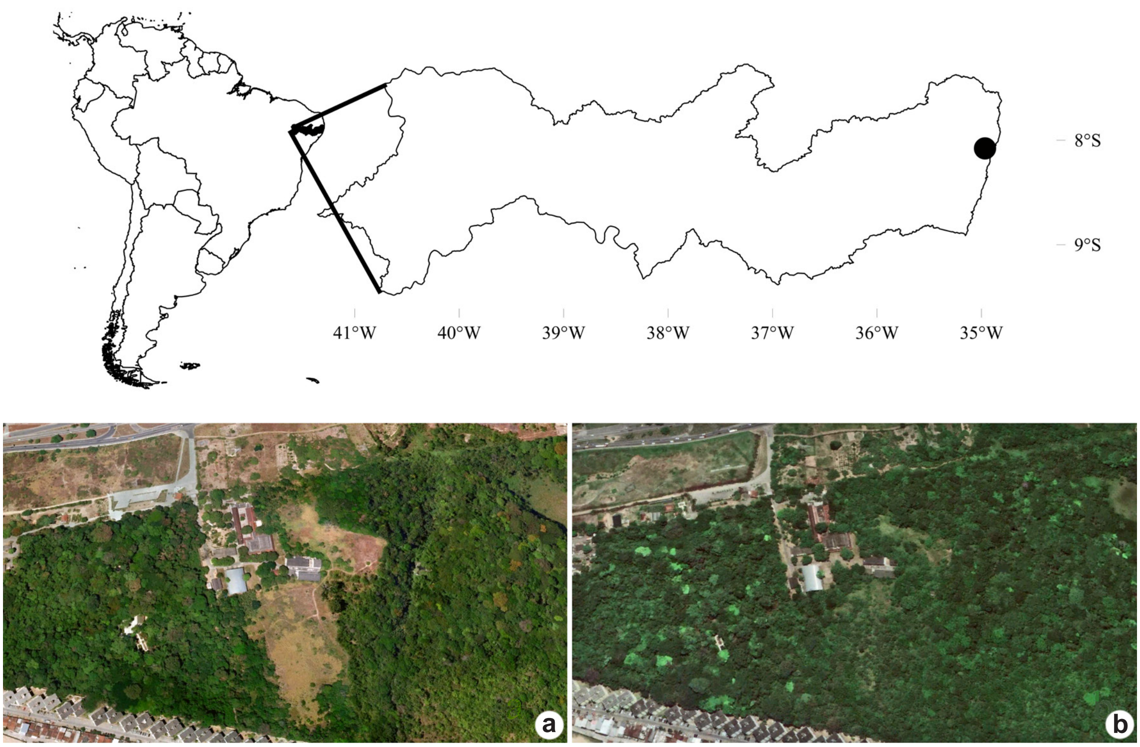

Figure 1 – a-b. Study area location and aspect of phytophysiognomy – a. before reforestation; b. after reforestation. Satellite imagery taken from Google Earth shows the area in September 2009 (a) and October 2018 (b).

All the specimens used in our study came from this rescue. Although *H. ramageana* occurs in the forest remnants adjacent to the study area, spontaneous individuals of this species have not been reported after the reforestation until our intervention. In addition, the reforestation programs in the area have used only trees, excluding other groups such as bromeliads (Nascimento *et al.* 2017).

Prior to translocation, shoots from different individuals were separated to avoid the use of clones. Before transplanting plants to the area of study, we washed the tanks of the bromeliads to remove all organisms present in them. We planted twenty adult individuals of *H. ramageana* as epiphytes (n = 10) and terrestrial (n = 10) along a transect in the reforested area in February 2017. We reintroduced plants in pairs, where epiphytes were fixed in a tree 1.7 to 2 meters above to where a terrestrial was planted. Epiphyte plants were attached to the trees with naturally worn cotton twine. We collected data on colonization of rosettes from March to October 2017. The data collection consisted in: (1) passive searching of the visiting fauna lasting ten minutes for each translocated individual; (2) active search inside the rosette for five minutes (manual scan on phytothelma) and around each individual. Observations were recorded by photograph and later identified at Order level.

We performed z-tests to evaluate differences in richness of orders of animals and in the number of visited plants between epiphytic and terrestrial translocated plants. For testing differences in taxonomic composition between epiphytic and terrestrial translocation, we run an ANOSIM test with 10,000 permutations over a Jaccard matrix of similarity. We carried out multiple Chi-squared tests to check for differences in richness and number of visited plants by month. Finally, we performed correlation analysis to evaluate the response of richness of orders and number of visited plants to precipitation. We ran all the analysis in R-Environment (R Core Team 2020).

We recorded visiting animals in almost the same number of terrestrial (9) and epiphyte (8) tank-bromeliad along the eight months ($z = -0.50$, $p = 0.61$). However, we found a significant difference between the number of visited epiphytes and terrestrial plants in September ($X^2 = 4$, df = 1, $p = 0.04$). Animals occupied epiphyte plants for more time than terrestrial plants (Fig. 2).

Eight orders of animals were found in each habitat (Figs. 2-3). In the first month, four terrestrial and three epiphyte plants were visited by three orders of animals (Fig. 2). We found no differences in richness of animal orders between epiphyte and terrestrial plants by month, according to the Chi-Squared test. Taxonomic composition of the colonization was similar between epiphytes and terrestrials, despite it varied slightly (ANOSIM: R = 0.05, $p = 0.23$). Araneae, Coleoptera, and Hymenoptera visited the bromeliads first. Araneae, Phyllodocida, Hemiptera, Hymenoptera, Lepidoptera, and Orthoptera used both epiphytes and terrestrial habitats. While Anura and Squamata appeared only in epiphyte plants, Didelphimorphia and Coleoptera visited only terrestrial plants. We recorded vertebrates from the fifth month until the end of the experiment (Fig. 2).

The number of occupied plants and the richness of animal orders increased in the wettest months and started to decrease in the beginning of the dry season (Fig. 2). We found that precipitation explained a significant proportion of variation of the number of visited plants (cor = 0.41, $p = 0.31$) and richness of animal orders (cor = -0.53, $p = 0.18$), but these correlations lack statistical support. Finally, we identified a gap in animal activities in the second month of the survey. An unidentified stochastic event might have caused this anomaly in the data.

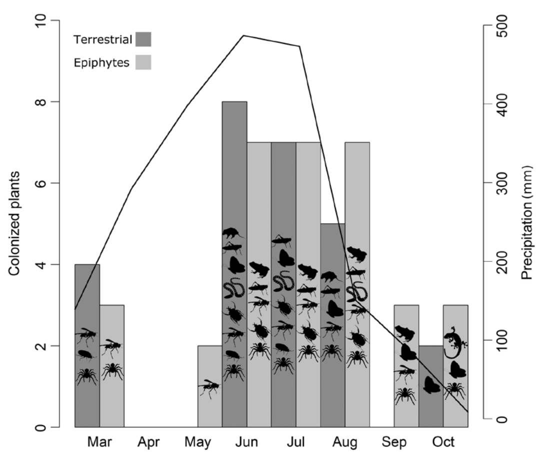

Figure 2 – Number of used plants and dynamics of fauna occupation of epiphyte and terrestrial plants after enrichment with *Hohenbergia ramageana* in a reforested area of the Atlantic Forest in Pernambuco. The line represents the monthly rainfall recorded in 2017 when the reintroduction experiment was performed. Silhouettes symbolize the orders recorded in the bromeliads in the sequence of appearance: Araneae, Coleoptera, Hymenoptera, Hemiptera, Phyllodocida, Lepidoptera, Orthoptera, Didelphimorphia, Anura and Squamata.

Our results confirm the importance of using tank-bromeliads in reforested and add proves that reintroduced bromeliads in alternative habitats also play the same role for animal colonization as in their original habitat. Fernandez-Barrancos *et al.* (2016) found that using tank-bromeliad raised richness and abundance of arthropods in a reforested ecosystem in Costa Rica. In another study, Melo *et al.* (2016) noted that translocation of bromeliads to enriching reforested ecosystems promoted local maintenance of biodiversity. Conclusions of these works reinforce our observations in translocation of *H. ramageana*. However, Fernandez-Barrancos *et al.* (2016) and Melo *et al.* (2016) deal specifically with the impact of tank-bromeliad on arthropods, while we bring a more complete view of the faunal colonization of tank-bromeliad habitats.

We add more evidence of immediate use of habitats offered by bromeliads after translocation procedure. Bromeliads provide essential resources for breeding, sheltering and feeding of several animal groups (Benzing 2000). This explains the fast exploration of tank habitats of *H. ramageana* by animals. Previous studies found a long gap between the translocation and the first observations of animal activities in tank-bromeliads (Fernandez-Barrancos *et al.* 2016; Melo *et al.* 2016), probably as an effect of the experimental design.

We observed that arthropods started the initial occupation of habitats offered by *H. ramageana*, that richness of orders increased gradually, and that vertebrates appeared when the community of invertebrates diversified. Usually, invertebrates of class Insecta predominate among the faunal community of thank-bromeliad habitat (Rocha *et al.* 2004). In our study, Didelphimorphia species used only terrestrial plants while Anura species used only epiphyte plants, following a pattern of habitat composition described in literature (Rocha *et al.* 2004).

Bromeliads are viable in reforested areas and essential for any program of ecological recovery in Atlantic Forest, as we can conclude from our results. Bromeliaceae play a role that can ease the continuous habitat loss in Atlantic Forest. This paper illustrates that restoring populations of bromeliad increases habitat in restored areas. Finally, this study adds new empirical evidence on ecological relationships of bromeliads bringing an example of the process of colonization of tank-bromeliad habitat.

Acknowledgements

We are grateful to Prefeitura da Cidade do Recife, for the fellowship of the first author. We also thank the manager staff of Jardim Botânico do Recife, for logistical support to this work.

Data availability statement

In accordance with Open Science communication practices, the authors inform that all data are available within the manuscript. Raw data for analyzes can be requested to the corresponding author.

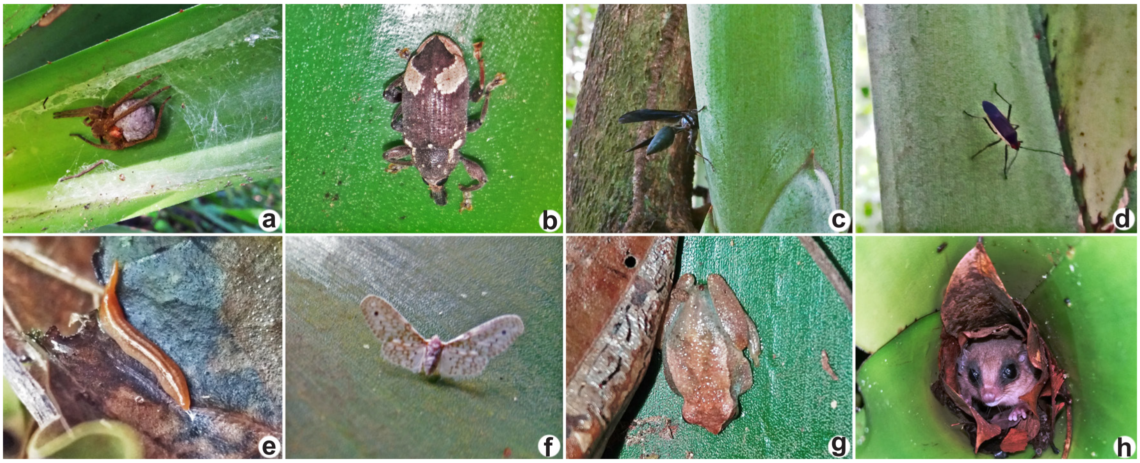

Figure 3 – a-h. Representative species of orders recorded in tank-bromeliads of *Hohenbergia ramageana* used to enrich a reforested area in Atlantic Forest – a. Araneae; b. Coleoptera; c. Hymenoptera; d. Hemiptera; e. Phyllodocida; f. Lepidoptera; g. Anura; h. Didelphimorphia.

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Area Editor: Dr. Jerônimo Sansevero
Received on December 07, 2022. Accepted on December 19, 2023.