Bromeliad translocation in Atlantic Forest fragments, Brazil

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SUMMARY

Habitat loss and fragmentation have negative impacts on the environment, reducing the habitat available to species. In order to minimize these effects we need strategies to enhance the value of refuge areas. Bromeliads are important microhabitats for many taxa during certain stages of their life cycles, and can potentially be readily transplanted. In this study we transplanted terrestrial bromeliads to test their capacity to survive the transplantation procedure over time, and assess whether they are able to maintain their arthropod communities. The experiment was performed between two Atlantic Forest fragments with bromeliads of the genus *Hohenbergia*. We transplanted 66 plants and monitored them over three years. We assessed plant survival and reproduction as measures of transplantation success, and made comparisons among arthropod communities to evaluate faunal maintenance post-transplantation. All the bromeliads survived the transplantation over the four-year study and conserved their arthropod community. Therefore we recommend this technique as a method for enhancing the value of fragmented habitats, because it both maintains the bromeliad fauna and aids conservation of endangered bromeliads species in the face of environmental change.

BACKGROUND

Over 25 years ago, a small Atlantic Forest area in the municipality of Salvador, Bahia, Brazil became fragmented. Fragmentation occurred due to several environmental impacts, including road building, establishment of a concrete factory, and development of a major port complex (Figure 1). According to Brazilian environmental agencies' laws, any development project is responsible for environmental monitoring (CONAMA 1986) and restoration (IBAMA 2011), and this should include any remaining forest fragments. However, these laws do not define which species of fauna and flora should be the focus of restoration programs in the disturbed areas (IBAMA 2011). Despite this, some restoration techniques have been applied to forest fragments. Among these efforts, Benati *et al*. (2011) evaluated the viability of reintroducing ant and spider species through the transfer of leaf-litter from a nearby remnant forest area. In another project in disturbed restinga (coastal sand dune forest) areas in Brazil, the translocation of arboreal plants was used as a technique to establish ecological corridors (Menezes *et al*. 2007). In both studies translocations worked well, and results demonstrated the potential for this technique to enhance the conservation of disturbed environments, especially in the western tropical region.

Considering these studies, we believe that bromeliads (Family Bromeliaceae) have the potential to be successfully translocated, along with the associated fauna that they support. This particular group of plants was selected due to its importance as a micro-habitat for a great number of organisms in tropical ecosystems (Stuntz *et al*. 2002, Tinoco *et al*. 2008). The family Bromeliaceae is diverse and widely distributed in Brazil and, although it is commonly found in natural and impacted environments (Forzza *et al*. 2013a), some species are threatened with extinction (Forzza *et al*. 2013b). In this study we translocated terrestrial bromeliads to evaluate their ability to survive the technique over time, and assessed whether they were able to maintain their arthropod communities.

ACTION

Study area: This work was conducted in two forest fragments located at Aratú Bay, Salvador (12º47'32"S 38º28'15"W, Figure 1). Both fragments are classified as Atlantic Rainforest and Mangrove within the Atlantic Forest biome, and occur within a priority conservation area (Heringer & Montenegro 2000). The first fragment (receptor fragment), of approximately 5 ha, is isolated and in an advanced state of degradation (Benati *et al.* 2011). The second fragment (donor fragment), of more than 80 ha, is about 1 km distant from the receptor fragment and is the nearest natural area to it. Both fragments have been monitored for the last 10 years.

Experimental design: The translocation process was conducted from September 2009 to August 2010. All translocated bromeliads were of the genus *Hohenbergia*. This genus, commonly found across several vegetation types in the northeast, southeast and south of Brazil, shows diverse life history traits (Forzza *et al*. 2013a). For transplantation, we chose terrestrial bromeliads occurring in clusters of at least five individuals at the donor fragment. We removed three similar-sized plants from each cluster, and left the remaining plants at the donor fragment to preserve the subpopulation. We chose receptor areas with similar environmental variables (light, temperature and air humidity) to the donor area; these criteria were used to reduce translocation stress for the plants and other organisms they contained (for more detail see Statistical Analysis below). Environmental variables at donor and

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Figure 1. Aerial image of the bromeliad transplantation area. Red arrow – receptor fragment; yellow arrow – donor fragment.

receptor sites were measured using a multiparameter instrument (Instrutherm Thal-300).

Two types of translocation were carried out:

- weithin fragment translocation (WFT): we located all bromeliad clusters in the receptor fragment and chose 30 individuals to be translocated. The selected plants were translocated to five sites within the receptor fragment in September 2009.
- between fragment translocation (BFT): we located nine bromeliad clusters at the donor fragment and 12 receptor sites at the receptor fragment. We translocated a total of 36 individual bromeliads, which were distributed across 12 sites within the receptor fragment. In May 2010, the first 18 plants were translocated and distributed evenly among six sites. In August 2010 the remaining 18 plants were transplanted to the remaining six sites.

To evaluate the translocated bromeliads' capacity to maintain arthropod communities, in August and October 2010 we surveyed the fauna within 24 plants that had been translocated (Table 1). Of the 24 surveyed plants, 12 were used as reference to describe the animal community originally present within bromeliads at the two sites (six from the donor fragmentand six from the WFT); we also inventoried 12 plants that had been moved as part of the BFT (six from the May translocation and six from August translocations). To control for the effect of bromeliad size on richness, abundance and diversity of resident arthropod communities (Armbruster *et al.* 2002, Araújo *et al.* 2007), we inventoried only similar-sized bromeliads. The plants were also monitored at six month intervals to assess survivorship and vegetative reproduction.

Bromeliad translocation and transportation: All the translocated bromeliads were terrestrial, and grew in soil. We removed all the bromeliads by uprooting them using gardening equipment, taking care to minimize translocation of the soil they were growing in. Plants were packed in plastic bags to prevent arthropods from escaping, and transported manually to areas for re-planting in soil of the forest floor within a three hour period. In the receptor areas we arranged bromeliads in clusters of three, without any treatment to facilitate survivorship (e.g. addition of fertilizer, irrigation).

Bromeliads size and arthropod inventory: For each inventoried bromeliad (WFT, BFT1 and BFT2, Table 1) we measured the width of the central reservoir and recorded the number of leaves. To assess the arthropod community within the bromeliads, we submerged each bromeliad in water and collected any arthropods that emerged. We then removed and washed each leaf in a white plastic tray containing water and collected any remaining arthropods. The resulting arthropods were counted and identified to order level.

Statistical analysis: To evaluate similarities between the receptor and donor areas, environmental matrices (three variables: light, temperature and air humidity) of the recipient and donor fragments were analyzed using hierarchical cluster analysis, with Euclidean distance used for environmental data, and Ward´s linkage method (PcOrd©: McCune & Mefford 2011). The Euclidean distance is the recommended measure for continuous data, and we therefore applied it to the environmental measures. This hierarchical cluster analysis method was applied for both treatments (WFT and BFT). From these data, we created a similarity cluster, and identified receptor areas for translocation that were environmentally similar to donor locations.

Bromeliad reservoir size and number of leaves were compared between treatments (WFT, BFT1 and BFT2) with a multi-response permutation procedure using the Euclidean

Table 1. Description of bromeliads used to survey arthropods during the transplant evaluation period.

Origin of bromeliad	Transplant date	Inventory date	Individuals inventoried
Baseline sampling in Donor Fragment	--	August 2010	6
Within fragment translocation (WFT)	September 2009	October 2010	6
Between fragment translocation (BFT1)	May 2010	October 2010	6
Between fragment translocation (BFT2)	August 2010	October 2010	6

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distance (Pythagorean). We also ran a multi-response permutation procedure using presence-absence data to reveal differences between bromeliads in arthropod communities using the Sorensen distance (Bray-Curtis) usually applied for community data, and in larvae abundances using Euclidean distance (Pythagorean). We used the Sorensen distance in our analysis of arthropods because tropical arthropod communities can be highly variable in their abundance distribution - that is some groups tend to present very non-discrete abundance distribution (e.g. termites or ants) whereas other tend to show very discrete abundance distributions, such as beetles or spiders (Schowalter 2011). This multi-response permutation procedure approach takes into account the fact that sample units are ecologically independent, but does not assume normality and homoscedasticity of samples (McCune & Grace 2002). This approach generates, besides the p value, T and A statistics. The T values describes the segregation among groups; high negative values ($\leq$ -3) indicate stronger segregation. The A values describes intra-group homogeneity, with acceptable values being $\geq$ 0.3 (McCune & Grace 2002).

CONSEQUENCES

In April 2014, four years after the translocation, all 66 transplanted bromeliads (30 from WFT, and 36 from BFT) were still alive. In addition 67 new bromeliads had been added to the receptor fragment by vegetative reproduction. We found no significant differences in size between bromeliads from WFT, BFT1 and BFT2 treatments ($p = 0.12$, $A = 0.051$, $T = -1.19$).

From a total sample of 24 inventoried bromeliads, we identified 2909 arthropods, comprising 1854 adults and 1055 larvae (Table 2, Figure 2). The most abundant orders were ants, bees, wasps and sawflies (Hymenoptera, n = 1056, 36.3%), cockroaches (Blattodea, n = 244, 8.38%), pillbugs, slaters and woodlice (Isopoda, n = 160, 5.50%), termites (Isoptera, n = 158, 5.43%) and spiders (Araneae, n = 123, 4.22%). No difference was found between the arthropod communities sampled from WFT, BFT1, BFT2 and donor fragment ($p = 0.10$, $A = 0.035$, $T = -1.29$). We found high arthropod larvae abundance within bromeliads, with no statistical difference between bromeliads from donor fragment, WFT, BFT1 and BFT2 ($p = 0.20$, $A = 0.053$, $T = -0.76$). This result shows that translocated bromeliads (WFT, BFT1 and BFT2) remain important as reproductive areas.

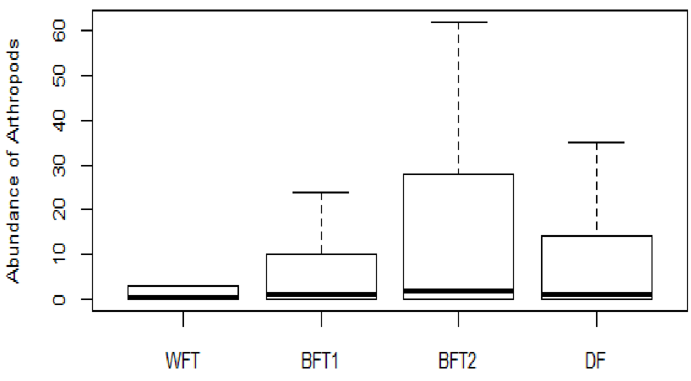

Figure 2. Variance in arthropod abundance under different treatments. WFT = within fragment translocation; BFT1 = between fragment translocation (May 2010); BFT2 = between fragment translocation (August 2010); DF = donor fragment.

Table 2. Number of arthropods sampled in baseline and post-transplantation bromeliads inventoried in August and October 2010. WFT = within fragment translocation; BFT1 = between fragment translocation (May 2010); BFT2 = between fragment translocation (August 2010); DF = donor fragment. Six bromeliad plants were present in each sample.

Taxon	WFT	BFT1	BFT2	DF	Total
Arachnida					
Acarina	0	0	1	2	3
Araneae	50	24	35	14	123
Opiliones	0	10	28	0	38
Pseudoscorpiones	0	1	3	0	4
Crustacea					
Isopoda	88	10	62	0	160
Hexapoda					
Blattodea	144	48	17	35	244
Coleoptera	2	2	1	0	5
Collembola	3	0	0	4	7
Dermaptera	1	0	0	0	1
Diptera	0	0	1	2	3
Hemiptera	0	4	4	24	32
Homoptera	1	1	0	1	3
Hymenoptera	527	234	234	61	1056
Isoptera	3	0	124	31	158
Lepidoptera	0	0	0	1	1
Orthoptera	0	1	0	0	1
Psocoptera	0	0	1	0	1
Thysanura	0	1	0	0	1
Trichoptera	0	1	0	0	1
Myriapoda					
Chilopoda	1	3	3	1	8
Diplopoda	0	0	4	0	4
Larva	391	161	128	375	1055
Total	**1211**	**501**	**646**	**551**	**2909**

DISCUSSION

The high survival rate of bromeliads observed after translocation indicates that this is a potentially valuable technique for boosting bromeliad numbers in modified environments and fragmented areas. In the Atlantic Forest, bromeliads are one of the most important plant groups for conservation, due to their high levels of endemism (Martinelli *et al.* 2008). Our work highlights the potential value of translocation to safer locations when natural environments are being disturbed by human activities.

In Brazil the family Bromeliaceae is largely used for gardening and has potential economic value; therefore, collection, transport and sale is regulated (IBAMA 1985). In addition, 202 species of bromeliads are listed as being under some level of extinction threat (Forzza *et al.* 2013b). Therefore, we emphasize the importance of translocation as an aspect of bromeliad conservation, particularly of endemic and threatened species, such as *Hohenbergia littoralis* (Forzza *et al.* 2013b).

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A remarkable aspect of bromeliad biology is that their rosette-shaped structure is used as a shelter and micro-habitat by many organisms at different stages of their life cycle (Mestre *et al*. 2001, Stuntz *et al*. 2002, Gasca & Higuera 2008, Martinelli *et al*. 2008, Schuttz *et al*. 2012). Bromeliads are thus important environmental resources and habitats, and their translocation could increase the availability of resources and habitats at the receptor sites, potentially enhancing survival chances for several species in human modified habitats.

Among the variety of species sheltered by bromeliads, we emphasize bromelicolous organisms (Schuttz *et al*. 2012), that are dependent on bromeliads in at least one stage of their life-history. These organisms are easily transported within bromeliads, and therefore can be introduced to areas with declining populations through bromeliad transplant (Griffith *et al*. 1989). Amphibians, for example *Aparasphenodon brunoi*, *Frostius pernambucensis*, *Xenohyla truncate* and species of the genus *Phyllodytes* and *Scinax* (Tinoco *et al*. 2008, IUCN 2013), are among bromelicolous biota threatened by habitat loss. In Brazil, the list of species that use bromeliads as a habitat or a resource and so are threatened by their loss, includes a damselfly (*Leptagrion acutum*), a frog (*Scinax Alcatraz*), the slender antbird *Rhopornis ardesiacus* and the golden-headed lion tamarin *Leontopithecus chrysomelas* (Machado *et al*. 2008). In consequence, bromeliad translocations can aid conservation of a range of vulnerable species via habitat and resource maintenance.

Concern about bromeliads should involve not only economic issues, as they enter into the horticultural and illegal wildlife trades (IBAMA 1985), but also their ecological importance as habitats associated organisms, such as invertebrates and frogs. At present, only fauna is rescued and translocated as part of environmental mitigation practices at development sites (IBAMA 2007). Clearly the protection of forest areas of importance for bromeliads should be the priority for their conservation, but where this is not possible we argue that bromeliad translocation should also be considered as an approach to preserve these plants. This will not only aid bromeliad conservation, but also conservation of the diverse animal fauna associated with bromeliads.

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