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ARTICLE

Richness of gall morphospecies along a secondary successional gradient of Atlantic Forest in northeastern Brazil

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ABSTRACT: (Richness of gall morphospecies along a secondary successional gradient of Atlantic Forest in northeastern Brazil). Galling insects have been recommended as an excellent tool to evaluate environmental changes and habitat quality. In this study, we assessed the richness of gall morphospecies, as well as host-plant richness and abundance, to detect environmental changes in six patches of secondary Atlantic Forest in Northeast Brazil. The patches of forest varied in age (between 25 and 42 yrs) and size. In each patch, the plants between 1 and 3 meters tall were evaluated for a period of one hour, totaling six hours. A total of 50 gall morphospecies were found on 37 host-plant species (88 plant individuals). We identified 27 (72%) host-plant species belonging to 19 plant families. Richness of gall morphospecies and host-plant richness and abundance were not significantly affected by the age and size of the patch. However, the richness of gall morphospecies increased significantly as the host-plant percentage of shade-tolerant trees increased. Considering that the differences observed in this study, between younger and older patches, developed in a relatively short time period of forest recovery (*c*. 18 yrs), and that some host-plant species occurred exclusively in older patches, this study showed that gall-inducing insects are a good tool for evaluating changes in a secondary successional gradient. The use of gall-inducing insects as bioindicators in restoration and conservation programs is not only a good opportunity to advance this type of study but is also a useful application, at local and regional scales, to monitor the successional progress of forests.
Key words: gall insects, bioindicators, restoration and conservation programs.

RESUMO: (Riqueza de morfoespécies de galhas ao longo de um gradiente sucessional em trechos de floresta Atlântica secundária no nordeste do Brasil). Insetos galhadores têm sido indicados como uma excelente ferramenta para avaliar as mudanças ambientais e a qualidade do habitat. Neste estudo, a riqueza de morfoespécies de galhas como também a riqueza e abundância de plantas hospedeiras foram avaliadas para detectar possíveis mudanças ambientas em seis trechos de floresta secundária em um remanescente de Floresta Atlântica localizado no nordeste do Brasil. Os trechos apresentaram diferentes tamanhos e idades de regeneração (entre 25 e 42 anos). Em cada trecho, as plantas entre 1-3 metros de altura foram inspecionadas durante uma hora, totalizando seis horas. Um total de 50 morfoespécies foi encontrado em 37 plantas hospedeiras (88 indivíduos). Foram identificadas 27 (72%) plantas distribuídas em 19 famílias. A riqueza de morfoespécies e a riqueza e abundância de plantas hospedeiras não foram afetadas com a idade de regeneração ou pelo tamanho do trecho. Porém, a riqueza de morfoespécies aumentou significantemente aumentando a porcentagem de plantas hospedeiras tolerantes à sombra. Considerando que nossos resultados foram observados em um curto intervalo sucessional (*ca*. 18 anos), e que algumas das plantas hospedeiras ocorreram exclusivamente em trechos mais avançados, é possível indicar os insetos galhadores como uma eficiente ferramenta de biomonitoramento. O uso destes insetos como bioindicadores em programas de restauração e conservação não é apenas uma boa oportunidade para avançar os estudos e tornar sua aplicação viável em uma escala local e regional, mas também decisivo no monitoramento do progresso sucessional.
Palavras-chave: Insetos galhadores, bioindicadores, programas de restauração e conservação.

INTRODUCTION

Galling insects have been suggested as an excellent tool to evaluate habitat quality and the restoration process of degraded or regenerating forests (Julião *et al*. 2005, Moreira *et al*. 2007). Three advantages of using galling insects as bioindicators are: (1) each galling insect is species-specific, (2) the galls are commonly conspicuous on the plant and are morphologically diverse (*e.g.*, conical, discoid, globoid), and (3) most galls persist on plant parts even after the insect emerges or dies (Rohfritsch & Shorthouse 1982, Rohfritsch 1992, Price *et al*. 1998, see also Ribeiro *et al*. 1999). Due to the extreme specificity with their host plants, it is thought that changes in plant communities (*i.e.*, species richness, abundance and compositional changes of plants) after disturbances, such as the clearing of original forest or selective logging, will promote changes in galling insect communities, which successively occupy and replace each other over a period of time.

For example, due to the increased percentage of pioneer plants in degraded forests and secondary forests (*e.g.*, Tabarelli *et al*. 1999, Oliveira *et al*. 2004, Laurance *et al*. 2006), a large change in spatial distribution and species

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composition of gall insects is expected (see Moreira *et al.* 2007). In general, pioneer species are more palatable and have fewer chemical and physical defenses compared to shade-tolerant species (Coley 1983, Coley *et al.* 1985), and the survival of gall-inducing insect populations can be higher when host-plant species have high amounts of chemical defenses (*e.g.*, Taper & Case 1987, Fernandes & Price 1988). The primary ecological role of the gall is to protect the immature insect from attacks by pathogens, predators and parasitoids (Price *et al.* 1986). Thus, plants with high concentrations of tannins, for example, may provide an effective defense against pathogens and parasites because the tannins act as a chemical barrier (see Cornell 1983). It is reasonable to expect a higher gall-inducing insect richness in areas presenting more unpalatable plants. For example, we should expect a higher richness of gall-inducing insects in (1) primary forests when compared to degraded and secondary forests and (2) in the interior of a forest when compared to the edge of a forest.

The aim of this study was to evaluate the richness of gall-inducing insects and host-plant species along a secondary successional gradient located in a single remnant of Atlantic Forest. In this scenario, we tested the "plant species richness hypothesis" (Southwood 1960, Murdoch *et al.* 1972, Lawton & Shröder 1977, Southwood *et al.* 1979) where a positive correlation is expected between gall-inducing insect species and plant species richness. We believed that the richness of gall-morphospecies increased as the age of the successional patch increased. Based on the species-area relationship (MacArthur & Wilson 1967, Simberloff 1976), we also expected that the gall morphospecies would increase as patch size increased, independently of habitat heterogeneity. We also considered the host-plant percentage of shade--tolerant trees as an explanatory variable, expecting that it would show a positive correlation with gall-inducing insect richness. Further, host-plant abundance was also investigated. We suspected that the host-plant abundance would increase as patch age and patch size increased.

MATERIALS AND METHODS

This study was conducted at a 3500-ha remnant of Atlantic Forest that is locally known as Coimbra, which belongs to a private sugarcane company (Usina Serra Grande) and is located in the municipality of Ibateguara, in the state of Alagoas, in Northeast Brazil (8º30'S, 35º50'W, Fig. 1). This remnant is an excellent site to evaluate biotic changes in a successional gradient (5-65 yrs old) within different stands of secondary growth created by the clearing of the original forest (ca. 90%) and abandonment after 5-10 yrs of subsistence agriculture (corn, cassava, beans). When considering the abundance and richness of pioneer and shade-tolerant species that occur in the different patches there is a remarkable difference in floristic composition (Almeida-Santos *et al.* 2007). For example, according to Almeida-Santos *et al.* (2007), who evaluated some functional attributes (*e.g.*, tree species richness, percentage of pioneer species, emergent species, large-seeded species) on tree assemblages, the number of species, and percentage of large-seeded and emergent species had a positive relationship with recovery time (years of regeneration) of the secondary forest patches, while the percentage of pioneer species decreased as the age of the secondary forest patch increased. Further, these patches also varied in size.

To characterize the species richness and abundance of gall-inducing insects along a secondary successional gradient, we selected six secondary forest patches that were 25 to 42 yrs old. Furthermore, the forest patches presented different sizes and were more than 500m away from each other. In each patch, we developed a 60min census by examining all plants, between 1 and 3 meters tall, for gall-inducing insects (see Price *et al.* 1998). The host plants were packed in plastic bags for subsequent identification and description of the external morphology of the galls. Host plants were identified based on the Angiosperm Phylogeny Group II system (APG II). Further, the functional groups (*i.e.*, pioneers or shade--tolerant) of the host-plants were determined, which was based on Almeida-Santos (2005) and Grillo (2005). We also considered that the structural attributes (external morphology) of galls are different, which were used to describe the morphospecies, and have also been used frequently as species indicators of gall-inducing insects (see Price *et al.* 1998, Moreira *et al.* 2007). The structural attributes were classified according to McGrady-Steed *et al.* (1997) by considering the (1) shape (e.g., discoid, cylindrical, conical, spherical, oval, elliptical, triangular or non-regular); (2) pubescence (pilose or glabrous); (3) color; (4) gall location on the leaves (basal, medial, apical, adaxial, abaxial, petiole, limbo, margin, midvein, secondary veins); (5) gall distribution on the leaves (grouped or solitary); and (6) the presence (closed gall) or absence (opened) of gall insect larvae.

The effects of explanatory variables (*i.e.*, patch age, patch size, and the host-plant percentage of shade-tolerant trees) on gall-morphospecies richness and host-plant richness and abundance (except for host-plant percentage of shade-tolerant trees) were tested using a multiple linear regression. In addition, the effect of patch age and size on the host-plant percentage of shade-tolerant trees was also investigated using a multiple linear regression. The best subset of predictor variables was selected using stepwise regression, which is a statistical method for model building (Sokal & Rohlf 1995). The subset of variables indicated was based on the backward selection process in stepwise procedure. The best model requires a minimum number of predictor variables considering a significant p and the lowest Akaike information criterion (AIC) (Sokal & Rohlf 1995, Burnham & Anderson 2002). The AIC is an estimate of the mean log-likelihood (Akaike 1974). Three subset models for morphospecies richness and two models for each variable were generated. The analyses were based on Sokal & Rohlf (1995) and performed using

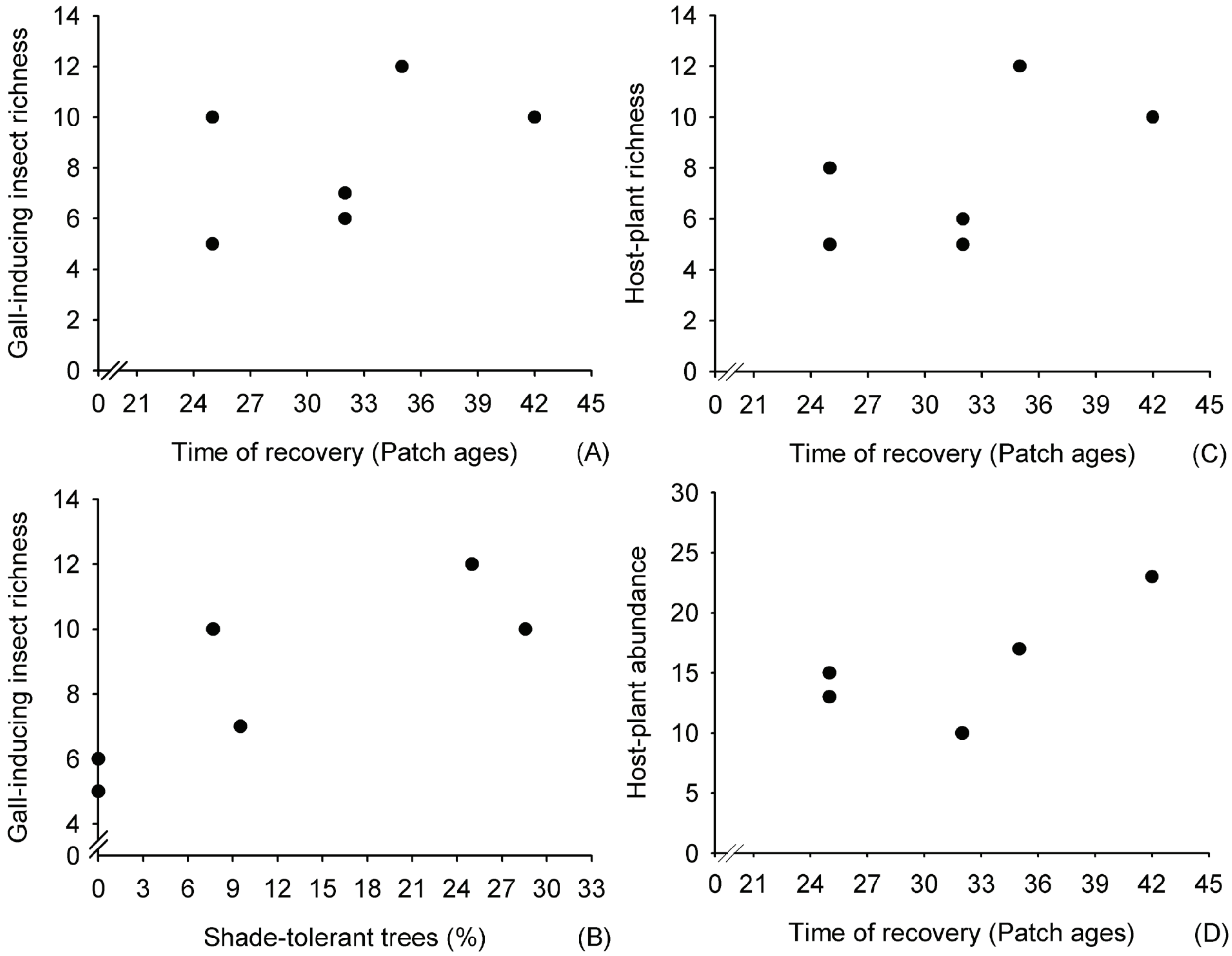

Figure 1. Relationship between **(A)** richness of gall morphospecies and time of recovery (yrs); **(B)** richness of gall morphospecies and the host-plant percentage of shade-tolerant individuals; and, **(C)** host-plant richness and **(D)** host-plant abundance and time of recovery (yrs) in six secondary growth patches within the Coimbra forest in Serra Grande, Brazil.

the software PAST (Hammer *et al.* 2001). The normality of samples was tested using a posteriori Lilliefors tests.

RESULTS

A total of 50 gall morphospecies (GMs) were found on 37 host-plant species (88 plant individuals). Gall morphospecies and host-plant richness were not significantly affected by patch age and did not increase as the patch size became larger (models 1, 2 and 3 to GMs richness and models 4 and 5 to host-plant richness; Tab. 1; Fig. 1A and 1C). However, gall-morphospecies richness increased significantly as the host-plant percentage of shade-tolerant trees increased (model 3, Tab. 1; Fig. 1B). In fact, when considering not only the AIC but also the number of variables and the significance (p) of the whole model, model 3 was the best model that explained the variation in richness of gall morphospecies. The percentage of shade-tolerant trees explained 60% of the variation in richness of gall morphospecies. With regard to host-plant richness, models 5 and 6 showed a reduction of AIC as the number of explanatory variables declined, but no specific model was indicated as the best model with a significant *P*. Host-plant abundance did not vary with patch age and patch size (models 6 and 7; Tab. 1; Fig. 1D).

Among the 37 host-plant species found, only 27 (72%) belonging to 19 families were identified (Tab. 2). Of these, 22 (77%) host-plant species were assigned to a functional group; 16 (70%) were pioneer species and 6 (30%) were shade-tolerant species. Only one host-plant individual of a shade-tolerant species (*Coccoloba cf. ochleorata* Wedd.; Polygonaceae) was found on the edge of a patch, which was 25 yrs old. The others were found in the interiors of patches that were more than 32 yrs old. In this scenario, considering the host-plant species, the percentage of shade-tolerant trees increased significantly as the regeneration age increased (models 8 and 9; Tab. 1) and was about four times as much in the patches that were 32–42 yrs old (16.32%) when compared to patches that were 25 yrs old (4.16%).

Fifty-three morphotypes of galls were associated with leaves of 19 host-plant families. Galls were characterized by their coloration, how they were grouped, if they were glabrous and by their amorphous, spherical and cylindrical shapes.

The two most important families (when considering the number of gall-morphospecies per plant family) were

Table 1. The effects of explanatory variables (*i.e.*, patch ages, patch size, and the host-plant percentage of shade-tolerant trees) observed in secondary growth forests with different regeneration ages (patch age), of an Atlantic Forest remnant in Northeast Brazil, on the richness of gall morphospecies, and host-plant richness and abundance, based on a multiple linear regression. The best subset of predictor variables was selected using stepwise regression and Akaike information criterion (AIC).

Models	*Response Variables*	*Explanatory variables (P values)*			*Whole model*	R^2	AIC
		Patch ages	Patch size	(ST) Shade-tolerant trees (%)			
1	GMs richness	0.240	0.485	0.088	0.187	0.67	**6.70**
2	GMs richness	0.222	-	0.047*	0.073	0.70	**6.55**
3	GMs richness	-	-	0.041*	0.041*	0.60	**8.03**
4	HP richness	0.329	0.733	-	0.518	-0.07	**14.95**
5	HP richness	0.238	-	-	0.238	0.15	**13.22**
6	HP abundance	0.254	0.919	-	0.466	-0.002	**20.99**
7	HP abundance	0.180	-	-	0.180	0.24	**19.01**
8	ST trees (%)	0.087	0.431	-	0.14	0.54	**31.04**
9	ST trees (%)	0.052*	-	-	0.052*	0.56	**26.79**

Melastomataceae (12) and Piperaceae (3). The most important plant family considering the number of host-plant species per family was Melastomataceae (10) followed by Piperaceae (3). The other families had just one host-plant species each. Considering the total abundance of host plants, Melastomataceae (38), Boraginaceae (6) and Piperaceae (6) were the three most important, which together accounted to 56.81% (50) of the plant individuals (88) sampled. Further, the Melastomataceae accounted to 57.14% (16) of 28 host-plant individuals sampled along the edges of patches and 36.66% (22) of 60 individuals sampled in the interiors of patches.

Miconia prasina (Melastomataceae) was the host plant that had the highest number of individuals with galls (21), followed by *Cordia nodosa* (6) (Boraginaceae), *Miconia* sp. 1 (Melastomataceae) and *Trichilia lepidota* (Meliaceae) with five individuals each. Some gall morphospecies were exclusive to a given patch. For example, the gall morphospecies found in *Himathanthus bracteatus* (Apocynaceae), *Eriotheca crenulaticalyx* (Malvaceae), *Eschweilera ovata* (Lecythidaceae), *Piper* sp.1 (Piperaceae) only occurred in the patch that was 42 yrs old, and others such as *Virola gardneri* (Myristicaceae), *Casearia javitensis* (Salicaceae), *Eriotheca crenulaticalyx* (Malvaceae), *Eschweilera ovata* (Lecythidaceae), *Henriettea succosa* (Melastomataceae) were restricted to the interiors of patches.

DISCUSSION

Based on the plant species richness hypothesis (Southwood 1960, Murdoch *et al.* 1972, Lawton & Shröder 1977, Southwood *et al.* 1979), we expected that the richness of gall morphospecies would increase relative to recovery time (patch age) due the presence of new plant species in patches that were at a more advanced successional stage (*i.e*, in patches between 32–42 yrs old). As argued by Blanche & Ludwig (2001), the chance that a gall-inducing insect will find its specific host-plant species increases as the number of plant species increases. High plant species richness represents more niches to be explored and used by galls insects (see also Gonçalves-Alvim & Fernandes 2001 and Mendonça 2001). In fact, the plant species richness hypothesis has been corroborated by others studies (Wright & Samways 1996, 1998, Blanche & Ludwig 2001, Proches & Cowling 2006), but in this study no significant variation was found based on patch age.

In addition, no relationship was observed between morphospecies richness of galls and patch size. We expected an increase in the morphospecies richness as the patch size increased, considering the species-area relationship (MacArthur & Wilson 1967, Simberloff 1976), independent of habitat heterogeneity caused by patch location and/or patch age. Comparable results were obtained in another study developed in the Pantanal floodplain in Brazil, a region predominately dominated by savanna (Julião *et al.* 2004). This study showed a difference in gall-inducing insect species composition between edge and interior habitats, but the richness of species did not vary. Further, the number of gall species and host plant species was not influenced by patch area (but see MacGarvin 1982).

However, we found a consistent effect when considering the host-plant percentage of shade-tolerant trees as an explanatory variable. The gall-morphospecies richness increased as the percentage of shade-tolerant trees increased, which partially supports the plant species richness hypothesis. This indirectly indicates that older patches (32–42 yrs old) have a more structured forest with a higher diversity of plant species, including shade-tolerant species, relative to younger patches (25 yrs old), which was demonstrated by Almeida-Santos *et al.* (2007). Further, all plant individuals of shade-tolerant species in this study (n = 6) were found in the interior of patches over 32 yrs old, with the exception of *Coccoloba cf. ochleorata* Wedd. Consequently, the host-plant percentage of shade-tolerant trees was about four times as much in the 32–42 yr old patches when compared to the 25 yr old patches. Considering that we found a direct and positive link between gall-morphospecies richness and the percentage of shade-tolerant trees, in a relatively short time period of forest recovery (*c.* 18 yrs old), we suggest that the plant species richness and composition (when shade-tolerant species are included) should be not discarded as a variable that explains gall species richness patterns (see Mendonça 2001).

With regard to host-plant richness and abundance, an

Table 2. Host-plant species and their associated gall morphospecies from secondary growth forests of different regeneration ages (patch age) in an Atlantic Forest remnant, in Northeast Brazil.

Family	Host-plant species	Nº. of Plant individuals	Patch ages	Host Functional Grouped	Gall-morpho species Colors	Gall-morpho species Shape	Presence or absence of gall maker	Galls location on the leaf surface	Spatial Distribution on leaf*	Pubescence	Group
Anacardiaceae	Unknow	1	35	-	Brown	Discoid	Opened	Both	Leaf	Glabrous	Solitary
Apocynaceae	*Himatanthus bracteatus* (A.DC.) Woodson	2	42	Pioneer	Green	Discoid	Closed	Both	Leaf	Glabrous	Solitary
Bignoniaceae	*Tabebuia* sp.	3	35	Pioneer	Green	Discoid	Closed	Both	Leaf	Hairy	Solitary
Boraginaceae	*Cordia nodosa* Lam.	4	25	Pioneer	Brown	Amorphous	Opened	Both	Vein	Hairy	Grouped
		2	35	Pioneer	Brown	Amorphous	Opened	Both	Vein	Hairy	Grouped
Clusiaceae	*Tovomita mangle* G. Mariz	1	35	Shade-tolerant	Green	Amorphous	Opened	Both	Vein	Hairy	Grouped
Lecythidaceae	*Eschweilera ovata* (Cambess.) Miers	1	42	Shade-tolerant	Brown	Discoid	Opened	Both	Leaf	Hairy	Solitary
Malphighiaceae	*Byrsonima stipulacea* Juss.	1	25	Pioneer	Brown	Amorphous	Opened	Abaxial	Vein	Glabrous	Solitary
Malvaceae	*Eriotheca crenulaticalyx* A.Robyns	1	42	Pioneer	Green	Discoid	Closed	Both	Leaf	Glabrous	Solitary
Melastomataceae	*Clidemia* sp.	1	25	Pioneer	Green	Cylindrical	Closed	Abaxial	Leaf	Hairy	Solitary
	Henriettea succosa (Aubl.) A.DC.	1	32	Pioneer	Green	Spherical	Closed	Both	Leaf	Glabrous	Grouped
		1	32	Pioneer	Green	Rosette	Closed	Adaxial	Leaf	Glabrous	Solitary
	Miconia compressa (Naud.) Naudin	1	32	Pioneer	Green	Cylindrical	Closed	Abaxial	Leaf	Glabrous	Solitary
		1	32	Pioneer	Green	Rosette	Opened	Adaxial	Vein	Glabrous	Solitary
	Miconia prasina (SW) DC.	1	25	Pioneer	Green	Cylindrical	Closed	Both	Leaf	Hairy	Solitary
		2	25	Pioneer	Green	Rosette	Closed	Both	Leaf	Glabrous	Solitary
		3	25	Pioneer	Green	Amorphous	Closed	Both	Leaf	Glabrous	Solitary
		3	32	Pioneer	Green	Cylindrical	Closed	Both	Leaf	Hairy	Solitary
		12	42	Pioneer	Green	Cylindrical	Closed	Both	Leaf	Glabrous	Grouped
	Miconia sp. 1	5	25	Pioneer	Green	Cylindrical	Closed	Both	Leaf	Glabrous	Solitary
	Miconia sp. 2	2	25	Pioneer	Green	Rosette	Closed	Adaxial	Leaf	Glabrous	Solitary
	Miconia sp. 3	1	35	Pioneer	Brown	Amorphous	Opened	Both	Leaf	Glabrous	Grouped
	Miconia sp. 4	2	42	Pioneer	Green	Rosette	Opened	Adaxial	Leaf	Glabrous	Solitary
	Sp. 1	1	25	Pioneer	Green	Cylindrical	Closed	Abaxial	Leaf	Glabrous	Solitary
	Sp. 2	1	25	Pioneer	Green	Cylindrical	Closed	Abaxial	Leaf	Glabrous	Solitary

Table 2. Cont.

Family	Host-plant species	Nº. of Plant individuals	Patch ages	Host Functional Grouped	Gall-morpho species Colors	Gall-morpho species Shape	Presence or absence of gall maker	Galls location on the leaf surface	Spatial Distribution on leaf*	Pubescence	Group
Meliaceae	*Trichilia lepidota* Mart.	3	25	Pioneer	Green	Globoid	Closed	Both	Leaf	Glabrous	Solitary
		1	35	Pioneer	Brown	Amorphous	Closed	Both	Leaf	Glabrous	Solitary
		1	42	Pioneer	Green	Discoid	Closed	Both	Leaf	Glabrous	Solitary
Siparunaceae	*Siparuna guianensis* Aubl.	2	35	Shade-tolerant	Brown	Discoid	Opened	Both	Leaf	Glabrous	Grouped
Myristicaceae	*Virola gardneri* (A. DC.) Warb.	1	35	Shade-tolerant	Brown	Discoid	Opened	Both	Leaf	Glabrous	Grouped
Myrtaceae	*Myrcia splendens* (Sw.) DC.	1	35	Pioneer	Brown	Cylindrical	Opened	Abaxial	Leaf	Glabrous	Solitary
Piperaceae	*Piper* sp. 1	1	42	Pioneer	Green	Discoid	Closed	Both	Leaf	Glabrous	Grouped
	Piper sp. 2	1	25	Pioneer	Green	Discoid	Closed	Both	Leaf	Glabrous	Grouped
	Piper sp. 3	4	32	Pioneer	Green	Spherical	Closed	Both	Leaf	Glabrous	Grouped
Polygonaceae	*Coccoloba cf. ochleorata* Wedd.	1	25	Shade-tolerant	Brown	Globoid	Opened	Both	Vein	Glabrous	Grouped
		1	32	Shade-tolerant	Brown	Discoid	Opened	Both	Vein	Glabrous	Grouped
		1	42	Shade-tolerant	Brown	Globoid	Opened	Both	Vein	Glabrous	Grouped
Rubiaceae	*Palicourea crocea* (Sw.) Roem. & Schult.	1	32	Pioneer	Green	Cylindrical	Closed	Abaxial	Leaf	Glabrous	Solitary
Salicaceae	*Casearia javitensis* Kunth	1	32	Pioneer	Green	Amorphous	Closed	Both	Vein	Glabrous	Solitary
		2	35	Pioneer	Green	Amorphous	Closed	Both	Leaf	Glabrous	Solitary
Sapindaceae	*Paullinia trigonia* Vell.	1	35	-	Brown	Discoid	Closed	Abaxial	Leaf	Glabrous	Solitary
		1	42	-	Brown	Discoid	Closed	Abaxial	Leaf	Glabrous	Solitary
Sapotaceae	*Pouteria* sp.	1	32	Shade-tolerant	Green	Discoid	Closed	Both	Leaf	Glabrous	Grouped
Unknow	Unknow 1	1	25	-	Brown	Cylindrical	Opened	Both	Leaf	Glabrous	Solitary
Unknow	Unknow 2	1	25	-	Brown	Cylindrical	Closed	Both	Leaf	Glabrous	Solitary
Unknow	Unknow 3	3	32	-	Green	Conical	Closed	Both	Leaf	Glabrous	Solitary
Unknow	Unknow 4	1	32	-	Brown	Cylindrical	Opened	Both	Leaf	Glabrous	Grouped
Unknow	Unknow 5	1	32	-	Brown	Discoid	Opened	Abaxial	Leaf	Glabrous	Grouped
Unknow	Unknow 6	1	35	-	Brown	Discoid	Opened	Abaxial	Leaf	Glabrous	Solitary
Unknow	Unknow 7	1	42	-	Brown	Discoid	Opened	Abaxial	Leaf	Glabrous	Solitary

*Leaf means Leaf blade and Vein means Main Vein.

increase in patch age and patch size was not significant. Initially, we expected higher host-plant richness and abundance in older patches (relative to younger patches) and with an increase in patch size (considering the species-area relationship; MacArthur & Wilson 1967, Simberloff 1976). Older patches and larger patches could accumulate more species of plants and consequently host-plant species and individuals. However, we suppose that the location of a patch can have a strong effect on host-plant richness and abundance.

In this study, two patches that were 25 yrs old were located in edge habitats of Coimbra. Together they accounted for 13 host-plant species (36.11% of the total – 37 host-plant species) in comparison to the 28 host-plant species (77.77%) from the four patches located within the interior of the Coimbra forest. Compared to interior habitats, plants in edge habitats are physiologically more stressed due to the elevated air temperature, reduced humidity and high penetration of photosynthetically active radiation (PAR) (see also Kapos 1989, Kapos *et al.* 1993). This unquestionably can influence the survival and population size of gall insects, which are well adapted to living in stressful environments (see Fernandes & Price 1988, Blanche & Westoby 1995).

In an urban remnant of Atlantic Forest, Fernandes *et al.* (2009) found thirty-two morphotypes of galls associated with 13 families of host plants, which were located in the leaves (67.14%), stems (28.57%) and buds (<5%). In their study, galls were characterized by their green coloration (66.66%), if they were grouped (55.55%), if they were glabrous (92.6%) and if they were amorphous (42.59%), spherical (25%) or cylindrical (15%) shaped, and were distributed in 13 host plant families; mainly Burseraceae (24.07%), Lecythidaceae (20.37%), Annonaceae and Melastomataceae (11.11%)

In our study, considering the total abundance of host plants, the Melastomataceae was one of three most important families. The Melastomataceae alone accounted to 16 of 28 (57.14%) host-plant individuals in 25 yrs old patches compared to only 22 of 60 (36.66%) individuals in interior patches. This family was also important when considering the richness of gall morphospecies and host-plant species. As demonstrated by Fernandes (1992), the size of a plant family (*i.e.*, number of genera and species) may be a very important factor that affects the gall-inducing insect richness. Based on the number of plant species, Melastomataceae are considered very important in the Coimbra forest, (Oliveira 2003, Almeida-Santos 2005). In general, the incidence of galls in members of this family has been considered high (*e.g.*, Fernandes *et al.* 2001, Maia & Fernandes 2004). In our study, *Miconia prasina* (Melastomataceae) was the most abundant host plant.

Monitoring the diversity of gall-inducing insects is a good method for evaluating changes in secondary successional gradients, and further development of studies that focus on these insects as bioindicators would make this method an indispensable tool (Julião *et al.* 2005). There is a lack of studies about gall insects that support conservation initiatives in degraded and fragmented forests. The Atlantic Forest is a dramatic case with a long history of fragmentation and degradation (see Ranta *et al.* 1998). We believe that the use of gall-inducing insects as bioindicators in restoration and conservation programs is not only a good opportunity to advance this topic of study but is also a useful application, at local and regional scales, to monitor the successional progress of forests. We suggest that at a regional scale new studies should consider not only (1) plant composition and diversity, (2) percentage of shade-tolerant and pioneer plants, (3) distance between fragments, and (4) shape and size of fragments, but also (5) some environmental variables (*e.g.*, temperature, soil fertility, humidity, light) and forest attributes (*e.g.*, tree height, plant density, plant community stratification).

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