ECOLOGY, BEHAVIOR AND BIONOMICS

Species Richness in Natural and Disturbed Habitats: Asteraceae and Flower-Head Insects (Tephritidae: Diptera)

Soraia Diniz[1], Paulo I Prado[2], Thomas M Lewinsohn[3]

[1]*Lab de Ecologia Animal, Depto Botânica e Ecologia, IB, UFMT, 78060-900, Cuiabá, MT, Brasil; saf@ufmt.br*
[2]*Depto de Ecologia, Instituto de Biociências, Univ de São Paulo, São Paulo, SP, Brasil*
[3]*Lab de Interações Insetos-Plantas, Depto Zoologia, IB, Unicamp, CP 6109, 13083-970, Campinas, SP, Brasil*

Edited by Angelo Pallini - UFV

Neotropical Entomology 39(2):163-171 (2010)

ABSTRACT - Anthropogenic changes in the landscape result in an environmental mosaic with serious consequences for biodiversity. The aim of the present study was to assess the effects of the anthropogenic changes on Asteraceae richness and abundance, and to evaluate the consequences for the richness of Tephritidae assemblages in five sampling sites, with three sampled habitats in each: *cerrado* (Brazilian savanna), eucalyptus stands and pasture. Sampling was carried out in 15 random transects (*cerrados* and one pasture) and in 30 transects (eucalyptus stands and the remaining pastures). Composition, species richness and insect abundance in each habitat type was estimated by sampling the flower heads for each species of host plant, collected by four people for 1h. Differences in mean abundance of plant population between habitats and sites were tested by two-way ANOVA. Differences in plant species richness between habitats and sites and effects of habitat, site and host plant richness on insect richness were tested using a generalized linear model with Poisson errors. Within each sampling site, *cerrados* showed higher species richness of Asteraceae than pastures and eucalyptus stands. There were also significant differences in plant richness among sites. Mean population abundance values were significantly different among habitats, but not among sites. Increased host plant richness led to significant insect species richness. There were no additional significant effects of habitat on insect richness. Therefore, anthropogenic alterations in landscape determined the impoverishment of plant assemblages and therefore of insect assemblages, because of the positive relationship between host plant richness and insect richness.

KEY WORDS: Savanna, pasture, eucalyptus stand, landscape

Anthropogenic changes in the landscape produce spatial mosaics of different types of land use and habitats, with serious consequences for species richness (Turner 1989, Gibbs & Stanton 2001, Wagner & Edward 2001). At local level, diversity is restricted by environmental conditions such as habitat disturbance and its structural heterogeneity (Schluter & Ricklefs 1993) that can be caused by species richness itself (Stewart *et al* 2003), particularly in plant-herbivore systems. Anthropogenic disturbances, instead of contributing to spatial heterogeneity, tend to homogenize landscape patterns, at least on fine or intermediate scales (Wiens 2000). These effects of land resonate across all food chains, and one serious consequence thereof can be the loss of species diversity in associated communities**.**

The Brazilian *cerrado* is considered one of the world's hotspots (Myers *et al* 2000), and it has been converted to pastures, agriculture and other uses in the past 35 years (Klink & Machado 2005). Its biodiversity has been seriously threatened (Silva & Bates 2002, Mittermeier *et al* 2005). Asteraceae is a family of native plants to the Brazilian *cerrados*, and it is one of the largest families of higher plants, with 1,535 genera and more than 23,000 known species (Bremer 1994). It is a cosmopolitan group that affords comparisons between study sites, continents and biomes, and has been well studied taxonomically (Almeida *et al* 2005). Due to the high dispersion capacity and to heliophily, several species may invade ruderal fields, pastures, agricultural areas and other lands that have been changed by some land use strategy. In this scenario, these plant species may even lead to considerable damage. Thus, areas like these, which have been appropriately managed, may act as corridors between *cerrado* fragments in the dispersion and maintenance of host plant populations and, therefore, of herbivorous insects and their parasitoid assemblages.

Insects that breed on Asteraceae likewise form a taxonomically diverse group. In the southern and southeastern parts of Brazil, the most important endophagous insects of Asteraceae belong to the orders Diptera (Tephritidae, Cecidomyiidae and Agromyzidae) and Lepidoptera (Tortricidae, Pterophoridae, Pyralidae and Gelechiidae) (Prado *et al* 2002). The taxonomy, population ecology and bionomy of some important groups of flower-head insects such as Tephritidae have been well studied, because some of the species of this genus are pests, while others have biocontrol potential or are part of intensively studied systems (Lewinsohn *et al* 1997). Tephritidae is one of the richest families of flower-head endophagous species in temperate regions (Zwölfer 1982, 1988) as well as in Brazil (Prado *et al* 2002), and most analyses are focused upon this group.

The current contribution of insect-herbivore assemblages to a general perspective of terrestrial diversity is not commensurate with their diversity or importance (Lewinsohn *et al* 2005). The estimation of local richness for studies of associated communities is essential to understand species richness patterns and their implications (Ricklefs 1987). Thus, studies of insect-plant systems in different locations with different land uses enable the evaluation of the relative importance of local and regional processes, providing the means to determine the best management practices and the rational land use.

Although quite a few studies on the Asteraceae/endophagous insects system have been conducted in Brazil, they address mainly to natural environments (Prado *et al* 2002, Almeida *et al* 2005, 2006, Fonseca *et al* 2005). Nevertheless, few data on the impact of fragmentation on these communities associated to tropical areas are available. The present study was conducted in three habitat types, the *cerrado* (Brazilian savanna), pastures and eucalyptus stands in the State of São Paulo, Brazil, to evaluate the effect of anthropogenic changes in Asteraceae species richness and the consequent influence on the richness of associated insect communities.

Material and Methods

Study areas. The study was carried out at five sampling sites in the State of São Paulo, which is in the southern limit of the *cerrado* domain, in the municipalities of Agudos, Assis, Itirapina, Mogi-Guaçu and Águas de Santa Bárbara, with three sampled habitats in each: *cerrado*, eucalyptus stands, and pastures (Table 1).

Cerrados, eucalyptus stands and two pastures were located in protected areas (Table 1). Three pastures were near conservation reserves. Cattle were present in Mogi-Guaçu, Agudos and Itirapina, and have been excluded from the Assis pasture for 20 years. The Santa Barbara pasture had not been cleared for 20 years, and was being used as pasture though for a small number of animals. Pastures in Mogi-Guaçu and Agudos were cleared annually and farmers adopted herd rotation across different locations in the farm so as to prevent the overuse of pasture areas. The Itirapina pasture was cleared at two-year intervals, but the farmer kept some shrubs and trees native of the *cerrado* vegetation. All eucalyptus stands were over 30 years old, and were used only for sporadic logging, which lead to the formation of clearings. The exception was the Agudos stand, which was cleared every seven years.

Sampling methods. The insect-plant communities were sampled from April to May 2001, during the main reproductive period of Asteraceae in the region. The sampling methods were similar to those used by Fonseca *et al* (2005) and Almeida *et al* (2005, 2006) in the same areas. Sampling was carried out in 15 random transects (*cerrados* and the pasture at Águas de Santa Bárbara) and in 30 transects (eucalyptus stands and all the other pastures, due to their low Asteraceae population density), each measuring 30 m x 5 m. In each site, the presence/absence and abundance of Asteraceae were recorded and voucher specimens collected. For each flowering or fruiting species of Asteraceae, population density was measured in abundance classes: 1, 1;

Table 1 Abundance and richness of Asteraceae (observed and estimated by rarefaction) and Tephritidae, habitat type, site and geographic coordinates of 15 study localities in São Paulo State, Brazil.

Physiognomy	Site	Coordinates	Plant richness	Tephritidae richness
Cerrado	Agudos	22º28’27 S 48º53’52 W	10	3
Cerrado	Assis	22º35’59 S 50º22’12 W	12	5
Cerrado	Itirapina	22º15’44 S 47º48’34 W	19	9
Cerrado	Mogi Guaçu	22º14’21 S 47º51’43 W	15	8
Cerrado	Santa Bárbara	23º05’30 S 49º13’37 W	28	8
Eucalyptus	Agudos	22º26’46 S 48º59’14 W	3 (2)[1]	4
Eucalyptus	Assis	22º35’56 S 50º22’11 W	0	0
Eucalyptus	Itirapina	22º13’10 S 47º51’03 W	3 (1)[1]	2
Eucalyptus	Mogi Guaçu	22º17’25S 47º08’31 W	2	0
Eucalyptus	Santa Bárbara	22º39’25 S 49º14’04 W	0	0
Pasture	Agudos	22º28’34 S 48º54’49 W	5 (4)[1]	1
Pasture	Assis	22º36’04 S 50º24’13 W	9 (7)[1]	3
Pasture	Itirapina	22º16’50 S 47º49’19 W	14 (9)[1]	11
Pasture	Mogi Guaçu	22º17’26 S 47º08’31 W	6 (4)[1]	3
Pasture	Santa Bárbara	22º39’25 S 49º14’04 W	18	8

[1] Values for Asteraceae richness adjusted using rarefaction for size equivalent to all other samples (15 transects).

2, 2; 3, 3-10; 4, 11-30; 5, 31-100; 6, 101-300; 7, 300-1000. The mean plant population abundance per site was calculated by averaging class numbers across species. Rare species were sampled by active search outside transects.

The insect species richness in each habitat type was estimated through sampling of flower heads for each species of host plant, with a standardized effort of four person-hours (see Fonseca *et al* 2005). Flower-head samples were kept in plastic containers with mesh lids and examined daily for emerging insects over eight weeks, so that any insects that emerged could be removed. Insects that emerged were anesthetized with CO_2, removed and maintained in a refrigerator before being mounted on entomological pins, except for Cecidomyiidae, which were preserved in 70% ethanol. The insects were pinned, labeled, identified and deposited in the entomological collection of the Universidade Estadual de Campinas Museum. After two months, each flower-head sample was dried at 70° C for 24h and then weighed using an analytical balance.

Data analysis. The values for plant species richness were estimated using rarefaction curves (Gotelli & Graves 1996) for the total community of each location recorded in the 15 transects from the pasture (except for that of Santa Bárbara) and eucalyptus stands (Table 1).

Differences in mean abundance of sampled plant population between habitats and sites were tested using an ordinary two-factor ANOVA. Differences in plant species richness (as response variable) between habitats and sites (as explanatory variables), were tested by a generalized linear model with Poisson errors, which is more appropriate for count data (Crawley 2002).

The effects of habitat, site and host plant richness on insect richness were tested by a generalized linear model with Poisson errors. The effects were evaluated after differences in sampling effort were factored out. To accomplish this, a model including only the total dry weight of flower heads sampled as explanatory variable was compared with models to which the other variables were added. The increase in fit due the addition of each variable was evaluated by F-tests (for least-squares models) or deviance analysis with the Chi-square approximation (for Poisson models, Crawley 2002).

The models were fitted with the 'lm' (linear models) and 'glm' (generalized linear models) functions under the R environment version 2.4.0 for LINUX (R Core Team 2006). Residuals of each model were checked and did not show noticeable departures from the theoretical assumptions (Draper & Smith 1981, McCullagh & Nelder 1989).

Results

In the three physiognomies, 54 species of Asteraceae were found. Of these, 19 were rare, with less than three individuals recorded by locality and 34 (63%) occurred in just one habitat. Forty-one species were sampled in the *cerrados*, 31 in the pastures, and five in eucalyptus stands (Tables 1 and 2). Four species were shared among the three habitats (Fig 1a): *Chromolaena squalida*, *Gochantia pulchra*, *Vernonanthura membranacea* and *Piptocarpha rotundifolia* (Table 2). Fifteen species were shared among *cerrados* and pastures, and one among *cerrados* and eucalyptus stands. Twenty-two species occurred only in the *cerrados*, and 12 only in pastures (Fig 1a). In two eucalyptus stands (Assis and Águas de Santa Bárbara), no Asteraceae species were found.

Considering each site independently, *cerrados* showed higher Asteraceae species richness than pastures and eucalyptus stands (richness average: 16.8 ± 7 SD; 84 ± 5.7 SD; 1 ± 1 SD, respectively; deviance = 73.7, 2 d.f., $P < 0.0001$) (Fig 1). There were also significant differences in plant richness among sites (Deviance = 18.6, 4 d.f., P = 0.001) (Fig 2a), with Santa Bárbara being the richest site (36 species) and Agudos the poorest (14 species). The mean population abundance values were significantly different among habitats ($F_{2, 12} = 7.0$, $P = 0.01$), but not among sites ($F_{4, 10} = 0.55$, $P = 0.70$) (Fig 2b).

Tephritidae represented 63% of all insect species sampled and they were present in all sites with high frequency among host plant species (from five tribes). A total of 17 species and 1,346 individuals were reared from flower heads from all habitats: 13 species and 1,013 individuals in the *cerrados*; 14 species and 238 individuals in pastures, and four species and 95 individuals in eucalyptus stands (Table 2). Four species occurred in three habitats (Fig 1b): *Xanthaciura chrysura* S.G. Thomson., *Xanthaciura* sp, *Cecidochares connexa* Macquart and *Cecidochares* sp.E (Table 3). Six species occurred in both pastures and *cerrados*, three species occurred only in *cerrados* and four only in pastures (Fig 1b).

Almost all individuals (92%) were reared from only five species of host plants, *Chromolaena chaseae*, *C. odorata*, *C. pedunculosa*, *C. pungens* and *C. squalida*. Except for *C. chaseae*, all those plant species occurred with high population abundances and high frequency on the sites (Table 2). Although *C. chaseae* occurred with lower abundance and frequency (Table 2), 137 individuals of Tephritidae emerged from their flower heads.

Insect species richness at each site increased significantly with sample weight of flower heads (Deviance = 14.5, 1 d.f., P = 0.0001) (Fig 3), which represented the sampling effort. The inclusion of host plant richness in the model (as a quadratic term), however, increased the fit significantly (Deviance = 9.0, 2 d.f., P = 0.011), and thus the increase in insect richness due to the richness of host plants is not a sampling artifact (Fig 4a). There were no additional significant effects of habitat on insect richness (Added Term Deviance = 2.6, 2 df, P = 0.275) (Fig 4b).

Discussion

The low occurrence of many Asteraceae species had already been noticed in previous inventories with a similar protocol; 39% to 70% of Asteraceae species were recorded in a single locality (Prado & Lewinsohn 2000, Almeida *et al* 2004, 2005).

Local richness of some pastures showed the importance of appropriate management to species richness maintenance. Pastures can act as temporary corridors along which species of Asteraceae and their associated insects can disperse from *cerrado* fragments. Pastures are constantly regenerating,

Table 2 List of the 54 species of Asteraceae recorded in the 15 study sites of cerrados, pastures e eucalyptus stands in São Paulo state. The numbers correspond to abundance classes for the morphspecies in each location: 1) rare, 2) 1, 3) 2, 4) 3-10, 5) 11-30, 6) 31-100, 7) 101-300, 8) 300-1000 individuals. The squares represent samples with insects present and, in grey shading, the occurrence of the family Tephritidae. Tribes: A: Astereae; E: Eupatorieae; G: Gnaphalieae; H: Helenieae; He: Heliantheae; M: Mutisieae; P: Plucheeae; S: Senecioneae; V: Vernonieae. Species in bold occurred in one site only.

Code	Host plant	Cerrado					Pasture					Eucalyptus stands			Freq./site(%)	Tephritidae richness	Tephritidae abundance
		Santa Bárbara	Itirapina	Mogi-Guaçu	Assis	Agudos	Santa Bárbara	Itirapina	Assis	Mogi-Guaçu	Agudos	Agudos	Itirapina	Mogi-Guaçu			
1A	*Bidens* cf. *gardneri* Baker	**4**	**5**				**2**		**4**						31	1	28
2A	*Baccharis dracunculifolia* DC.	**5**		**5**		3									23		
3A	*Baccharis* sp. 1	5					**7**								15	1	3
4A	*Conyza canadensis* (L.) Cronquist	2					3								15		
5A	*Baccharis* aff. *dracunculifolia*	4													8		
6E	*Chromolaena squalida* (DC.) K&R[1]	**6**	**6**	**5**	**6**	**5**	**8**	5				**4**			62	8	254
7E	*Chromolaena odorata* (DC.) K&R[1]	**6**	**5**	**7**		3		**4**	**5**	**2**					54	8	197
8E	*Chromolaena pedunculosa* (Hook & Arn.) K&R[1]	**6**	**6**	**6**	2	**6**		**8**			1				54	8	347
9E	*Mikania* aff. *cordifolia*	**3**	**6**	**4**			**4**	**4**			**4**				46	1	1
10E	*Chromolaena pungens* (Gardner) K&R[1]	**5**	**7**		**6**							**4**	**3**		38	6	293
11E	*Chromolaena chaseae* (B. Robinson) K&R[1]	4	**1**	**4**											23	3	137
12E	*Chromolaena* aff. *pedunculosa*				2	4									15		
13E	*Praxelis clematidea* (Griseb.) K&R[1]							1	2						15		
14E	*Koanophyllum* sp. 1	**4**					2								15		
15E	*Chromolaena* aff. *squalida*			**2**											8		
16E	*Chromolaena ascendens* (Sch. Bip. ex. Baker) K&R[1]						5								8		
17E	*Chromolaena laevigata* (Lam.) K&R1			**2**											8	3	12
18E	*Chromolaena* sp. 1						**5**								8	1	1
19E	*Eupatorieae* sp. 1				**3**										8	2	6
20E	*Grazielia* sp. 2	**4**													8	2	2
21E	*Grazielia* sp. 3				2										8		
22E	*Koanophyllum* sp. 2		3												8		
23E	*Stevia* aff. *commixta*	**3**													8		
24E	*Stevia* sp. 1						**5**								8		
25G	*Achyrocline satureioides* (Lam.) DC.	2	5	2	**2**	4	4	2							54		
26G	*Achyrocline* sp. 1	2					5								15		
27H	*Porophyllum* sp. 2	2													8		
28He	*Viguiera robusta* Gardn.	**5**		2											15		

Continue

Table 2 Continuation.

Code	Host plant	Cerrado					Pasture					Eucalyptus stands			Freq./site(%)	Tephritidae richness	Tephritidae abundance
		Santa Bárbara	Itirapina	Mogi-Guaçu	Assis	Agudos	Santa Bárbara	Itirapina	Assis	Mogi-Guaçu	Agudos	Agudos	Itirapina	Mogi-Guaçu			
29He	*Aspilia* sp. 13						2								8		
30He	*Calea verticillata* (Klatt) Pruski	1													8		
31He	*Heliantheae* sp. 1					4									8		
32He	*Wedelia paludosa* D.C.									2					8		
33M	*Gochnatia pulchra* (Spreng.) Cabrera	**6**	**4**	**5**		4		**5**				2		5	54	1	3
34M	*Gochnatia barrosii* Cabrera			**1**											8	1	1
35P	*Pterocaulon* cf. *alopecuroides*		**4**				**4**	**4**							23	1	12
36P	*Pterocaulon* sp. 2							1	**2**		**5**				23		
37P	*Pterocaulon* sp. 3							**2**		1					15		
38S	*Emilia sonchifolia* (L.) DC.	4	1				2								23		
39S	*Erecthites* sp. 1		2												8		
40V	*Orthopappus angustifolius* (Sw.) Gleason	**3**	**4**	4		2	**2**	**6**	**6**	**5**	4				69	1	10
41V	*Vernonanthura membranácea* (Gardn.) H.Rob.	2	**4**	**5**	2			**4**	**4**		**6**		**1**	**2**	69		
42V	*Piptocarpha rotundifolia* Baker	**5**	3	**4**	2			1					3		46	2	31
43V	*Elephantopus mollis* Kunth				1			5	**6**	**5**					31	1	4
44V	*Lepidaploa salzmannii* (DC.) H.Rob.	**7**			**5**	7			**8**						31		
45V	*Lessingianthus bardanoides* (Less.) H.Rob.		2				**5**								15	1	1
46V	*Stenocephalum* sp	1			4										15		
47V	*Chrysolaena platensis* (Spreng.) H. Rob.						**2**								8		
48V	*Elephantopus* sp. 3		1												8		
49V	*Elephantopus* aff. *biflorus*						4								8		
50V	*Lepidaploa* sp. 3								4						8		
51V	*Lessingianthus aff. bardanoides*	1													8		
52V	*Lessingianthus* sp. 6									2					8		
53V	*Stilpnopappus* sp. 1		**4**												8	1	3
54V	*Vernonieae* sp. 2	1													8		
Hostplant richness		28	19	15	12	10	18	14	9	6	5	3	3	2			
Tephritidae richness		8	9	8	5	3	8	11	3	3	1	4	2	0		17	
Tephritidae abundance		29	500	386	84	14	58	150	7	22	1	22	73	0			1346

remaining in an early successional stage. Accelerated levels of cattle grazing can lead to the local extinction of native species and/or reduce their abundance and richness in native pastures (McIntyre *at al* 2003). Even though the plant communities in some pastures in this study had fairly high species richness, they had just a few dominant species. The re-colonization of these habitats may be implemented by means of a seed bank, dispersion of nearby *cerrado* environments or even by re-budding (Durigan *et al* 1998). In fact, pastures represented a mosaic of different habitats,

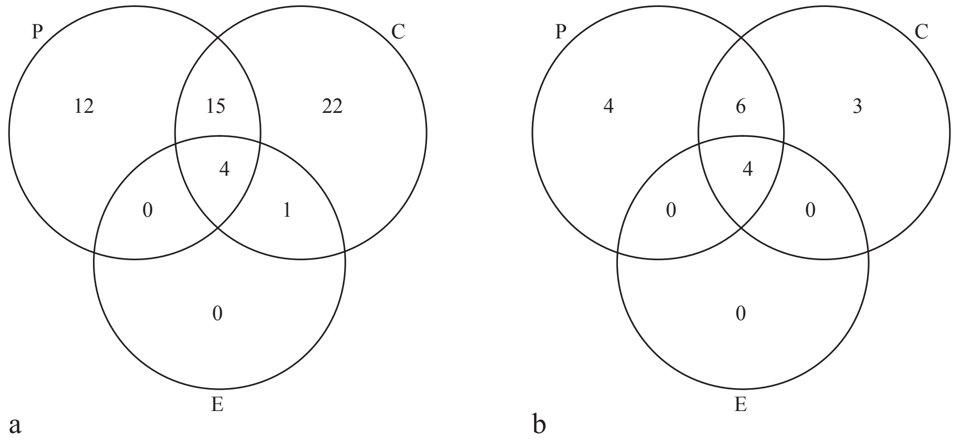

Fig 1 Species overlap among (a) Asteraceae assemblages and (b) Tephritidae assemblages in *cerrados*, pastures and eucalyptus stands.

which are the result of multiple disturbances and uses.

Asteraceae communities within eucalyptus stands are very impoverished, with low population abundances and correspondingly low insect species richness, probably because of excessive shading that represents high stress to heliophilous species. However, the regeneration of *cerrados* within eucalyptus stands was observed, particularly by arboreal species of other families in Assis, in exactly the same study area studied in here (Durigan *et al* 1997). Plants collected in these areas belong mainly to the *Chromolaena* genus, which represents a group of host species whose richness of associated insect species is frequently expressive (Prado *et al* 2002). Lower insect species richness in the eucalyptus stands may have also been influenced by the vegetation texture. Herbivores might have difficulty finding host plants, especially if these are scarce or hidden due to their proximity to other, non-host plants (Kareiva 1983). Apart from this, eucalyptus stands provide resistance to insect dispersion, increasing isolation effects on *cerrado* fragments (see Ricketts 2001).

The relationship between host plant richness and insect richness, such as observed in the present study, is well established in the literature on insect-plant interactions (Strong *et al* 1984, Novotny *et al* 2006, Ødegaard 2006). Therefore, habitat type had an indirect effect on these communities. Gonçalves-Alvim & Fernandes (2001) studied gall-making insects in four *cerrado* physiognomies in Minas Gerais, and found a significant correlation between insect

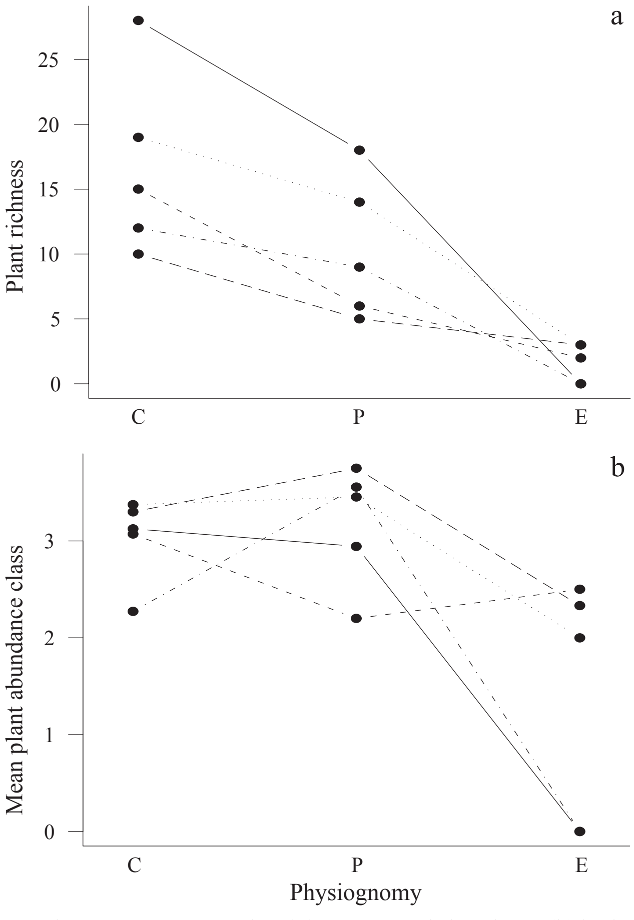

Fig 2 Asteraceae species richness (a) and abundance (b) in the three habitats. C: *cerrado*, P: pasture, E: eucalyptus stands.

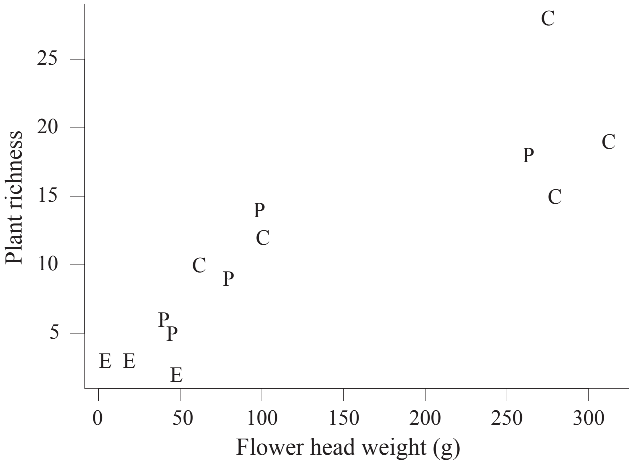

Fig 3 Insect richness variation in relation to flower-head weight. C: *cerrado*, P: pasture, E: eucalyptus stands.

Table 3 Abundance of the 17 species of flower head Tephritidae recorded in the 15 study sites of *cerrados*, pastures e eucalyptus stands in São Paulo state.

Species	*Cerrado* - Itirapina	*Cerrado* - Mogi-Guaçu	*Cerrado* - Santa Bárbara	*Cerrado* - Assis	*Cerrado* - Agudos	Pasture - Itirapina	Pasture - Santa Bárbara	Pasture - Mogi-Guaçu	Pasture - Assis	Pasture - Agudos	Eucalyptus -Agudos	Eucalyptus - Itirapina	Freq %	Total
Xanthaciura chrysura S.G. Thomson	95	152	15	51	8	28		14	2	1	4	39	92	409
Xanthaciura sp.	247	183	1	27	5	98		3			13	34	75	611
Cecidochares connexa Macquart	16		4	4	1	10	5		3		1		67	44
Neomyopites paulensis Steyskal	3	3	1	1		2	1						50	11
Trupanea sp. 1	8	1	1			3	14						42	27
Tetreuaresta sp. 1			1			1	5	5	2				42	14
Cecidochares fluminensis Lima		16	5	1		1							33	23
Xanthaciura biocellata S.G. Thomson	7	1				3	1						33	12
Cecidochares sp. E	119					2					4		25	125
Tomoplagia sp. 1		29	1										17	30
Tomoplagia trivittata (Lutz & Lima)	2					1							17	3
Xanthaciura insecta H. Loew							28						8	28
Dictyotrypeta sp. 2	3												8	3
Trypanaresta sp.							3						8	3
Caenoriata		1											8	1
Tomoplagia cf. *achromoptera*							1						8	1
Xanthaciura mallochi Aczek						1							8	1
Total	500	386	29	84	14	150	58	22	7	1	22	73		1346
Richness by site	9	8	8	5	3	11	8	3	3	1	4	2		17
Total richness			13					14				4		17

richness and herbaceous species richness. On the other hand, they also found a strong correlation between gall-making insect richness and certain edaphic factors. Richness of galling insect species on *Baccharis concinna* (Asteraceae)

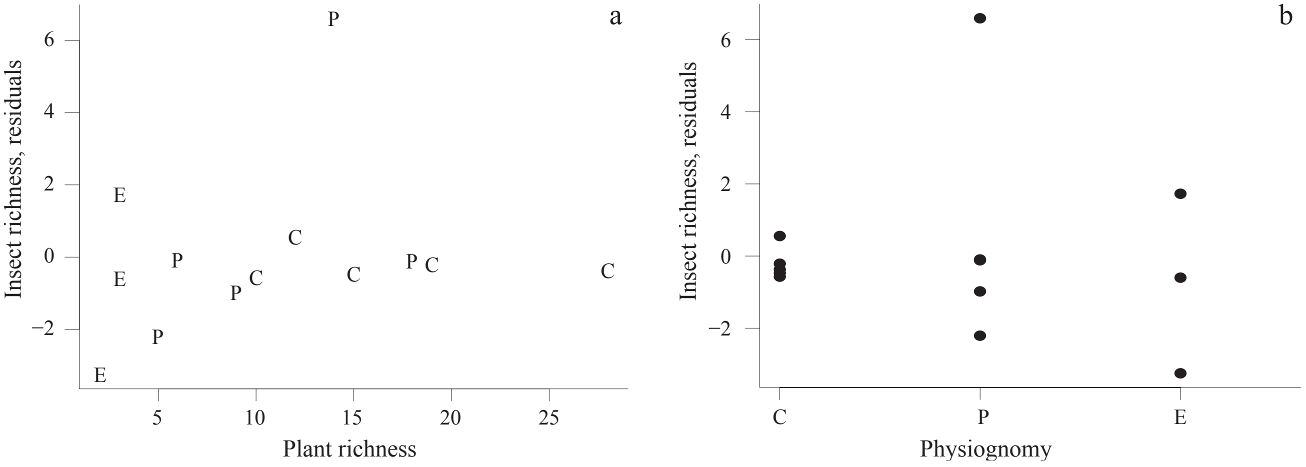

Fig 4 Insect richness in relation to host plant richness (a) and physiognomy (b) C: *cerrado*, P: pasture, E: eucalyptus stands.

seemed to be regulated by local determinants such as habitat plants (Carneiro *et al* 2005).

The analysis of the abundances of Tephritidae in pastures, *cerrados* and eucalyptus stands indicates that these species did not persist in large pasture areas. Debano (2006) studying the effects of livestock grazing on insect communities, observed that, in general, insects were more abundant on ungrazed sites, although total species richness did not differ significantly between ungrazed and grazed areas in Arizona

All in all, the anthropogenic alterations in landscape determined the impoverishment of plant communities and consequently also of insect assemblages, as host plant richness and insect richness are positively correlated. Therefore, although some sort of effect related to habitat type is observed, this is of indirect nature. Finally, the appropriate management of areas of anthropogenic activities is essential in transforming them into corridors for the dispersion of host plants and the maintenance of associated insect populations.

Acknowledgments

A M Almeida, M Almeida-Neto, U Kubota, M R Braun, R L G Raimundo, L A Anjos, T G Mendonça, S M Futada, R Fabiano, A T R Dias assisted in field and laboratory work. C Fonseca, H Morais, A Freitas and A M Almeida commented on earlier versions. We thank Instituto Florestal de São Paulo, Instituto de Botânica and AMBEV for permits and support in their conservation units and preservation areas. This work was supported by research grant 98/05085 from the BIOTA-FAPESP program of the Fundação de Amparo à Pesquisa do Estado de São Paulo and by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – CAPES.

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Received 13/II/08. Accepted 16/X/09.