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# Flower-Visiting Insects of Five Tree Species in a Restored Area of Semideciduous Seasonal Forest

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**Abstract**

The reinstatement of biodiversity and ecological processes must be the major goal in restoration projects, which requires the establishment of biological interactions in addition to native plant population recovery. Therefore, we assessed the flower visitors of five tree species in a restored area of Semideciduous Seasonal Forest, in Ribeirão Preto, SP, Brazil. The specimens were collected using entomological net on flowers of *Acacia polyphylla*, *Aegiphila sellowianna*, *Croton floribundus*, *Croton urucurana* and *Schinus terebinthifolius* from October 2007 to September 2008. A total of 139 insect species belonging to five orders were collected. Hymenoptera was the most diverse order collected. From a total of 37 families, Vespidae (15 species), Cabronidae (12), Apidae (10), Halictidae (10), Syrphidae (12), Tachinidae (6) and Hesperidae (7) were the richest ones. *Schinus terebinthifolius* flowers presented the most abundant and diverse insect visitors (60), suggesting it is an important attractive species to the fauna in restoration programs. Our data suggest that mutualistic interactions between some of these plants and their flower-visiting insects may be in a reinstatement process, and will support the design and monitoring of future restoration efforts.

## Introduction

Habitat loss and fragmentation are drastically altering the structure and composition of tropical forests (Metzger 2000, Tabarelli *et al* 2004, Laurance *et al* 2006). As a consequence, biological diversity is being lost at an unprecedented rate, and ecological processes (*i.e.* energy flow, nutrient cycling) as well as ecosystem services (pollination, climate regulation) (Ehrenfeld 2000) are undergoing detrimental changes. Such increasing habitat devastation makes studies on conservation and restoration biology a priority.

In this context, restoration ecology is a relatively new science that during the past two decades has become vital to the sustainable development and maintenance of ecosystems throughout the globe (Metzger 2003, Roberts *et al* 2009). However, there are still many uncertainties concerning basic ecological concepts related to restoration activities (Ehrenfeld & Toth 1997). According to Michener (1997), the lack of a well-documented knowledge base for planning restoration projects is related to the deficiency of formal evaluations of successes and failures associated with them.

Successful restoration is, many times, limited by several environmental and biological factors (Souza & Batista 2004). Standard restoration practices usually emphasize structural aspects of biodiversity, such as plant species richness and abundance. However, an approach focusing on the restoration of ecosystems' functional aspects, such as interactions between species, has been increasingly recommended (Forup & Memmott 2005, Zych *et al* 2007, Forup *et al* 2008). Among the most important ecosystems services, pollination is one that must be reinstated for restoration to be successful.

In tropical forests, the majority of angiosperms are allogamous (Bawa *et al* 1985a) and animal-pollinated (Bawa *et al* 1985b), with insects definitively playing a major role on pollen transference for cross-fertilization. Therefore, pollinators provide a critical service in terrestrial ecosystems (Allen-Wardell *et al* 1998, Kearns *et al* 1998) and their importance in such ecosystems can be proved by a broad body of empirical data. Many studies have found that the disruption of plant-pollinator interactions by habitat fragmentation can negatively affect both plant reproductive success (*i.e.* fruit set, thus seed dispersal and seedling recruitment) (Cunningham 2000a, b) and insect populations (Brown & Albrecht 2001, Liow *et al* 2001, Wilcock & Neiland 2002), even to the point of promoting local extinction (Memmott *et al* 2004). Furthermore, insect pollination is critical not only for plants and pollinators, but also for nectarivorous, frugivorous and seed dispersers, which depend on the plant reproductive success for survival

In spite of this major relevance, little has been done in the restitution of pollinator services in ecological restoration projects (Forup & Memmott 2005, Forup *et al* 2008, Dixon 2009). In Ribeirão Preto and many other regions of São Paulo State, where formerly forested landscapes were converted into mosaics of small patches of forest remnants (ISA, 2001), restoration activities are especially important. However, there is still a lack of studies approaching insect-plant interactions on restored areas regardless the increase of restoration projects in Brazil since 1990's (Kageyama & Gandara 2000). Most of the studies have primarily focused on the recovery and development of the vegetation (*e.g.* Souza & Batista 2004), whereas research into insect fauna is basically inexistent (but see Pais & Varanda 2010).

Considering that habitat fragmentation has the potential to negatively affect some plant-pollinator interactions (Aizen & Feinsinger 1994a, b, Girão *et al* 2007) and that pollinators have a recognized role in forest maintenance, the concern for them in restoration actions is no doubt relevant (Kageyama *et al* 2003). So the present work was intended to determine the diversity of flower-visiting insects in a restored area of Semideciduous Seasonal Forest, with the main purpose of providing valuable parameters for comparison of the visitors fauna among restored areas, as well as for design and monitoring of future restoration efforts.

## Material and Methods

Field work was developed on a 75 ha restored area of Semideciduos Seasonal Forest located at the Universidade de São Paulo, Ribeirão Preto, São Paulo state, Brazil (21°5'S, 47°50'W). Ribeirão Preto is located at a mean altitude of 540 m, with well defined dry and wet seasons. The dry season receives less than 30 mm rainfall in the coldest month, with average temperature rarely below 18°C, and in the wet season precipitation exceeds 250 mm in the warmest month, with an average temperature greater than 22°C.

The restored forest was established between April 1998 and March 2003 using mathematical design as well as ecological succession concepts aiming for the restoration and conservation of genetic variability of regional native trees. The first established site (in 1998-1999) encompassed a 30,000 m$^2$ area where 116 thousand seedlings of 70 native tree species were planted, while the second one (from 2000 to 2003) included the planting of more than 90 thousand seedlings of 45 species in a 45,000 m$^2$ area. This second site is a genetic bank that contains the offspring of endangered native forest trees, and because of its specific and innovative design, Floresta da USP is now a mix of different age patches which contain genetic material from more than three thousand trees. An area established between 2000 and 2001, 7-8 years old at the time of the study, was chosen for the present work.

The study site was visited bimonthly from October 2007 to September 2008 to check for flowering plants. Among all flowering tree species in the study area (a total of ten), the ones with individuals higher than 5 m and whose canopy could not be reached by entomological nets were excluded from our sampling, as well as the species with only a few flowering individuals. As a result, a total of five tree species, including *Acacia polyphylla* (Fabaceae), *Aegiphila sellowianna* (Lamiaceae), *Croton floribundus*, *Croton urucurana* (Euphorbiaceae) and *Schinus terebinthifolius* (Anacardiaceae) were surveyed, with samplings taking place only when the majority of individuals of each species was in full bloom. Flower visitors were sampled for a total 12-15h period (from 6 am to 6 pm, with extra observation hours on major visitation periods) for each tree species, with individual plants being randomly selected (*i.e.*, by walking along planting lines and choosing any flowering tree for ca. 30 min observation) and not excluded from subsequent rounds of sampling. In case of strong winds, rain or even cloudy sky, the observations were halted and the remaining hours were completed at the corresponding hour on subsequent days.

All insects visiting flowers were captured using entomological nets, killed in ethyl acetate killer chambers and stored for further identification. Whenever possible, the individuals were identified to family level and to species in each family based on Carvalho & Ribeiro (2000), Carpenter & Marques (2001), Silveira *et al* (2002), Fernández & Sharkey (2006) and Marinoni *et al* (2007).

Specimens are deposited in the "Setor de Botânica, Departamento de Biologia, Faculdade de Filosofia, Ciências e Letras de Ribeirão Preto, USP".

## Results and Discussion

A total of 139 species of flower-visiting insects belonging to five orders and 37 families were collected on the flowers of the five tree species surveyed (*Online Supplementary Material*). Hymenoptera was the most diverse order with 65 species (46.8%), followed by Diptera with 31 species (22.3%), Lepidoptera with 26 species (18.7%), Coleoptera with 12 species (8.6%) and Hemiptera with five species (3.6%). Among Hymenoptera, 44% of the species collected were from Vespoidea and 56% from Apoidea. Although the presence of flower visitors does not necessarily indicate that pollination is occurring, the large number of insect species observed visiting the flowers demonstrates that interactions are taking place.

Vespidae (with 15 species), Cabronidae (with 12), Apidae and Halictidae (both with 10) were the richest out of the 11 families of Hymenoptera collected. In Diptera, Syrphidae (12 species) and Tachinidae (6 species) were the richest families, while Hesperidae (7 species) was the most diverse family among Lepidoptera.

Both families of bees and butterflies collected are well known pollinators (Kevan & Baker 1983), once their diet (especially for bees) is more or less exclusively composed of pollen and nectar collected from flowers (Goulson 2003). Syrphidae is the family with the major number of pollinator among Diptera (Souza-Silva *et al* 2001, Morales & Köhler 2008), and its occurrence is considered a positive bioindicator due to the larval feeding preference and environmental requirements (Marinoni *et al* 2007). Thus, its occurrence definitely represents an optimistic result for the restored area.

*Apis mellifera* L. and *Trigona spinipes* (Fabr.), as well as the flies *Palpada vinetorum* (Fabr.) and *Ornidia obesa* (Fabr.), were the most generalist visitors, being the only insects that visited all five tree species. Conversely, 70% of all visitor species collected were found interacting with only one tree species (Fig 1). This unique occurrence of so many insects could be related to their rarity or occasional visitation more than to their degree of specialization (Memmott *et al* 2004), once this result seems opposite to the one expected for pollinating species of pioneer trees (Reis & Kageyama 2003) or that it may only reflect the existence of far more insect species than plant species (Taki & Kevan 2007).

*Schinus terebinthifolius* was visited by the largest number of insect species, representing 43% of the total number of collected species (Fig 2). *Croton urucurana*, *A. polyphylla* and *C. floribundus* had similar visitor diversity, around 30% of all collected species. The least visited tree

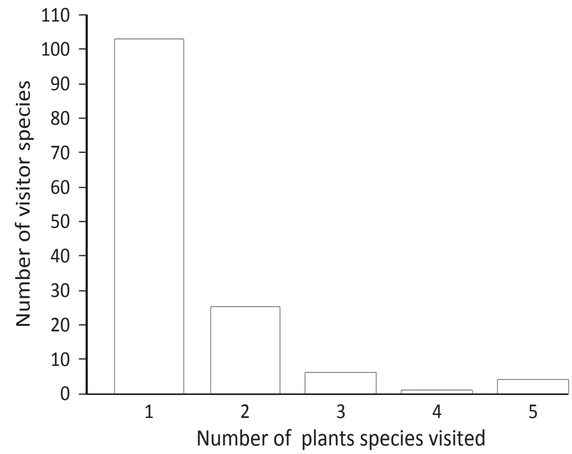


Fig 1 Distribution of plant species visited per insect species visitor at Floresta da USP, Ribeirão Preto, São Paulo state, Brazil.

was *A. sellowiana*, in which only 11% of the total insect species were collected foraging on flowers of this tree. Except for *A. polyphylla* and *A. sellowiana*, which have no data available regarding their pollination biology, the flower-visiting fauna collected on the remaining tree species bared some similarities to that recorded on other studies (Passos 1995, Lenzi *et al* 2003, Lenzi & Orth 2004, Pires *et al* 2004). Based on this study, we observed that among some orders and families of insects, the diversity of visitors is similar or even higher (*e.g.* Apidae visitors of *S. terebinthifolius* and Lepidoptera visitors of *Croton* genus) than that previously observed.

*Apis melifera*, *O. obesa* and other *Palpada* hoverflies showed to be effective pollinators of two species of *Croton* studied by Passos (1995), so we can assume that at least these insect species are the ones pollinating *C. urucurana* and *C. floribundus* at "Floresta da USP". Additionally, other studies had demonstrated that *S. terebinthifolius* is

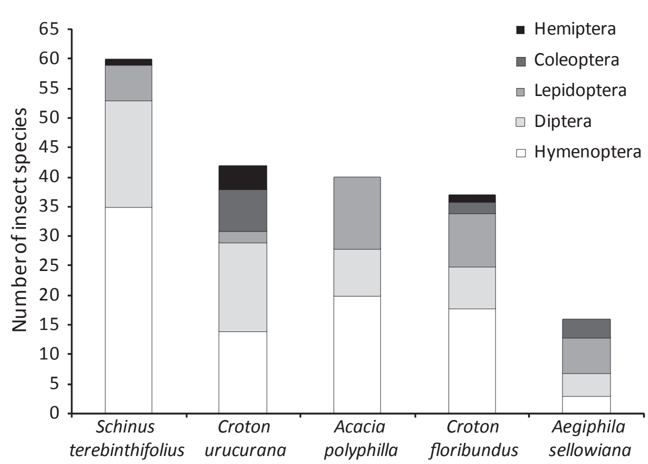


Fig 2 Number of flower visitor species by insect order collected in five tree species at Floresta da USP, Ribeirão Preto, São Paulo state, Brazil.

an entomophilous plant (Lenzi *et al* 2003, Lenzi & Orth 2004); the great diversity of flower-visiting insects found on this species at the studied area (1.4-1.6 times greater than that of *C. urucurana*, *A. polyphylla* and *C. floribundus* and 3.7 times greater than that of *A. sellowiana*) equally allow us to assume that pollination is being successful for this tree species as well.

Although we can not know for certain which flower-visiting insect species are effective pollinators of the surveyed trees, it is possible to attest that the tree species are essential for the flower visiting community, once these trees proved to represent food and other resources (*e.g.* nest sites and materials, places for protection and oviposition) for many insect species.

Taki & Kevan (2007) suggested that insects are more vulnerable to habitat loss than plants in the case of their mutualistic pollination interactions, and Kevan & Baker (1983) argued that floral and pollinator population densities must remain in some sort of equilibrium if their communities are to be maintained. Thus, ecologists can assess whether ecosystem processes are restored when including studies on the interactions between species, a key aspect for the young science of restoration ecology.

Our data show that mutualistic interactions between some of the studied plants and their insect flower visitors have been or are in a reinstatement process. From the present study, we highlight the relevance of monitoring restoration sites in order to better understand faunal colonization, especially when regarding to pollinators. Basic studies evaluating the functional aspects of restored areas, besides the structural ones, are essential for improving restoration techniques as well as our comprehension of how ecological succession works.

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