The Euglossini are neotropical bees, most of which are found in hot and humid equatorial regions (Moure 1967). As effective pollinators they display relationships with numerous associated plant species, including buzz-pollination flowers, resin flowers, perfume flowers and long-tubed nectar flowers, playing thus, a key role in maintaining diversity in tropical rainforests (Dressler 1982, Buchmann 1983, Ackerman 1985, Roubik 1989, Schlindwein 2000, Cameron 2004).

One of the outstanding features of euglossine bees is that males collect floral perfumes (volatile lipids) produced in osmophores of more than 700 species of Orchidaceae and other plant families (Vogel 1962, 1966, 1999, Dressler 1982, Cameron 2004).

Several components of these fragrances that make part of the flowers’ bouquet may be used as chemically pure substances to attract euglossine males. This method has been re-
peatedly used to survey Euglossini and to perform studies about abundance, seasonality and population dynamics in various neotropical forest formations (see for example ROUBIK & ACKERMAN 1987, WITTMANN et al. 1988, BEZERRA & MARTINS 2001, ROUBIK 2001, 2004, NEVES & VIANA 2003).

The Brazilian Atlantic Rainforest currently covers less than 8% of its original area, encompassing around 91,000 km². In Pernambuco and other states of NE-Brazil, only small fragments of Atlantic Forest, that are usually surrounded by sugarcane plantations, are currently remaining (RANTA et al. 1998). Such monocultures do not offer any flower resource or nesting sites required by the bees, therefore isolating the fragments of forest. To guarantee the reproductive success of plants that depend on pollination by euglossine males like those of *Catatetum* Rich. ex Kunth., 1932, *Stanhopea* Frost ex Hook., 1829 and *Gongora* Ruiz & Pavón, 1794 species, flights of these males among forest fragments are necessary (MARTINI et al. 2003).

Euglossine bees are known to be long-distance pollinators in closed rainforests where flight ranges of more than 20 km have been demonstrated (JANZEN 1971, KROODSMA 1975, ACKERMAN et al. 1982). On the other hand, there is controversial information concerning to the flight ranges of these bees between forest fragments and the relationships between fragment size and abundance and species richness of Euglossini (POWELL & POWELL 1987, BECKER et al. 1991, FRANCESCHINELLI et al. 2003, TONHASCA et al. 2003). To get information on the flight behavior of euglossine males and on the relationship of the different euglossine species to forest habitats we tested attraction to scent baits in the extreme landscape of forest fragments inside a matrix of sugarcane monoculture in Pernambuco and asked the following questions: 1) Do Euglossini males leave the forest to collect fragrances outside the forest?, 2) Are there differences among the euglossine species in relation to their dependence on forest habitats?, and 3) To what distance do the male bees advance into sugarcane fields in search of fragrances?

**MATERIAL AND METHODS**

**Study site**

The field study was carried out in the forest fragment “Mata de Bujary” (476 ha, altitude 95 m MSL, 07º36.403’S, 34º58.925’W), municipality of Goiana, an area in the “Zona da Mata” region of Pernambuco, where vast sugarcane fields prevail and surround fragments of native Atlantic Rainforest. The studied forest remnant was separated from the next Atlantic Rainforest fragment by a distance of at least two kilometers (Fig. 1).

**Sampling of Euglossini**

The following seven sampling points were established along a transect: a) within the forest fragment, b) at the forest edge, c) within the sugarcane plantation 10 m distant from the forest edge, d) 50 m distant, e) 100 m distant, f) 250 m distant, and g) 500 m distant.

Five samples were collected on the following days: 25/XI/2002, 09/XII/2002, 17/III/2003, 16/IV/2003 and 01/VIII/2003. The euglossine males were attracted by scent baits (pieces of filter paper containing droplets of fragrance solution) between 9:00 h and 12:00 h, at peak bee activity. The traps were posted in trees within the forest, at its edge and in sugarcane plants inside the plantations, allowing a minimum distance of three meters between them. The baits were monitored simultaneously with one person at each point. Five fragrances that proved to be effective in attracting euglossine males at the study site were used at all points (benzyl acetate, ß-ionone, skatol, eugenol and methyl salicylate). The bees were caught with entomological nets and stored in glasses containing droplets of ethyl acetate and later identified in the laboratory by comparison with the reference collection of the workgroup. The bees were deposited in the Entomological Collection of the Federal University of Pernambuco, Recife. Collection data were entered into a database program.

**Data Analysis**

We calculated the Shannon-Wiener index of diversity (H') to the base log, for each sampling point. The Shannon-Wiener indices of diversity were compared using Hutcheson’s t-test (ZAR 1996).

The frequency of species and individual abundance between the sampling points was analyzed through G-test for one sample – adherence (ZAR 1996). This test was performed with the software Systat 8.0 (WILKINSON 1998).

We used Jaccard index (KÖBB 1989) through NTSYSpc 2.01t software (ROHLEN 2000) to evaluate qualitatively the bees' similarity between each sampling point. From the pairwise similarity we generated a single-linkage dendrogram (VALENTIN 2000), where the sampling points were grouped by UPGMA (Unweighted Pair Group Method with Arithmetic mean) method.
RESULTS

A total of 945 individuals of Euglossini were recorded: 259 inside the forest, 297 at the edge, 171 at a distance of 10 m from the edge, 96 at 50 m, 49 at 250 m and 28 at 500 m distance. The bees belonged to 16 species: 4 to *Eulaema* Lepeletier, 1841, 9 to *Euglossa* Latreille, 1802, 2 to *Exaerete* Hoffmannsegg, 1817, and 1 to *Eufriesea* Cockerell, 1908 (Tab. I).


Species richness (*G* = 15.389, g.l. = 6, *p* = 0.0209) and abundance (*G* = 534.95, g.l. = 6, *p* = 0) were significantly different between the sampling sites (Figs 2 and 3). The same was true for diversity (Shannon-Wiener index, Fig. 4). The sampling point inside the rainforest showed the highest species richness (13 species) and diversity (*H*’ = 2.27), followed by the point at the edge (11 species and *H*’ = 1.76). The total diversity of all points together was *H*’ = 2.06.

The sampling point inside the forest showed a high similarity to the edge point, whereas the sampling points inside the sugarcane plantation were very similar to each other and dissimilar to the forest and edge points (Fig. 5).

The scent which attracted the highest number of individuals was ß-ionone (63.8%), followed by skatol (22.9%) and benzyl-acetate (8%) (Tab. II). Methyl salicylate, eugenol and benzyl-acetate baits showed poor attractiveness outside the forest (Tab. II).
DISCUSSION

The baiting experiment shows that the different species of Euglossini have different connections to the forest. To males of 11 out of a total of 16 species, the sugarcane plantation seems to be a barrier to their activity range. These species are closely bound to forest habitats and the males seem to avoid flying over open areas. These species should be more affected by Atlantic Rainforest destruction and fragmentation. Nevertheless, this conclusion has to be treated with care, as some of the forest-restricted species were rare.

In the Brazilian Amazon, Powell & Powell (1987) showed that the conversion of rainforest to pasture forms barriers to euglossine males. Becker et al. (1991) suggest that the bees’ size is related to the distance between fragments that they can cross. In this context, males of Eulaema bombiformis or E. flavescens should be more capable to leave the forest than smaller bees. The present results show, however, that the different connections of the species of Euglossine to closed forest are not related to body size. Males of the considerably smaller Euglossa cordata occurred in high numbers at the most distant sampling points while no male of Eulaema bombiformis was recorded outside the forest.

Males of species that were frequently recorded at the sampling points in the sugarcane plantation, like Eulaema nigrita, E. cingulata and Euglossa cordata show a high flexibility and capacity of adaptation to disturbed areas. Several studies showed

<table>
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<th>Species</th>
<th>Forest</th>
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<td>171</td>
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</table>
that Eulaema nigrita and Euglossa cordata occur in urban environments where they were also found building nests (Zucchi et al. 1969, Wittmann et al. 2000, Silveira et al. 2002, Darrault et al. 2003). Males of these species should be able to link isolated rainforest fragments.

In other studies related to the flight behavior of euglossine males in fragmented habitats Euglossa cordata, Eulaema nigrita and E. cingulata were also sampled outside forests (Raw 1989, Wittmann et al. 2000). In an experiment of marking and recapture, Tonhisca et al. (2003) showed that these species cross open areas between fragments of Atlantic Rainforest in the state of Rio de Janeiro. Moreover, Euglossa cordata is frequently collected in the region of open Caatinga (succulent thorn-shrub savannah) in Northeastern Brazil (Neves & Viana 2003).

All studies were performed attracting males with scent baits. Unfortunately, there is only little information on female behavior due to the difficulty of sampling. This would be especially important because the activity range of females is limited by the nest locality. Females make foraging flights and always return to their nest, while males can move by chance in a given region (Janzen 1971, Ackerman et al. 1982).

Janzen (1971) showed that females of Euplistis surinamensis (Linnaeus, 1758) returned to their nest when released more than 23 km away. This activity range, however, was determined in an area of continuous rainforest. In regions where forest habitats are restricted to distant fragments, most of the euglossine species seem to stay in the fragments, avoiding open areas. In this condition they consequently may not act as long-distance pollinators.

The reduced or absent flights between forest fragments certainly have a negative effect on the reproductive success of plants that depend on pollination by euglossine bees, especially orchids with perfume flowers. In small forest remnants, the original population of these orchid species is reduced to tiny rest-populations, which may lose their capacity of reproduction. Such a small rest-populations of Gongora guinquenervis (Orchidaceae), for instance, showed no fruit set despite of a 100% pollinaria removal rate by Euglossa cordata and E. perpulchra in a small forest fragment near the present study site (Martini et al. 2003). Species of Catasetum (Orchidaceae) are threatened in the same way, as these dioecious orchids in the Atlantic Rainforest of Pernambuco are pollinated exclusively by males of Eulaema bombyciformis (Carvalho & Machado 2002), bees that in our study did not leave the closed forest.

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