

# The orchid-bee fauna (Hymenoptera: Apidae) of ‘RPPN Feliciano Miguel Abdala’ revisited: relevant changes in community composition

Nemésio, A.\* and Paula, IRC.

Instituto de Biologia, Universidade Federal de Uberlândia, Rua Ceará S/N, Campus Umuarama, CEP 38.400-902, Uberlândia, MG, Brazil

\*e-mail: andre.nemesio@gmail.com

Received June 4, 2012 – Accepted August 8, 2012 – Distributed August 31, 2013

(With 1 figure)

## Abstract

The orchid-bee fauna of ‘Reserva Particular do Patrimônio Natural Feliciano Miguel Abdala’, a 957-ha preserve of Atlantic Forest in eastern Minas Gerais, southeastern Brazil, was surveyed 12 years after the first inventory in the area. Orchid-bee males were actively collected with insect nets when attracted to seventeen chemical compounds used as scent baits. Three hundred and nineteen males belonging to nine species were collected during 40 hours in late December, 2011, when orchid bees are supposedly more active. *Euglossa despecta* Moure, 1968, one of the dominant species in the area 12 years ago, was not recorded in the present study. *Eulaema nigrata* Lepeletier, 1841, on the other hand, represented only 16% of the collected bees in 1999 and 61% in the present study. Possible causes and consequences of these changes are discussed.

**Keywords:** Atlantic Forest, conservation, Euglossina, euglossine bees, Hexapoda.

## A fauna de abelhas-das-orquídeas (Hymenoptera: Apidae) da RPPN Feliciano Miguel Abdala revisitada: mudanças relevantes na composição da comunidade

### Resumo

A fauna de abelhas-das-orquídeas da ‘Reserva Particular do Patrimônio Natural Feliciano Miguel Abdala’, uma reserva de 957 ha de Mata Atlântica no leste de Minas Gerais, sudeste do Brasil, foi amostrada doze anos após o primeiro inventário na área. Machos de abelhas euglossinas foram ativamente coletados com o uso de redes entomológicas quando atraídos a dezessete compostos aromáticos utilizados como iscas. Trezentos e dezenove machos pertencentes a nove espécies foram coletados durante 40 horas de amostragem no fim de dezembro de 2011, no período em que essas abelhas estão supostamente mais ativas. *Euglossa despecta* Moure, 1968, uma das espécies dominantes na área doze anos antes, não foi registrada no presente estudo. *Eulaema nigrata* Lepeletier, 1841, por outro lado, representou apenas 16% das abelhas coletadas em 1999 e 61% no presente estudo. As possíveis causas e consequências dessas mudanças são discutidas.

**Palavras-chave:** Abelhas euglossinas, conservação, Euglossina, Hexapoda, Mata Atlântica.

### 1. Introduction

Orchid bees (Hymenoptera: Apidae: Euglossina) are important Neotropical pollinators (see Dressler, 1982a) and have gained in popularity among field researchers since the late 1960s, when it was realized that their males are easily attracted to aromatic compounds artificially synthesized that mimic floral fragrances (Vogel, 1966; Dodson et al., 1969).

As a direct consequence of this baiting methodology, large numbers of orchid bees began to be deposited in museums and entomological collections and it was soon realized that the previously known alpha-diversity of this group of insects had been underestimated. Many species were thus described during the two subsequent decades (e.g. Moure, 1967, 1968, 1969, 1970; Dressler, 1978,

1982b, c, d; Kimsey, 1977, 1982). Surveys of orchid bees in previously unsampled areas became an important part of orchid-bee studies, in order to fully understand the actual diversity of the group and, also, establish their precise geographic distributions (e.g. Braga, 1976; Powell and Powell, 1987; Rebêlo and Garófalo, 1991; 1997; Morato et al., 1992; Morato, 1994; Oliveira and Campos, 1995; Bonilla-Gómez, 1999; Bezerra and Martins, 2001; Santos and Sofia, 2002; Tonhasca Jr. et al., 2002; Nemésio and Silveira, 2006, 2007, 2010; Rasmussen, 2009; Nemésio and Vasconcelos, 2013).

As a consequence, very few studies have been carried out in areas where samplings had already been performed. Since many orchid bees are forest-dependent species (Dressler, 1982a; Morato et al., 1992; Morato,

1994) and at least one biome inhabited by these bees, the Atlantic Forest of eastern Brazil, has been heavily deforested and is still under strong anthropogenic pressure, it is reasonable to suppose that populations of the most sensitive species in these areas may be somehow affected. There is almost no study to show whether and how populations of these bees have been changing in the last years. The only study that addressed this subject (Nemésio, 2013b) suggested that the population of *Euglossa marianae* Nemésio, 2011b, a highly sensitive species, at a large remnant of Atlantic Forest in Linhares, state of Espírito Santo, has declined in almost 50% in a 12-year interval.

The main goal of the present study was to survey, twelve years after the first preliminary inventory, the orchid-bee fauna of a medium-sized Atlantic Forest remnant in southeastern Brazil (Nemésio, 2003) to assess possible changes in its community composition.

## 2. Material and Methods

### 2.1. Study sites

This study was conducted at 'Reserva Particular do Patrimônio Natural Feliciano Miguel Abdala' (RFMA), a 957-ha preserve situated in the municipality of Caratinga, in the state of Minas Gerais, southeastern Brazil, in late December, 2011, when orchid bees are most actively foraging in the region (e.g., Nemésio and Silveira, 2007, 2010). Vegetation at RFMA is Tropical Semideciduous Forest, included in the Tropical Atlantic domain (Ab'Saber, 1977), and presents different successional stages (Hatton et al., 1983). Precipitation is highly seasonal, with a rainy season, from October to March, and a well-defined dry season from April to September (Strier, 1986). Elevations range from 400 to 680 m above sea level (Silva, 1993).

### 2.2. Sampling

Twenty hours of active sampling with insect nets were performed exactly in the same sites sampled 12 years before (see Nemésio, 2003), totaling 40 hours, following the methodology proposed by Nemésio (2010a, b, 2011a, b). The exact location of each site is: site-1, or the interior of forest in Nemésio (2003) (19°43'54" S - 41°49'26" W, ca. 500 m above sea level) was sampled on the 21<sup>st</sup> (from 09:00 h to 14:00 h), 22<sup>nd</sup> (from 08:00 h to 15:00 h) and 24<sup>th</sup> of December, 2011 (from 08:00 h to 16:00 h); site-2, or the site close to the edge in Nemésio (2003) (19°44'00" S - 41°49'16" W, ca. 500 m above sea level) was sampled on the 23<sup>rd</sup> and 25<sup>th</sup> of December, 2011 (in both dates from 07:00 h to 17:00 h). At each site, 17 scent baits were placed ca. 2.0 meters apart from each other at about 1.5 m above the ground. These baits were made of cotton wadding soaked with one of the following substances, known or believed to be attractive to orchid bees: benzyl acetate, benzyl alcohol, *r*-carvone, 1,8-cineole, *p*-cresol acetate, dimethoxybenzene, eugenol,  $\beta$ -

ionone, methyl benzoate, methyl *trans*-cinnamate, heneicosane, methyl salicylate, skatole, tricosane, *p*-tolyl acetate, vanillin, and a mixture (1:1) of methyl *trans*-cinnamate and *p*-tolyl acetate. Baits with cineole, the most volatile compound, were recharged every hour. Bees arriving on the baits during the sampling period were collected with insect nets and killed with ethyl acetate. They were labeled as belonging to the project "Euglossina de Caratinga" and were deposited at the Entomological Collection of Universidade Federal de Uberlândia (UFU), where they were numbered from 22141-65214 to 22286-65603.

### 2.3. Data analysis

Diversity was estimated through Shannon-Wiener diversity index ( $H'$ ), as  $H' = -\sum p_i \ln(p_i)$ , where  $p_i$  is the proportion of total number of species made up of the  $i$ th species (Pielou, 1975). Evenness ( $E$ ) was estimated through the formula  $E = H' / \ln(S)$ , where  $S$  is the species richness. Diversity and evenness were estimated both to the samplings carried out in the present study and to the samplings carried out in 1999 (Nemésio, 2003) for comparison. Similarity in faunistic composition between collections carried out in 1999 (Nemésio, 2003) and in the present study was estimated by the percent similarity index of Renkonen, recommended by Wolda (1981) and Balmer (2002) for small samples.

### 2.4. Taxonomy

Taxonomy follows Nemésio & Rasmussen (2011).

## 3. Results

Three hundred and nineteen orchid-bee males belonging to eight species in three genera were collected in the present study, 172 (in 6 species) at site-1 (interior of forest) and 147 (in 6 species) at site-2 (close to the edge) (Table 1). Additionally, a single specimen of *Euglossa carolina* Nemésio, 2009 was collected at a third site not included in the analysis, because it was sampled during only five hours. One specimen of a species belonging to the *Euglossa analis* Westwood, 1840 species group visited the skatole bait at site-2, but was not collected. Although it is impossible to know the exact species it belongs to, it is not *Eg. marianae* because the last three terga were reddish, not green. *Eulaema nigrata* Lepelletier, 1841 (61% of the total specimens, and the dominant species at both sites) was the most common species at RFMA, followed by *Eulaema marcii* Nemésio, 2009 (17%) and *Eg. fimbriata* Moure, 1968 (14%). These three species together represented 92% of the orchid-bee community during the sampling period. The only species represented by a singleton was *Eg. truncata* Rebêlo and Moure, 1996. Abundance (ca. 8.6 specimens/hour), diversity ( $H' = 1.26$ ) and evenness ( $E = 0.65$ ) were higher at site-1 than at site-2 (ca. 7.3 specimens/hour;  $H' = 1.04$ ;  $E = 0.58$ ). Renkonen similarity index between samplings carried out in 1999 and in the present study was only 38%.

**Table 1** - Diversity, evenness, species richness and number of specimens of each orchid-bee species collected at sites 1 (forest) and 2 (edge) at RPPN Feliciano Miguel Abdala in late December, 2011.

Espécie	Ponto 1	Ponto 2	Total
<i>Eufriesea surinamensis</i> (Linnaeus, 1758)	03	00	03
<i>Ef. violacea</i> (Blanchard, 1840)	15	01	16
<i>Euglossa fimbriata</i> Moure, 1968	18	26	44
<i>Eg. pleosticta</i> Dressler, 1982	02	00	02
<i>Eg. securigera</i> Dressler, 1982	02	04	06
<i>Eg. truncata</i> Rebêlo and Moure, 1996	00	01	01
<i>Eulaema marcii</i> Nemésio, 2009	33	21	54
<i>El. nigrita</i> Lepeletier, 1841	99	94	193
Total	172	147	319
Species	7	6	8
Diversity	1.26	1.04	1.20
Evenness	0.65	0.58	0.58

#### 4. Discussion

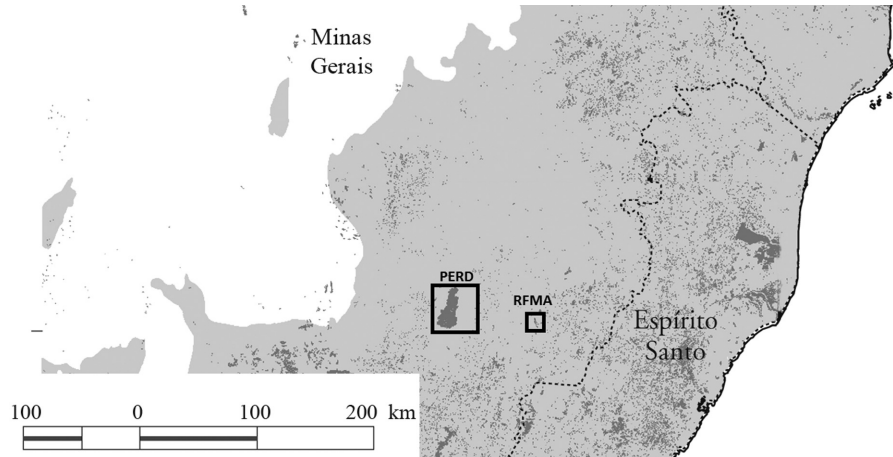
The efficiency of the sampling methodology used here was previously discussed in depth (Nemésio 2011a; Nemésio et al., 2012). The relatively low abundance found in the present study (seven to nine specimens/hour) compared to other studies using the same methodology (Nemésio, 2010a, b, 2011a, b, 2013a-d), may be partially understood as natural of the area, since the previous studies were carried out at Centro de Endemismo Pernambuco (Nemésio 2010a, b) and 'Hileia Baiana' (Nemésio 2011a, b), two regions well known for their high abundance and diversity (Bonilla-Gómez, 1999; Bezerra and Martins, 2001). On the other hand, it must be noticed that abundance at RFMA in 1999 was higher (ca. 12 specimens/hour, or 50% higher) than in the present study. It also should be stressed that collections in 1999 were carried out during only five hours in each site (vs. 20 hours in each site in the present study); as abundance is here given as the number of specimens collected per hour, this difference in sampling effort is, thus, reduced.

Seven species were collected in 1999 and only *Euglossa despecta* Moure, 1968 was collected then (Nemésio, 2003) and not collected in the present study. However, this species was one of the dominant species in 1999 and its absence in the present study is remarkable, especially because the bait that most strongly attracted it ( $\beta$ -ionone) was also used in the present study. On the other hand, four species collected in the present study were not recorded in 1999: the highly seasonal *Eufriesea surinamensis* (Linnaeus, 1758) and *Ef. violacea* (Blanchard, 1840), and *Euglossa carolina* (collected in a third site not included in the present analysis), besides one specimen belonging to the *Euglossa analis* species group, not collected, but attracted to skatole at site-2, and presenting the last three terga reddish. In the nearby 'Parque Estadual do Rio Doce' (see Figure 1), two spe-

cies belonging to the *Eg. analis* species group were collected, *Euglossa cognata* Moure, 1970 and *Eg. marianae* (see Nemésio and Silveira, 2006 - *Eg. marianae* listed as *Eg. analis*), but *Eg. marianae* should be discarded since this species presents the last three terga green-colored. A third species, *Eg. mixta* Friese, 1899 was recorded deep in the interior of Minas Gerais (Nemésio, 2012), almost at the same longitude as RFMA, but at a lower latitude. It is impossible, thus, to know to which species the observed specimen belongs to. The number of species known to occur at RFMA, consequently, rises to eleven.

Although being a relatively large forest remnant of the Atlantic Forest in the state of Minas Gerais, and although considered to be of very high to extreme importance for conservation for many taxonomic groups (Fonseca and Rylands, 1998; Marini and Lamas, 1998; Silva and Mendonça, 1998; Haddad, 2000), including invertebrates (Silveira, 1998), RFMA apparently does not hold a rich and diverse orchid-bee fauna. In fact, the dominant species, especially *Eulaema nigrita* and *El. marcii*, are among the most common orchid-bee species in the Neotropics and considered to be tolerant to disturbed areas (Morato, 1998; Tonhasca Jr. et al., 2002; Nemésio and Silveira, 2006). Even smaller forest remnants, immersed in an urban matrix, and located in drier portions of the Atlantic Forest (Nemésio and Silveira, 2007, 2010) seem to present a more diverse orchid-bee fauna than RFMA.

The fluctuation in the orchid-bee community composition between both samplings (Nemésio, 2003 and the present study) is also remarkable. Although diversity and abundance did not change greatly, and almost all species collected in 1999 were also collected in the present study, their relative abundances changed dramatically and the only missing species from 1999 to 2011 (*Eg. despecta*) was an important part of the orchid-bee community twelve years before. The absence of *Eg. despecta*, and the



**Figure 1** - Map showing the exact locations of ‘Reserva Particular do Patrimônio Natural Feliciano Miguel Abdala’ (RFMA) and the nearby ‘Parque Estadual do Rio Doce’ (PERD), also mentioned in the text.

enormous rise of the relative contributions of *Eg. fimbriata* and *El. nigrita* to the orchid-bee community of RFMA in the present study made the similarity of both “faunas” to be only 38%, a very low value. Seasonality may respond for at least part of the observed change: the first sampling was carried out in August, 1999, in the middle of the dry season, while the present sampling was conducted in late December, exactly when precipitation is the highest at RFMA. Some species, as *El. nigrita*, present their lowest abundance during the middle to the end of the dry season in the region (Nemésio, unpub. data), and it may account for the observed differences. On the other hand, the absence of *Eg. despecta* is not easily explained. It is known that populations of many species of orchid bees largely fluctuates (Roubik, 2001). However, this species occurred in relatively high abundances during the rainy season in recent collections in the ‘Hileia Baiana’ (Nemésio, 2011a, b). Moreover, its population did not “fluctuate”, but entirely “disappeared” and there is no apparent explanation for its absence from RFMA. *Euglossa despecta* was also an important part of the orchid-bee fauna of ‘Parque Estadual do Rio Doce’, distant only 60 km from RFMA, in 1999 (Nemésio and Silveira, 2006). Nemésio and Silveira (2007) argued that deforestation and consequent fragmentation in many parts of the Atlantic Forest are relatively recent events, and populations of some species could be declining towards extinction in some of these forest remnants. The observed decline of populations of *Eg. marianae* at a large remnant in the state of Espírito Santo (Nemésio, 2013b) in a 12-year interval is suggestive of this hypothesis. Furthermore, except for this study and Nemésio (2013b), there is virtually no study comparing changes in orchid-bee community compositions in mid to long terms, and we largely ignore what is happening to populations of these forest-dependent species in most areas. Studies focusing on this approach are, thus, urgently needed.

## Acknowledgments

The Brazilian government, through the environmental departments IBAMA and ICMBio, provided the collecting permit (#29472-1). Universidade Federal de Uberlândia partially funded this study through a grant provided by “Edital PROPP 04/2011”. I express my gratitude to Marcello Nery (Sociedade para Preservação do Muriqui), administrator of ‘RPPN Feliciano Miguel Abdala’, for allowing me to sample the area and for all support during my field research. Bruna Karen Pinheiro Costa pinned the specimens. Two anonymous referees made valuable comments on the first draft of this manuscript.

## References

- AB’SABER, AN., 1977. Os domínios morfo-climáticos na América do Sul. Primeira aproximação. *Geomorfologia*, vol. 52, p. 1-22.
- BALMER, O., 2002. Species lists in ecology and conservation: abundances matter. *Conservation Biology*, vol. 16, p. 1160-1161.
- BEZERRA, CP. and MARTINS, CF., 2001. Diversidade de Euglossinae (Hymenoptera, Apidae) em dois fragmentos de Mata Atlântica localizados na região urbana de João Pessoa, Paraíba, Brasil. *Revista Brasileira de Zoologia*, vol. 18, p. 823-835.
- BLANCHARD, E., 1840. Orthoptères, Néuroptères, Hyménoptères, Lepidoptères, et Diptères. In LAPORTE, FL. *Histoire naturelle des animaux articulés, Annelides, Crustacés, Arachnides, Myriapodes et Insectes, Vol. 3*. Paris: Dumeril. 672 p.
- BONILLA-GÓMEZ, MA., 1999. *Caracterização da Estrutura Espaço-temporal da Comunidade de Abelhas Euglossinas (Hymenoptera, Apidae) na Hileia Bahiana*. Campinas: Universidade Estadual de Campinas. 153 pp. Tese de Doutorado.
- BRAGA, PIS., 1976. Atração de abelhas polinizadoras de Orchidaceae com auxílio de iscas-odores na campina, campinarana e floresta tropical úmida da região de Manaus. *Ciência e Cultura*, vol. 28, p. 767-773.

- DODSON, CH., DRESSLER, RL., HILLS, GH., ADAMS, RM. and WILLIAMS, NH., 1969. Biologically active compounds in orchid fragrances. *Science*, vol. 164, p. 1243-1249.
- DRESSLER, RL., 1978. An infrageneric classification of *Euglossa*, with notes on some features of special taxonomic importance (Hymenoptera; Apidae). *Revista de Biologia Tropical*, vol. 26, p. 187-198.
- , 1982a. Biology of the orchid bees (Euglossini). *Annual Review of Ecology and Systematics*, vol. 13, p. 373-394.
- , 1982b. New species of *Euglossa* II. (Hymenoptera: Apidae). *Revista de Biologia Tropical*, vol. 30, p. 121-129.
- , 1982c. New species of *Euglossa*. III. The *bursigera* species group (Hymenoptera: Apidae). *Revista de Biologia Tropical*, vol. 30, p. 131-140.
- , 1982d. New species of *Euglossa* IV. The *cordata* and *purpurea* species groups. *Revista de Biologia Tropical*, vol. 30, p. 141-150.
- FONSECA, MT. and RYLANDS, AB., 1998. Mastofauna. In COSTA, CMR., HERRMANN, G., MARTINS, CS., LINS, LV. and LAMAS, IR. (Eds.). *Biodiversidade em Minas Gerais - Um atlas para sua conservação*. Belo Horizonte: Fundação Biodiversitas. p. 34-36.
- FRIESE, H., 1899. Monographie der Bienengattung *Euglossa* Latr. *Természetráji Füzetek*, vol. 22, p. 117-172.
- HADDAD, CFB., 2000. Anfíbios e Répteis. In MINISTÉRIO DO MEIO AMBIENTE, CONSERVATION INTERNATIONAL DO BRASIL, FUNDAÇÃO SOS MATA ATLÂNTICA, FUNDAÇÃO BIODIVERSITAS, INSTITUTO DE PESQUISAS ECOLÓGICAS, SECRETARIA DO MEIO AMBIENTE DO ESTADO DE SÃO PAULO, SEMAD/INSTITUTO ESTADUAL DE FLORESTAS. *Avaliação e Ações Prioritárias para a Conservação da Biodiversidade da Mata Atlântica e Campos Sulinos*. Brasília: Ministério do Meio Ambiente. p. 19-21.
- HATTON, JNS. and THOMSON, K., 1983. In urgent need of protection-habitat for the woolly spider monkey. *Orix*, vol. 18, p. 24-29.
- KIMSEY, LS., 1977. New species in the genera *Euplusia* and *Eufriesia*. *Pan-Pacific Entomologist*, vol. 53, p. 8-18.
- , 1982. Systematics of bees of the genus *Eufriesia*. *University of California Publications in Entomology*, vol. 95, p. 1-125.
- LEPELETIER DE SAINT FARGEAU, ALM., 1841. *Histoire Naturelle des Insectes, Hyménoptères, Vol. 2*. Paris: Librairie Encyclopédique de Roret. 680 p.
- LINNAEUS, C., 1758. *Systema Naturae per Regna tria Naturae, secundum Classes, Ordines, Genera, Species, cum Characteribus, Differentiis, Synonymis, Locis*. Tomus I. Editio Decima Reformata. Stockholm: Laurentii Salvii. 823 p.
- MARINI, MA. and LAMAS, IR. 1998. Avifauna. In COSTA, CMR., HERRMANN, G., MARTINS, CS., LINS, LV. and LAMAS, IR. (Eds.), *Biodiversidade em Minas Gerais - Um atlas para sua conservação*. Belo Horizonte: Fundação Biodiversitas. p. 37-39.
- MORATO, EF., 1994. Abundância e riqueza de machos de Euglossini (Hymenoptera: Apidae) em mata de terra firme e áreas de derrubada, nas vizinhanças de Manaus (Brasil). *Boletim do Museu Paraense Emílio Goeldi, Série Zoologia*, vol. 10, p. 95-105.
- , 1998. Estudos sobre comunidades de abelhas Euglossini. *Anais do Encontro sobre Abelhas*, vol. 3, p. 135-143.
- MORATO, EF., CAMPOS, LAO. and MOURE, JS., 1992. Abelhas Euglossini (Hymenoptera, Apidae) coletadas na Amazônia Central. *Revista Brasileira de Entomologia*, vol. 36, p. 767-771.
- MOURE, JS., 1967. Descrição de algumas espécies de Euglossinae (Hym., Apoidea). *Atas do Simpósio sobre a Biota Amazônica*, vol. 5, p. 373-394.
- , 1968. Espécies novas de *Euglossa* da América Central. *Boletim da Universidade Federal do Paraná, Zoologia*, vol. 3, p. 13-64.
- , 1969. The Central American species of *Euglossa* subgenus *Glossura* Cockerell, 1917 (Hymenoptera, Apidae). *Revista de Biologia Tropical*, vol. 15, p. 227-247.
- , 1970. The species of euglossine bees of Central América belonging to the subgenus *Euglossella*. *Anais da Academia Brasileira de Ciências*, vol. 42, p. 148-157.
- NEMÉSIO, A., 2003. Preliminary sampling of Euglossina (Hymenoptera: Apidae: Apini) of Reserva Particular do Patrimônio Natural Feliciano Miguel Abdala, Caratinga, Minas Gerais state, Brazil. *Lundiana*, vol. 4, p. 121-124.
- , 2009. Orchid bees (Hymenoptera: Apidae) of the Brazilian Atlantic Forest. *Zootaxa*, vol. 2041, p. 1-242.
- , 2010a. *Eulaema (Apeulaema) felipei* sp. n. (Hymenoptera: Apidae: Euglossina): a new forest-dependent orchid bee found at the brink of extinction in northeastern Brazil. *Zootaxa*, vol. 2424, p. 51-62.
- , 2010b. The orchid-bee fauna (Hymenoptera: Apidae) of a forest remnant in northeastern Brazil, with new geographic records and an identification key to the known species of the Atlantic Forest of northeastern Brazil. *Zootaxa*, vol. 2656, p. 55-66.
- , 2011a. The orchid-bee fauna (Hymenoptera: Apidae) of a forest remnant in southern Bahia, Brazil, with new geographic records and an identification key to the known species of the area. *Zootaxa*, vol. 2821, p. 47-54.
- , 2011b. *Euglossa marianae* sp. n. (Hymenoptera: Apidae): a new orchid bee from the Brazilian Atlantic Forest and the possible first documented local extinction of a forest dependent orchid bee. *Zootaxa*, vol. 2892, p. 59-68.
- , 2012. The western limits of the 'Hileia Baiana' for orchid bees (Hymenoptera: Apidae: Euglossina), including seven new records for the state of Minas Gerais, eastern Brazil. *Spixiana*, vol. 35, p. 109-116.
- , 2013a. The orchid-bee fauna (Hymenoptera: Apidae) of 'Reserva Biológica de Una', a hotspot in the Atlantic Forest of southern Bahia, eastern Brazil. *Brazilian Journal of Biology*, vol. 73, n. 2, p. 347-352.
- , 2013b. Are orchid bees at risk? First comparative survey suggests declining populations of forest-dependent species. *Brazilian Journal of Biology*, vol. 73, n. 2, p. 367-374.
- , 2013c. The orchid-bee faunas (Hymenoptera: Apidae) of two Atlantic Forest remnants in southern Bahia, eastern Brazil. *Brazilian Journal of Biology*, vol. 73, n. 2, p. 375-381.
- , 2013d. The orchid-bee faunas (Hymenoptera: Apidae) of 'Parque Nacional do Monte Pascoal', 'Parque Nacional do Descobrimento' and three other Atlantic Forest remnants in southern Bahia, eastern Brazil. *Brazilian Journal of Biology*, vol. 73, n. 2, p. 437-446.
- NEMÉSIO, A., CERÂNTOLA, NCM., VASCONCELOS, HL., NABOUT, J.C., SILVEIRA, FA. and DEL LAMA, MA., 2012. Searching for *Euglossa cyanochlora* Moure, 1996 (Hymenoptera: Apidae), one of the rarest bees in the world. *Journal of Insect Conservation*, vol. 16, p. 745-755.
- NEMÉSIO, A. and RASMUSSEN, C., 2011. Taxonomic issues in the orchid bees (Hymenoptera: Apidae: Euglossina), and an updated catalogue. *Zootaxa*, vol. 3006, p. 1-42.

- NEMÉSIO, A. and SILVEIRA, FA., 2006. Edge effects on the orchid-bee fauna (Hymenoptera: Apidae) at a large remnant of Atlantic Forest in southeastern Brazil. *Neotropical Entomology*, vol. 35, p. 313-323.
- , 2007. Orchid bee fauna (Hymenoptera: Apidae: Euglossina) of Atlantic Forest fragments inside an urban area in southeastern Brazil. *Neotropical Entomology*, vol. 36, p. 186-191.
- , 2010. Forest fragments with larger core areas better sustain diverse orchid bee faunas (Hymenoptera: Apidae: Euglossina). *Neotropical Entomology*, vol. 39, p. 555-561.
- NEMÉSIO, A. and VASCONCELOS, HL. 2013. Beta diversity of orchid bees in a tropical biodiversity hotspot. *Biodiversity and Conservation*, vol. 22, p. 1647-1661.
- OLIVEIRA, ML. and CAMPOS, LAO., 1995. Abundância, riqueza e diversidade de abelhas Euglossinae (Hymenoptera: Apidae) em florestas contínuas de terra firme na Amazônia central, Brasil. *Revista Brasileira de Zoologia*, vol. 12, p. 547-556.
- PIELOU, EC., 1975. *Ecological diversity*. New York: John Wiley & Sons. 165 pp.
- POWELL, AH. and POWELL, GVN., 1987. Population dynamics of male euglossine bees in Amazonian forest fragments. *Biotropica*, vol. 19, p. 176-179.
- RASMUSSEN, C. 2009. Diversity and abundance of orchid bees (Hymenoptera: Apidae, Euglossini) in a tropical rainforest succession. *Neotropical Entomology*, vol. 38, p. 66-73.
- REBÊLO, JMM. and GARÓFALO, CA., 1991. Diversidade e sazonalidade de machos de Euglossini (Hymenoptera, Apidae) e preferência por iscas odores em um fragmento de floresta no sudeste do Brasil. *Revista Brasileira de Biologia*, vol. 51, p. 787-799.
- , 1997. Comunidades de machos de Euglossinae (Hymenoptera, Apidae) em matas semidecíduas do nordeste do estado de São Paulo. *Anais da Sociedade Entomológica do Brasil*, vol. 26, p. 243-256.
- REBÊLO, JMM. and MOURE, JS. 1996. [1995] As espécies de *Euglossa* Latreille do nordeste de São Paulo (Apidae, Euglossinae). *Revista Brasileira de Zoologia*, vol. 12, p. 445-466.
- ROUBIK, DW., 2001. Ups and downs in pollinator populations: when is there a decline? *Conservation Ecology*, vol. 5 Available from: <http://www.consecol.org/vol5/iss1/art2>.
- SANTOS, AM. and SOFIA, SH., 2002. Horário de atividade de machos de Euglossinae (Hymenoptera, Apidae) em um fragmento de floresta semidecídua no norte do estado do Paraná. *Acta Scientiarum*, vol. 24, p. 375-381.
- SILVA, AF. and MENDONÇA, MP., 1998. Flora. In COSTA, CMR., HERRMANN, G., MARTINS, CS., LINS, LV. and LAMAS, IR. (Eds.), *Biodiversidade em Minas Gerais - Um atlas para sua conservação*. Belo Horizonte: Fundação Biodiversitas. pp. 49-51.
- SILVA, LVC., 1993. Comparação fitossociológica entre duas amostragens numa área de clareira em anos consecutivos, Estação Biológica de Caratinga, MG. *Acta Botânica Brasileira*, vol. 7, p. 119-127.
- SILVEIRA, FA., 1998. Fauna de Invertebrados. In COSTA, CMR., HERRMANN, G., MARTINS, CS., LINS, LV. and LAMAS, IR. (Eds.), *Biodiversidade em Minas Gerais - Um atlas para sua conservação*. Belo Horizonte: Fundação Biodiversitas. pp. 25-29.
- STRIER, KB., 1986. *The behavior and ecology of the woolly spider monkey, or muriqui* (Brachyteles arachnoides E. Geoffroy, 1806). Cambridge: University of Harvard. Ph.D. Thesis.
- TONHASCA Jr., A., BLACKMER, JL. and ALBUQUERQUE, GS., 2002. Abundance and diversity of euglossine bees in the fragmented landscape of the Brazilian Atlantic Forest. *Biotropica*, vol. 34, p. 416-422.
- VOGEL, S. 1966. Parfümsammelnde Bienen als Bestäuber von Orchidaceen und Gloxinia. *Österreichische botanische Zeitschrift*, vol. 113, p. 302-361.
- WESTWOOD, JO., 1840. Entomology [Vol. 6]. Bees, comprehending the uses and economical management of the honey-bee of Britain and other countries, together with descriptions of the known wild species. In JARDINE, W. (Ed.). *The naturalist's library*. Edinburgh: W.H. Lizars. p. 17-301.
- WOLDA, H., 1981. Similarity indices, sample sizes and diversity. *Oecologia*, vol. 50, p. 296-302.