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## The western limits of the “Hileia Baiana” for orchid bees, including seven new records for the state of Minas Gerais, eastern Brazil

(Hymenoptera, Apidae, Euglossina)

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The orchid-bee faunas of Reserva Biológica da Mata Escura and RPPN Duas Barras, in the northeastern portion of the state of Minas Gerais, and one forest fragment in the municipality of Guaratinga, at the border of the states of Bahia and Minas Gerais, eastern Brazil, were surveyed for the first time. A total of 1182 males belonging to 26 species were attracted to 16 different scent baits and actively collected with insect nets during 160 hours from January, 2009 to February, 2011. Besides *Euglossa bembai* Nemésio, 2011 and *Exaerete salsai* Nemésio, 2011, recently described from the same region, and *Eufriesea brasilianorum* (Fries, 1899), recently reported from RPPN Duas Barras, seven orchid-bee species are here recorded for the first time for the state of Minas Gerais: *Euglossa amazonica* Dressler, 1982, *Euglossa augaspis* Dressler, 1982, *Euglossa ignita* Smith, 1874, *Euglossa mixta* Fries, 1899, *Euglossa roubiki* Nemésio, 2009, *Eulaema atleticana* Nemésio, 2009, and *Eulaema niveofasciata* (Fries, 1899). The orchid-bee faunas of RPPN Duas Barras and the forest fragment in Guaratinga show stronger resemblance to those of areas in the coast, whereas at REBIO Mata Escura it is more similar to those of drier areas in the states of Minas Gerais and São Paulo. These results suggest that the border between the states of Minas Gerais and Bahia is the western limit of the “Hileia Baiana” for orchid bees.

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### Introduction

The coastal Atlantic Forest of southern state of Bahia and northern state of Espírito Santo, eastern Brazil, was probably the most exuberant portion of the original Atlantic Rain Forest, with high levels of diversity and endemism (e. g. Dean 1995, Thomas et al. 1998). Due to its resemblance to the Amazon Forest (the “Hileia”), this portion of the Atlantic Forest was named “Hileia Baiana” by Andrade-Lima (1966). The limits of the Hileia Baiana have traditionally been restricted to the coastal areas, being replaced by semi-

deciduous forests as one moves westwards.

The distribution of orchid bees (Hymenoptera: Apidae: Euglossina) in the Atlantic Forest, including the “Hileia Baiana” region, is still poorly known, despite recent attempts to combine data from surveys carried out in this biome to infer potential geographic ranges of species (e. g. Nemésio & Silveira 2007, Nemésio 2009, Sydney et al. 2010). Except for fortuitous collections carried out in southern Bahia and northern Espírito Santo, and two unpublished studies carried out at the region (Bonilla-Gómez 1999, Melo 2005), virtually no detailed survey of the

orchid-bee fauna of the Hileia Baiana had been carried out until the recent works by Nemésio (2011a,b). Data from these latter studies suggest that there is a rapid impoverishment of the orchid-bee diversity with increasing distance from the coast, as inferred from the comparison between two areas close to the coast and one forest remnant situated deeper in the interior in northern Espírito Santo (Nemésio 2011b). Nevertheless, such inference based upon only one study and, especially, in a so devastated region as northern Espírito Santo, where the studied forest remnant (REBIO Córrego do Veado) is very small and completely isolated, surrounded by pastures (Nemésio 2011b), may not be conclusive of the extension of the influence of the “Hileia Baiana” westwards, concerning orchid bees. Thus, the main goals of this study were: (i) to inventory the orchid-bee faunas of two forest preserves at the northeastern portion of the state of Minas Gerais and (ii) to investigate the western limits of the coastal “Hileia Baiana” regarding euglossine bees.

## Material and methods

### Study sites

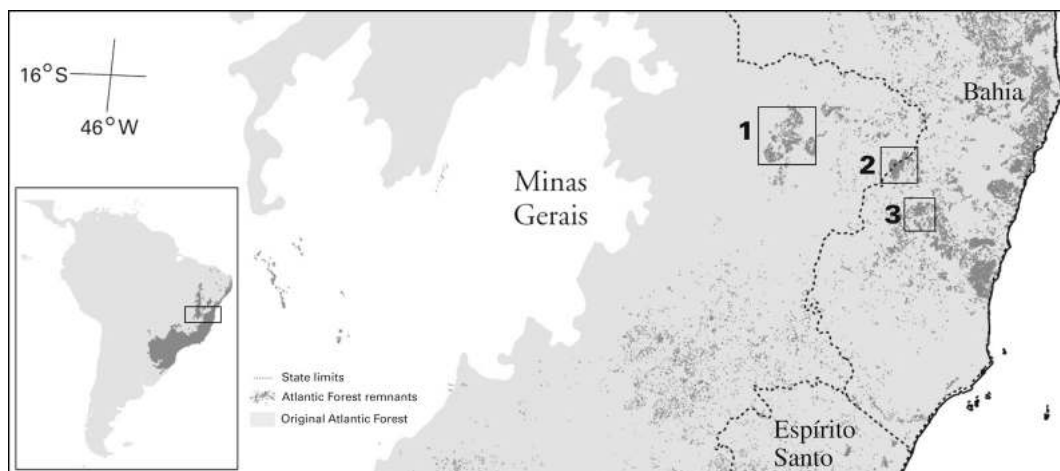
This study was conducted at two Atlantic Forest preserves in the state of Minas Gerais (Fig. 1): Reserva Biológica da Mata Escura (REBIO Mata Escura, 16°21'S 41°00'W, ca. 40000 ha, municipality of Jequitinhonha) and Reserva Particular do Patrimônio Natural Duas Barras (RPPN Duas Barras, 16°25'S 40°03'W, ca. 1200 ha, municipality of Santa Maria do Salto) and at one non-protected forest fragment in the municipality of Guaratinga (16°33'S 39°45'W, ca. 200 ha), state of Bahia, from January, 2009, to February, 2011, during three consecutive summers, when orchid bees are most active (e.g. Martins & Souza 2005). The original vegetation at the northeastern portion of Minas Gerais is a transition between the dense Atlantic Rain Forest and the semi-deciduous forest typical of the interior, but most part of the region was severely deforested for timber exploitation and only scattered forest fragments remain. The forest preserve at RPPN Duas Barras is situated exactly at the border between the states of Minas Gerais (municipality of Santa Maria do Salto) and Bahia (municipality of Guaratinga) and is entirely located at the top of mountains, ranging from 800 m to 1100 m a.s.l. Although having an area of only 1200 ha, it is surrounded by the recent created ‘Parque Estadual do Alto Cariri’, in Minas Gerais, and ‘Parque Nacional do Alto Cariri’, in Bahia. This area is much closer to the coast than the forested area of REBIO Mata Escura (Fig. 1). This latter area presents altitudes ranging from 200 m to 1200 m a.s.l.

### Sampling

Each of three sites were sampled once at both preserves, at RPPN Duas Barras one of the sites was sampled twice in two alternate years (2009 and 2011). Twenty hours of active sampling with insect nets were performed at each site in the preserves, totalling 140 hours: (i) REBIO Mata Escura, site-1 (16°21'03"S 40°59'37"W, ca. 720 m a.s.l.) was sampled from 7–9 March 2009; (ii) REBIO Mata Escura, site-2 (16°23'23"S 40°59'33"W, ca. 410 m a.s.l.) was sampled on 10–11 March and 22 December 2009; (iii) REBIO Mata Escura, site-3 (16°21'00"S 41°05'31"W, ca. 1,150 m a.s.l.) was sampled on 12–13 March and 23 December 2009; (iv–v) RPPN Duas Barras, site-1 (16°24'52"S 40°03'14"W, ca. 900 m a.s.l.) was sampled twice: 1) on 23–24 January and 12 February 2009, and 2) on 28–29 December 2010 and 3 February 2011; (vi) RPPN Duas Barras, site-2 (16°24'22"S 40°02'51"W, ca. 900 m a.s.l.) was sampled on 13–14 February 2009; (vii) RPPN Duas Barras, site-3 (16°24'41"S 40°03'43"W, ca. 900 m a.s.l.) was sampled on 25 January and 4–5 February 2009. In Guaratinga, a much smaller forest fragment (ca. 200 ha), only one sampling site was selected (16°33'58"S 39°45'13"W, ca. 200 m a.s.l.), where twenty hours of active sampling with insect nets were performed. The municipality of Guaratinga is adjacent to the municipality of Santa Maria do Salto, where RPPN Duas Barras is located. At each site, 16 scent baits were placed ca. 2.0 metres apart from each other at about 1.5 m above the ground. These baits were made of cotton waddings 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 and vanillin. 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 labelled as belonging to the project “Euglossina da Hileia Baiana” and were deposited at the Entomological Collection of the ‘Universidade Federal de Minas Gerais’ (UFMG), where they were numbered from 17337-49447 to 17373-49598 and from 18772-53746 to 18923-54163 (specimens from REBIO Mata Escura), and from 18487-52998 to 18770-53744 (specimens from RPPN Duas Barras).

### Data analysis

In order to assess the limits of the “Hileia Baiana” westwards, data from two other studies carried out in the region (Nemésio 2011a,b) were used for comparison with data of the present study. In both studies – one carried out at Parque Estadual da Serra do Conduru (PESC), state of Bahia (Nemésio 2011a) and the other one carried out at three preserves in northern Espírito Santo (Nemésio 2011b) – sampling methodology was exactly the same as in the present study. The similarity of the faunistic composition across all sites was estimated by the per cent similarity index of Renkonen, recom-



**Fig. 1.** Map showing the locations of (1) REBIO Mata Escura and (2) RPPN Duas Barras in the state of Minas Gerais, and (3) the 200-ha site in Guaratinga, state of Bahia.

mended by Wolda (1981) for small samples. Based on those similarities, the areas were grouped using UPGMA (Sneath & Sokal 1973). For this analysis, all sites of RPPN Duas Barras were grouped together, as well as all sites at REBIO Mata Escura, both sites at PESC (Nemésio 2011a), both sites of REBIO Córrego do Veadó and both sites of FLONA Rio Preto.

### Taxonomy

Taxonomy follows Nemésio & Rasmussen (2011).

### Results

Altogether 1182 orchid-bee males belonging to 26 species were collected in both preserves in Minas Gerais and in the forest fragment in Bahia (Tables 1–3). When the second collection at site-1 of RPPN Duas Barras is excluded, the abundance of orchid bees in both REBIO Mata Escura and RPPN Duas Barras with the same sampling effort (60 hours at each preserve) is almost the same (329 and 326, respectively). The second collection at site-1 of RPPN Duas Barras recorded 312 specimens, representing almost 50 % of all orchid bees collected at that area (Table 2). The abundance ranged from about three specimens collected per hour at RPPN Duas Barras, site-3, to around nine specimens collected per hour at REBIO Mata Escura, site-2, and 16 specimens collected per hour during the second collection at RPPN Duas Barras, site-1 (Tables 1 and 2). Twenty-one species were collected at RPPN Duas Barras, whereas 13 species were recorded at REBIO Mata Escura. *Eulaema nigrita* Lepeletier, 1841 was the dominant

species at both preserves. *Euglossa roubiki* Nemésio, 2009 was the second most common species at RPPN Duas Barras (this species was not recorded at REBIO Mata Escura) and *Euglossa fimbriata* Moure, 1968 was the second most common species at REBIO Mata Escura (only four specimens of this species were collected at RPPN Duas Barras) (Tables 1 and 2). Fourteen species were collected at the forest fragment in Guaratinga, and *Eulaema nigrita* was also the dominant species at this site (Table 3).

The ordination of the sites according to their faunas (Fig. 2) shows a great overall similarity among sites situated closer to the coast (PESC, RCG and FRP), regardless of the distance among them (notice that RCG and FRP are close to each other, but PESC is situated some 300 km northwards (see Fig. 1). The sites at Guaratinga (GUA) and REBIO Córrego do Veadó (RCV), intermediate between the coastal and the inner portions of the Atlantic Forest, also shares a great overall similarity. RPPN Duas Barras still shares ca. 50 % similarity with the coastal and intermediate areas and shows to be closer to them than to the innermost area, REBIO Mata Escura, which shows only ca. 38 % similarity with the other areas.

### Discussion

The strategy of intensive sampling over a few days during the rainy season has been demonstrated to be very useful (Nemésio 2010b, 2011a,b). The number of specimens collected per hour in this study is lower than those recorded in previous studies using the

same methodology (Nemésio 2010b, 2011a,b). But it should be pointed out that the areas sampled in the present study are situated in drier portions of the Atlantic Forest domain, where abundance and

diversity of orchid bees are usually low, even in large and well-preserved forest remnants (e.g. Nemésio & Silveira 2006b, 2010).

As shown above, the abundance of orchid bee

**Table 1.** Species and number of specimens of each species collected at each of the three sampling sites at REBIO Mata Escura, Minas Gerais, Brazil.

Species	Site 1	Site 2	Site 3	Total
<i>Eufriesea auriceps</i> (Friese, 1899)	0	0	2	2
<i>Ef. surinamensis</i> (Linnaeus, 1758)	0	3	0	3
<i>Euglossa aratingae</i> Nemésio, 2009	1	2	0	3
<i>Eg. carolina</i> Nemésio, 2009	4	16	4	24
<i>Eg. crassipunctata</i> Moure, 1968	5	3	1	9
<i>Eg. fimbriata</i> Moure, 1968	3	88	8	99
<i>Eg. leucotricha</i> Rebêlo & Moure, 1996	0	1	0	1
<i>Eg. mixta</i> Friese, 1899	1	5	0	6
<i>Eg. pleosticta</i> Dressler, 1982b	1	11	0	12
<i>Eg. securigera</i> Dressler, 1982b	5	6	1	12
<i>Eg. truncata</i> Rebêlo & Moure, 1996	1	1	1	3
<i>Eulaema marcii</i> Nemésio, 2009	11	2	4	17
<i>El. nigrita</i> Lepeletier, 1841	46	45	47	138
Total	78	183	68	329

**Table 2.** Species and number of specimens of each species collected at each of the three sampling sites at RPPN Duas Barras, Minas Gerais, Brazil. Two collections were carried out at site 1 (see Material and methods).

Species	Site 1	Site 1*	Site 2	Site 3	Total
<i>Eufriesea atlantica</i> Nemésio, 2008	2	3	2	1	8
<i>Ef. brasilianorum</i> (Friese, 1899)	0	3	0	0	3
<i>Euglossa amazonica</i> Dressler, 1982b	0	1	0	0	1
<i>Eg. augaspis</i> Dressler, 1982a	0	13	0	2	15
<i>Eg. bembei</i> Nemésio, 2011d	3	1	2	2	8
<i>Eg. carolina</i> Nemésio, 2009	5	7	2	0	14
<i>Eg. crassipunctata</i> Moure, 1968	3	6	5	0	14
<i>Eg. fimbriata</i> Moure, 1968	0	3	1	0	4
<i>Eg. ignita</i> Smith, 1874	8	20	11	4	43
<i>Eg. leucotricha</i> Rebêlo & Moure, 1996	0	2	0	0	2
<i>Eg. mixta</i> Friese, 1899	0	1	0	0	1
<i>Eg. pleosticta</i> Dressler, 1982b	0	2	1	0	3
<i>Eg. roubiki</i> Nemésio, 2009	50	81	32	19	182
<i>Eg. securigera</i> Dressler, 1982b	2	1	2	1	6
<i>Eg. stellfeldi</i> Moure, 1947	14	3	2	1	20
<i>Eg. truncata</i> Rebêlo & Moure, 1996	0	1	0	0	1
<i>Eulaema atlantica</i> Nemésio, 2009	0	0	1	3	4
<i>El. marcii</i> Nemésio, 2009	32	31	13	8	84
<i>El. nigrita</i> Lepeletier, 1841	38	130	34	15	217
<i>El. niveofasciata</i> (Friese, 1899)	1	2	0	0	3
<i>Exaerete salsai</i> Nemésio, 2011c	0	1	0	0	1
Total	158	312	108	56	634

\* Second collection at site 1. See text for details.

males is very similar in all areas (if discounted the extra collection at RPPN Duas Barras in site-1), but the species composition is quite distinct. The orchid-bee fauna of REBIO Mata Escura, the area deeper in the interior, is clearly similar to those found in drier areas in the Atlantic Forest domain (e.g. Rebêlo & Garófalo 1991, 1997, Nemésio & Silveira 2007, 2010) and even in more xeric areas such as the Brazilian “Cerrado” (Nemésio & Faria Jr. 2004), whereas the orchid-bee faunas of RPPN Duas Barras and the fragment in Guaratinga, the areas closest to the coast, are more similar to those in coastal areas of the “Hileia Baiana” (Nemésio 2011a,b). For example, only three species typical of coastal areas reach REBIO Mata Escura: *Eufriesea surinamensis* (Linnaeus, 1758), *Euglossa crassipunctata* Moure, 1968 and *Euglossa mixta* Friese, 1899, though the first two species had already been recorded in forested areas deeper in the interior (Nemésio & Silveira 2006a,b, Nemésio 2009). On the other hand, twelve species typical of coastal areas reach RPPN Duas Barras, seven of them representing the first record of occurrence in the state of Minas Gerais: *Eufriesea atlantica* Nemésio, 2008, *Eufriesea brasiliatorum* (Friese, 1899), *Euglossa amazonica* Dressler, 1982b, *Euglossa augaspi* Dressler, 1982a, *Euglossa bembai* Nemésio, 2011d, *Euglossa crassipunctata*, *Euglossa ignita* Smith, 1874, *Euglossa mixta*, *Euglossa roubiki* Nemésio, 2009, *Eulaema atlantica* Nemésio, 2009, *Eulaema niveofasciata* (Friese, 1899) and *Exaerete salsai* Nemésio, 2011c. Solely *Eufriesea atlantica*, *Euglossa crassipunctata* (see Nemésio 2009), *Exaerete salsai* (see Nemésio 2011c), *Euglossa bembai* (see Nemésio 2011d) and *Eufriesea brasiliatorum* (see Nemésio 2011e) had already been recorded for the state of Minas Gerais.

When the reverse point of view is considered, i.e., which species typical of the semi-deciduous forests reach areas closer to the coast, it is noticeable that *Euglossa fimbriata* Moure, 1968, *Eg. leucotricha* Rebêlo & Moure, 1996, *Eg. securigera* Dressler, 1982b, *Eg. stellfeldi* Moure, 1947 (sensu Nemésio 2009) and *Eg. truncata* Rebêlo & Moure, 1996 reach RPPN Duas Barras – and this is the northernmost record of *Eg. stellfeldi* in the Atlantic Forest to date (see Nemésio & Faria Jr. 2004). Concerning *Eg. stellfeldi*, it is noticeable that this species was not collected in coastal areas in the “Hileia Baiana” (Nemésio 2011a,b), which are situated at sea level, supporting the hypothesis presented by Nemésio & Silveira (2006b) and Nemésio (2007a) that this species only occurs at higher elevations in southeastern Brazil. Nevertheless, none of these species typical of semi-deciduous forests is very abundant at RPPN Duas Barras or the forest fragment in Guaratinga (Tables 2 and 3), whereas *Euglossa fimbriata*, for example, is one of the dominant orchid-bee species at REBIO Mata

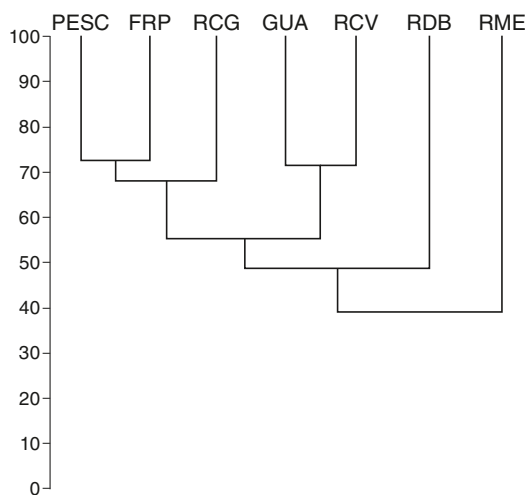
Escura, second only to *Eulaema nigrata* Lepeletier, 1841 (Table 1). On the other hand, the dominant species of *Euglossa* Latreille, 1802 at RPPN Duas Barras are *Eg. roubiki* and *Eg. ignita*, species which do not reach REBIO Mata Escura. It is remarkable that no species of *Euglossa* (*Glossura*) Cockerell, 1917 reach REBIO Mata Escura. This matter had already been noticed by Nemésio & Silveira (2006b), who pointed out the absence of any species of *Euglossa* (*Glossura*) at the large Parque Estadual do Rio Doce, whereas species of this subgenus are found both east (*Eg. ignita*, *Eg. imperialis* Cockerell, 1922, and *Eg. roubiki*) and west (*Eg. imperialis* and *Eg. stellfeldi*) of it. More surprising, however, is the absence of *Euglossa imperialis* from RPPN Duas Barras, since this species is common both at the coastal areas (e.g. Nemésio 2011a,b) and in the interior (e.g. Rebêlo & Garófalo 1991, 1997, Nemésio & Silveira 2007, 2010). Both species of *Eulaema* (*Eulaema*) recorded at the “Hileia Baiana” (Nemésio 2011a,b) also reach RPPN Duas Barras but are absent from REBIO Mata Escura. In common, all three areas present a strong dominance of *Eulaema nigrata* (see Tables 1–3) and one or two species of *Euglossa* (discussed above), a pattern typically found in orchid-bee communities along the Atlantic Forest (Nemésio 2007b).

The ordination of the sites according to their faunas confirmed what the close examination of species composition (above) revealed: faunas of coastal areas are more similar ‘inter se’ and there is a progressive ordination of the faunas from the coast to the interior (Fig. 2). Some authors (e.g.

**Table 3.** Species and number of specimens of each species collected at a forest fragment in the municipality of Guaratinga, Bahia, Brazil.

Species	Number of specimens
<i>Euglossa augaspi</i> Dressler, 1982a	13
<i>Eg. crassipunctata</i> Moure, 1968	21
<i>Eg. carolina</i> Nemésio, 2009	28
<i>Eg. cognata</i> Moure, 1970	1
<i>Eg. despecta</i> Moure, 1968	1
<i>Eg. fimbriata</i> Moure, 1968	4
<i>Eg. ignita</i> Smith, 1874	12
<i>Eg. mixta</i> Friese, 1899	1
<i>Eg. pleosticta</i> Dressler, 1982b	2
<i>Eg. securigera</i> Dressler, 1982b	6
<i>Eulaema atlantica</i> Nemésio, 2009	6
<i>El. marcii</i> Nemésio, 2009	47
<i>El. nigrata</i> Lepeletier, 1841	76
<i>El. niveofasciata</i> (Friese, 1899)	1
Total	219





**Fig. 2.** Clustering of the seven areas in the “Hileia Baiana”, eastern Brazil, according to the similarity of their orchid bee faunas. **GUA**, forest fragment in Guaratinga, Bahia; **FRP**, Floresta Nacional do Rio Preto, Espírito Santo; **PESC**, Parque Estadual da Serra do Conduru, Bahia; **RCG**, Reserva Biológica Córrego do Veado, Espírito Santo; **RCV**, Reserva Biológica Córrego Grande, Espírito Santo; **RDB**, Reserva Particular do Patrimônio Natural Duas Barras, Minas Gerais; **RME**, Reserva Biológica da Mata Escura, Minas Gerais.

Sydney et al. 2010, Mattozo et al. 2011) argued that clustering analysis is not suitable for understanding these patterns. Nevertheless, when applying different methodologies (e.g. detrended correspondence analysis and nonmetric multidimensional scaling), Sydney et al. (2010) found results extremely similar to those presented by Nemésio & Silveira (2007), who had used the same analysis employed here. Moreover, Sydney et al. (2010) and Mattozo et al. (2011) opted for not using data on species abundance, since their data pool was obtained from literature and several different methodologies had been applied to each study. In the present analysis, however, sampling methodology was exactly the same, the sampling effort was the same at each sampling site and the same 16 scents were used. Moreover, sampling was performed by the same researcher (Nemésio 2011a,b and this study), eliminating even the possible bias introduced by different collecting abilities by different collectors (Nemésio, in press). More important, in areas geographically close to each other and situated in the same biome, there is a huge tendency that most species are shared among them, and consequently the main difference will be that of community composition, with different dominant species at each site. In this situation, analyses

involving only presence/absence of species – such as the ones used by Sydney et al. (2010) and Mattozo et al. (2011) – underestimate the actual similarities among sites. For this reason, the per cent similarity index of Renkonen was used (see also Balmer 2002 for additional reasons for using Renkonen index).

Although more samplings are necessary to fully understand the limits of geographic distributions of most orchid-bee species, the present study clearly suggests that concerning orchid bees, the limits of the “Hileia Baiana” extends to the border of the states of Bahia and Minas Gerais, entering the latter state, but only tangentially since the species composition recorded at a large preserve situated only 80 km from the border (REBIO Mata Escura) shows little resemblance to the orchid-bee fauna found in areas situated in the typical “Hileia Baiana”. Nonetheless, both areas house a high richness of orchid bees and most of the region is under strong anthropogenic pressure. For example, in the region where RPPN Duas Barras is situated, only the forest remnants situated at higher elevations (over 900 m a.s.l.) remain, but hunting and timber logging are still common there (pers. obs.). Biodiversity of these areas is poorly known and new records of threatened species of birds, mammals and amphibians have been recently published (e.g. Feio & Caramaschi 2002, Melo et al. 2004) as well as new records (Nemésio 2011e) and new species of orchid bees (Nemésio 2001c,d) and other bee species (Nemésio and colleagues, in prep.). The possible small populations and restricted geographic range of these species new to Minas Gerais make them serious candidates to be part of lists of species under risk of extinction in this state. Two protected areas were recently established in the region (‘Parque Estadual do Alto Cariri’, in Minas Gerais, and ‘Parque Nacional do Alto Cariri’, in Bahia), but these areas still lack personnel and adequate infra-structure to deal with all the pressures (timber logging, hunting) in the area.

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who allowed me to survey the area, and Mr. João Tavares de Oliveira (Dão), Mr. Aleixo's employee, and his family, who made all the arrangements to warrant my field work at RPPN Duas Barras. Tiago Castro and Tiago Leão, managers of the REBIO Mata Escura, were also very helpful during my visits to that area.

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