Sociobiology
An international journal on social insects

RESEARCH ARTICLE - BEES

Species Distribution of Euglossini Bees (Hymenoptera: Apidae) at an Altitudinal Gradient in Northern Santa Catarina

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Article History

Edited by
Solange Augusto, UFU, Brazil
Received 09 May 2018
Initial acceptance 24 June 2018
Final acceptance 08 August 2019
Publication date 30 December 2019

Keywords
Altitude, 26°S latitude, orchid bees, Serra do Mar, Atlantic Rainforest, subtropical climate

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Abstract

Euglossini bees are found from southern USA to Central Argentina and southern Brazil. Variations in latitude and altitude can influence the distribution of these bees. This study focused in recognizing the Euglossini species in northern Santa Catarina state, evaluating the distribution over the gradient between sea level and 800 meters altitude. The bees were collected in six locations, between Spring and Summer from 2013 to 2015, using cotton balls containing the following odor baits: benzyl benzoate, 1,8 cineole, eugenol, menthol and vanillin. A total of 794 bees were sampled, belonging to 10 different species, including a possible new species. In terms of abundance *Eufriesea* Cockerell, 1908 (4 species) accounted for 552 individuals, followed by *Euglossa* Latreille, 1802 (5 species) with 218 and *Eulaema* Lepeletier, 1841 (2 species) 24 individuals. Five species were not found above altitude of 400 meters. *Eufriesea violacea* Blanchard, 1840, *Euglossa annectans* Dressler, 1982, and *Eulaema nigrita* Lepeletier, 1841 were the only species found in every location along the altitudinal gradient, but their abundance declines toward higher altitudes. The results surpassed the known orchid bee species for Santa Catarina state from 9 to 14 and confirmed the expected tendency of richness and abundance reduction toward the highlands.

Introduction

The tribe Euglossini (Hymenoptera: Apidae) is comprised of bees distributed in the Neotropical region and more numerous in rain forests near the Equator line (Dressler, 1982). Toward southern Brazil, there is a decrease in richness and abundance probably due to either climatic and vegetation transitions (Wittmann et al., 1988). Besides the effects of latitude, the altitude variation of the landscape implies fast abiotic changes of temperature, humidity, solar radiation and wind velocity, causing variation in species composition (Uehara-Prado & Garófalo, 2006; Aguiar & Gaglianone, 2012). However, it is difficult to identify which factors are responsible for the variation on species composition (Hagen et al., 2008). The territory of Santa Catarina state, in the southern Brazil, is ideal to explore the altitudinal variation on species composition, because in short stretch (within the same latitude) it is possible to go from the sea level to the plateau of the mountains.

Efforts to recognize Euglossini fauna of the state of Santa Catarina are presented by Steiner et al. (2006; 2010), Mouga (2009), Dec and Mouga (2014), and the compilations by Nemésio (2009) e Moure et al. (2012). The focus of this study is to survey the Euglossini species occurring in the northern region of Santa Catarina, as well as estimating the richness and abundance in the altitudinal gradient that varies between sea level and 800 meters a.s.l.

Material and Methods

Study Area

The study was performed in six locations in the northern region of state of Santa Catarina (all within the 26°S latitude):

1. Vila da Gloria (VG) (São Francisco do Sul municipality) at the sea level, with Lowland Dense Ombrophilous Forest; 2. Morro do Finder (MF), 3. Morro do Boa Vista (MBV) and 4. Mutucas (MUT), all at 200 meters a.s.l., with Sub-mountain Dense Ombrophilous Forest; 5. Rio Seco (RS) (400m); and 6. Castelo dos Bugres (CB) (800m), with Sub-mountain and Mountain Dense Ombrophilous Forest, respectively. The locations 2 to 6 belong to the Joinville municipality (Fig 1).

The locations of Morro do Finder and Morro do Boa Vista are protected forest fragments with 525 and 390 hectares, respectively, inserted in an urban area, while the other locations constitute continuous areas of Serra do Mar (Environmental Protection Area (APA) Serra Dona Francisca). According to the Köppen classification, the weather is humid subtropical climate (Cfa), without dry season.

The data collecting occurred between September/2013 to April/2014 and September/2014 to April/2015, which correspond to spring and summer in southern Brazil. Monthly, the bees were sampled in each site, by only one person, between 9 am to 4 pm. The bees were attracted with scents dripped to small cotton balls hanging on tree branches, 1.5 meters from the ground and approximately 10 meters of distance from one another. Each cotton ball had one of the following baiting odors: benzyl benzoate, 1,8-cineol, eugenol, menthol and vanillin. When necessary, the refill was made to compensate for evaporation of the substance.

The bees were captured with insect net and then they were sacrificed. In the laboratory they were pinned into entomological pins and identified through the key identification proposed by Faria Jr. and Melo (2007) and Nemésio (2009). The species identification was reviewed by specialists and then, deposited into the entomological collection CEPANN (IBUSP). The pollinaria of Orchidaceae found on the bees were identified by specialists. Climatic data presented were obtained from the Defesa Civil of Joinville.

Data Analysis

The statistical analyses were made with the software Paleontological Statistics (PAST 3.04). Diversity, uniformity and dominance of the species were measured by Shannon-Wiener index (H'), Pielou index (J') and Simpson index (1-D), respectively. The similarity between study sites was calculated by the Sorensen and Renkonen indexes. This second is suggested to small samples (Wolda, 1981). The change in species composition through the altitude gradient was verified by the Whittaker index.

Results

A total of 794 bees of the genus *Eufriesea* Cockerell, 1908 (*Ef.*); *Euglossa* Latreille, 1802 (*Eg*.) and *Eulaema* Lepeletier, 1841 (*El*.), were sampled and distributed through 10 species and potentially one new species, cryptic to *Eufriesea auriceps* (Friese, 1899), treated as *Eufriesea* aff. *auriceps* (Table 1).

Of the total, 531 bees (66.9%) belonged to *Eufriesea violacea* Blanchard, which were registered at all study sites. Although its abundance this species was recorded only between November and January, mainly in the locations at 200 meters a.s.l. The second most abundant species was

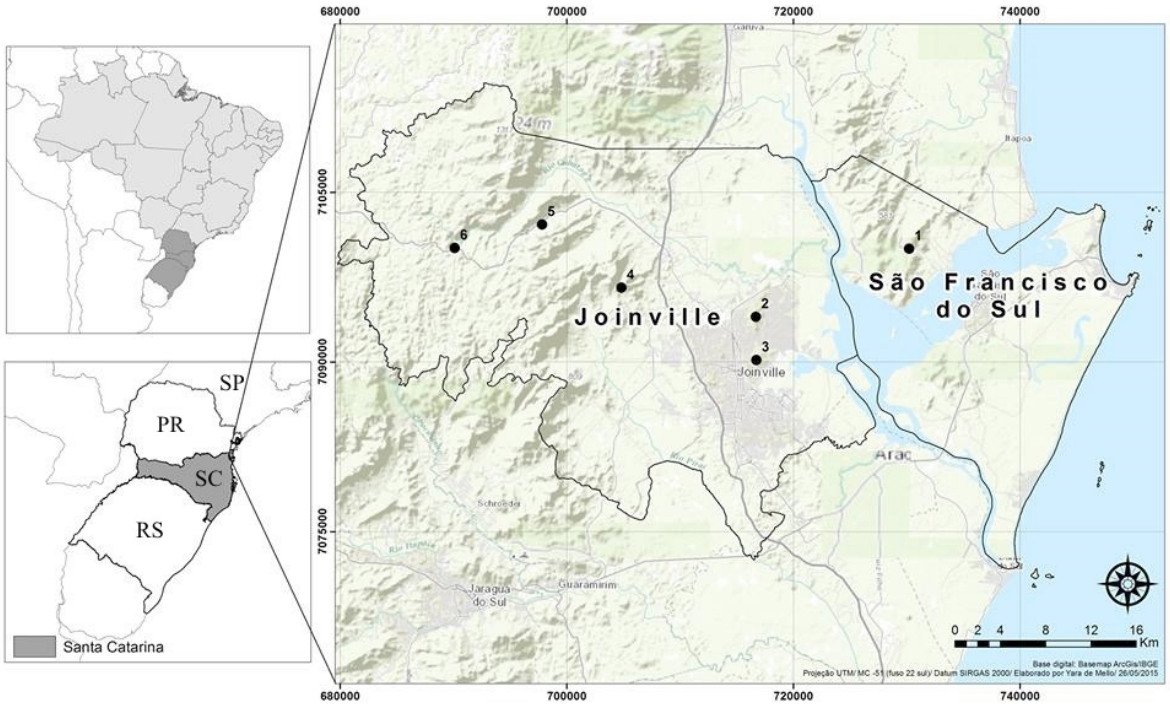

Fig 1. Specific location of the collecting areas for Euglossini in the state of Santa Catarina. Superior left: dark gray highlight for the South region of Brazil. Inferior left: South of Brasil with dark gray highlight for the state of Santa Catarina. Right: Joinville and São Francisco do Sul counties, where the collecting occurred: 1. Vila da Gloria, 2. Morro do Finder, 3. Morro do Boa Vista, 4. Mutucas, 5. Rio Seco, 6. Castelo dos Bugres.

Euglossa annectans Dressler, with 143 individuals (17.9%), also recorded in the six locations throughout the year (except for September/2013 and April/2014). On the other hand, *Euglossa iopoecila* Dressler was sampled only in late summer (March and April/2014 and 2015).

The Shannon index of diversity (H') varied between 0.8 in the Morro do Finder and Morro do Boa Vista locations and 1.54 in the Vila da Gloria (Table 1). The abundance of the species was more uniform at Vila da Gloria (J'= 0.8) compared to Morro do Finder and Morro do Boa Vista locations (J'= 0.34 and 0.36, respectively), where a strong dominance of the species *Ef. violacea* was evident. The Sorensen's similarity and Renkonen index (Table 2) were higher between the localities Morro do Finder and Morro do Boa Vista, which share nine species. The location Mutucas also presented a strong cluster with these two fragments of forest as well with Vila da Glória. The Whittaker's index has showed a low variation of species composition through the altitudinal gradient (βw=0.57).

Table 1. Captured species of Euglossini during the period of September/2013 to April/2014, and September/2014 to April/2015. Locations' acronyms: VG = Vila da Gloria; MF = Morro do Finder; MBV = Morro do Boa Vista; RS = Rio Seco; CB = Castelo dos Bugres.

Species	Number of bees						Total
	VG 20m	MF 200m	MBV 200m	MUT 200m	RS 400m	CB 800m	
Eufriesea aff. *auriceps*	-	-	-	-	1	-	1
Eufriesea dentilabris (Mocsáry, 1897)	6	2	7	3	-	-	18
Eufriesea mussitans Fabricius, 1787	-	1	1	-	-	-	2
Eufriesea violacea (Blanchard, 1840)	8	218	209	64	23	9	531
Euglossa cordata (Linnaeus, 1758)	-	2	1	1	-	-	4
Euglossa townsendi Cockerell, 1904	-	1	2	-	-	-	3
Euglossa annectans Dressler, 1982	33	31	12	40	16	11	143
Euglossa iopoecila Dressler, 1982	13	1	-	-	-	-	14
Euglossa stellfeldi Moure, 1947	18	10	13	10	3	-	54
Eulaema cingulata (Fabricius, 1804)	1	3	4	2	1	-	11
Eulaema nigrita Lepeletier, 1841	2	5	3	1	1	1	13
Richness	7	10	9	7	6	3	11
Abundance	81	274	252	121	45	21	794
Shannon Wiener (H')	1.54	0.8	0.8	1.22	1.14	0.85	
Pielou (J')	0.8	0.34	0.36	0.59	0.64	0.77	
Simpson (1-D)	0.74	0.33	0.34	0.61	0.61	0.54	

Among the odor baits, 1,8-cineol, vanillin and benzyl benzoate attracted, each one, six species of Euglossini, while eugenol and menthol attracted four species each (Table 3). Males of *Ef. violacea* were collected mainly with cineol (275) and vanillin (149). They were not attracted by eugenol that, moreover, attracted no species of *Eufriesea*. Vanillin was the only substance to attract two rare species in the region: *Ef*. aff. *auriceps* and *Ef. mussitans*, however it did not attract any species of *Euglossa*. The majority of males of *Euglossa* were attracted by eugenol and benzyl benzoate. Menthol was used for the capturing of 75 males of the genus *Eufriesea* and *Eulaema*.

Table 2. Indexes applied to all possible combinatory pairs for the studied location. Upper diagonal, Sorensen's index (in bold, the most similar locations); Lower diagonal, Renkonen's index (in bold, the most similar locations). Subtitles: VG = Vila da Gloria; MF = Morro do Finder; MBV = Morro do Boa Vista; RS = Rio Seco; CB = Castelo dos Bugres.

Local	VG	MF	MBV	MUT	RS	CB
VG		0.83	0.75	**0.93**	0.77	0.60
MF	0.70		**0.94**	**0.88**	0.62	0.46
MBV	0.60	**0.90**		0.82	0.71	0.50
MUT	**0.75**	0.70	**0.77**		0.71	0.54
RS	0.62	0.50	0.50	0.62		0.66
CB	0.42	0.30	0.30	0.42	0.50	

Table 3. Number of males for each species, baited by different odor baits in the periods between September/2013 and April/2015, in the northern region of Santa Catarina. Subtitles: BB- Benzyl benzoate; C- Cineole; E- Eugenol; M- Menthol; V- Vanillin.

Species / Baits	BB	C	E	M	V
Eufriesea aff. *auriceps*		-	-	-	1
Eufriesea dentilabris	-	4	-	7	7
Eufriesea mussitans	-	-	-	-	2
Eufriesea violacea	45	275	-	62	149
Euglossa annectans	10	7	125	-	-
Euglossa cordata	1	3	-	-	-
Euglossa iopoecila	1	-	14	-	-
Euglossa stellfeldi	6	-	48	-	-
Euglossa townsendi	2	1	-	-	-
Eulaema cingulata	-	-	3	5	3
Eulaema nigrita	-	9	-	1	3
Total number of individuals	65	299	190	75	165
Total number of species	6	6	4	4	6

Temperatures varied between 14º and 37ºC during the period of study, however, the bees appeared only above 21ºC. There were some picks of precipitation along the year, but no typical dry season. The means of monthly temperature and rainfall in the Joinville and São Francisco do Sul municipalities are shown in Figure 2, however there was difference among the localities due to the altitudinal variation.

The sampled males were carrying 123 pollinaria of eight species of Orchidaceae. By the total, 102 pollinaria were adhering to males of *Ef. Violacea*, being 91 of the orchid species *Gongora bufonia* Lindl (Table 4). Some males showed two, three or even four pollinaria, always adhering to the end of the scutellum.

Table 4. Number of orchid pollinaria recorded on Euglossini males captured in the six locations studied in the northern regions of Santa Catarina.

Orchid species	*Eufriesea aff. auriceps*	*Eufriesea dentilabris*	*Eufriesea violacea*	*Euglossa annectans*	*Euglossa stellfeldi*	*Eulaema nigrita*
Bifrenaria sp.	-	-	6	-	-	-
Catasetum sp. 1	-	4	-	-	-	-
Catasetum sp. 2	-	-	-	-	1	-
Cirrhaea sp.	-	-	1	-	-	-
Gongora bufonia Lindl.	1	-	91	-	-	-
Notylia sp.	-	-	-	15	-	-
Huntleya meleagris Lindl.	-	-	-	-	-	1
Rodriguezia venusta Rchb. f.	-	-	4	-	-	-

Discussion

With the records of this study the number of species of Euglossini in the State of Santa Catarina was raised from 9 to 14: *Ef. auriceps*, *Ef. dentilabris*, *Ef. mussitans*, *Eufriesea smaragdina* (Perty); *Ef. violacea*, *Eg. annectans*, *Eg. townsendi*; *Eg. cordata*, *Eg. iopoecila*, *Euglossa mandibularis* Friese, *Euglossa stellfeldi* Moure, *El. nigrita*, *Eulaema cingulata* Fabricius and *Exaerete dentata* Linnaeus (Steiner et al., 2006, 2010; Nemésio, 2009; Moure et al., 2012; Dec & Mouga, 2014). Additionally, a potentially new species was registered, cited as *Ef.* aff. *auriceps*. The species *Eg.cordata* was considered by Nemésio (2009) as occurring in the state (treated as *Euglossa carolina* Nemésio), and now confirmed in the present study.

In an inventory made in Antonina, Paraná, 100 km north from Joinville, Mattozo et al. (2011) registered the occurrence of *Euglossa roderici* Nemésio and *Euglossa viridis* Perty, which were not captured in Santa Catarina nor in Rio Grande do Sul (Wittmann & Hoffmann, 1990). Thus, even though the occurrence in the Dense Ombrophilous Forest, these species were never registered to latitudes farther than 26° south. Moreover the region of northern Santa Catarina might be the meridional limit for the distribution of the species *Eg. iopoecila* and *Eg. stellfeldi*, since Steiner et al. (2006; 2010) did not record these species in the Island of Florianópolis. Future sampling on these two regions may refine data about the distribution and limits or geographical barriers for these species.

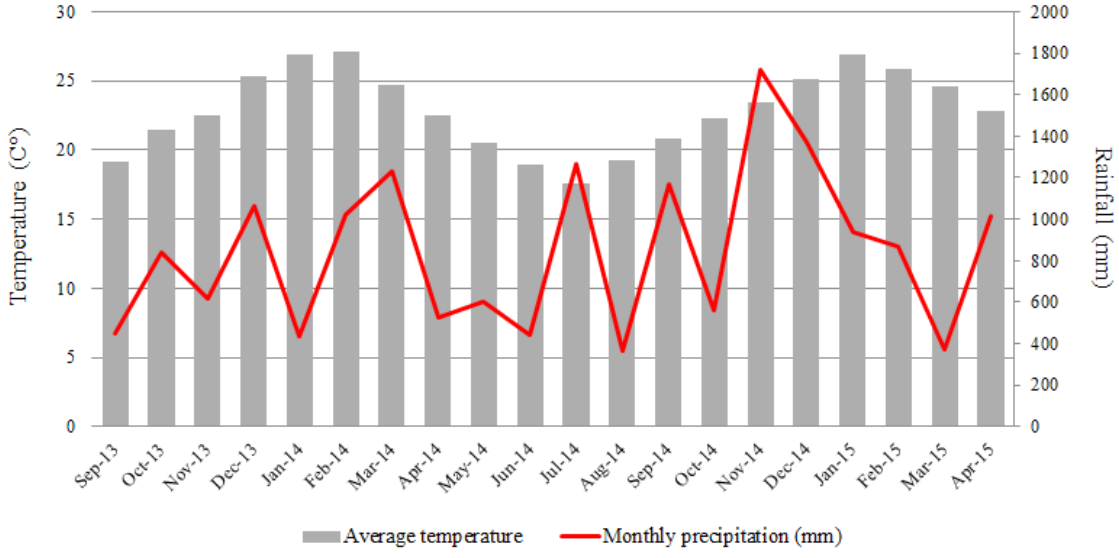

Fig 2. Mean monthly temperature (grey bars) and mean monthly rainfall (red line) between September/2013 and April/2015 in the Joinville and São Francisco do Sul municipalities.

Through the altitudinal gradient, it was verified that no species were exclusive to a determined altitude. In the locations between 400 and 800 meters a.s.l., the richness and abundance tend to decrease: 6 species (45 individuals) and 3 species (2 individuals), respectively. However, the Shannon's diversity of the community of CB (800 m) found a similar value to the communities MF and MBV (200 m) due to dominance of *Ef. violacea* in these two locations.

The two most abundant species in this study, *Ef. violacea* and *Eg. annectans*, were found in the six studied localities. In other regions of the country *Ef. violacea* was abundant in environments higher than 600 meters a.s.l., including inland areas in the states of Paraná and Minas Gerais (Sofia & Suzuki, 2004; Uehara-Prado & Garófalo 2006; Nemésio & Silveira, 2007a; Knoll & Penatti, 2012; Cordeiro et al., 2013). The distribution of this species extends to the states of Mato Grosso do Sul (Ferreira et al., 2011), Mato Grosso, and parts of Argentina (Kimsey, 1982). In the present study *Ef. violacea* was observed during 70 days, between November and January, with peaking activity in December. Peruquetti and Campos (1997) sampled this species for approximately 150 days, while Wittmann et al. (1987), recorded individuals for 90 days in Rio Grande do Sul. Similarly *Eg. annectans*, that was more frequent in low land sites usually is associated with higher altitudes in southeastern of Brazil (Knoll & Penatti, 2012; Garófalo et al., 1998).

To some authors *El. nigrita* is considered to be a bioindicator of impacted environments (Rebêlo & Cabral, 1997; Peruquetti et al., 1999; Tonhasca et al., 2002; Aguiar & Gaglianone, 2008). In the studied region, the low number of *El. nigrita* may be related to the natural absent of great populations, since according to Mattozo et al. (2011), Rocha Filho and Garófalo (2013) and Giangarelli et al. (2015) in low altitudes located on areas of Dense Ombrophilous Forest in São Paulo and Paraná, the species already shows a small population number.

Another species, *El.cingulata*, is usually numerous in inventories (Rebêlo & Cabral, 1997; Peruquetti et al., 1999; Tonhasca et al., 2002; Nemésio & Silveira, 2006; Rocha-Filho e Garófalo, 2013). Aguiar and Gaglianone (2012) considered this species fairly tolerant to anthropic perturbations. In the same way, Tonhasca et al. (2002) found many individuals in fragment of the Mata Atlântica, in Rio de Janeiro, in areas considered to be disturbed. Nemésio and Silveira (2006) collected more *El. cingulata* in border vegetation than in the interior of the forest and Nascimento et al. (2015) recorded this species in abundance in areas of eucalyptus in Mato Grosso state. On the other hand, Mattozo et al. (2011) found only one specimen of *El. cingulata* in the municipality of Sete Barras (SP) and none in Antonina (PR). In the present study the samples of *El. cingulata* were found in fragments as many as in continuous areas, with similar proportions to the *El. nigrita*.

Euglossa cordata is one of the most abundant species in the southeastern and northeastern cost of the country (Viana et al., 2002; Souza et al., 2005; Aguiar & Gaglianone, 2008, 2012; Rocha-Filho & Garófalo, 2013), however in the present study, only four individuals were captured. Mattozo et al. (2011) show that this species already have small population in the latitude 25°S.

For the interactions recorded between orchids and bees it stands out the presence of *G. bufonia* Lindl. in the five locations between sea level to submontane. There is a strict relation between *Ef. violacea* and *G. bufonia*, since 91 pollinaria were on the males of this species, corroborating with Singer and Sazima (2004), that reported *Ef. violacea* as pollinators of *G. bufonia*. This orchid presents a complex mechanism of pollination, therefore as other genus of Stanhopeinae, being dependent exclusively to bees Euglossini for pollination (Dressler, 1993).

According to Williams (1982), the *Gongora* produces an odor that has higher intensity in warmer hours of the day, coincidentally with the periods that most *Ef. violacea* males were attracted to the odor baits, between 11:30 am and 12:30 pm. Morro do Finder and Morro do Boa Vista were important scenario for this interaction, suggesting a well conserved state of these areas, since *Ef. violacea* seems to be a species sensitive to degradation of habitat (Giangarelli et al., 2009). Therefore we sustain the importance of these ecological fragments in the north of Santa Catarina.

Acknowledgments

The authors are grateful to CAPES for providing a scholarship to development this study; Dr. Gabriel A. R. Melo for identifying the bees; Dr. Emerson R. Pansarin and Dra. Ludmila M. Pansarin for the identification of pollinaria. Finally, we are grateful to the anonymous referees for their careful revision.

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