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BEE COMMUNITY AND ASSOCIATED FLORA IN LOWLAND RAIN FOREST AND MANGROVE IN SOUTHERN BRAZIL

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RÉSUMÉ.— *Le peuplement d'abeilles et la flore associée en forêt pluviale de plaine et en mangrove dans le sud du Brésil*.— Ce travail propose une première caractérisation de la biodiversité de l'apifaune (groupe des apiformes) et de la flore dans une zone protégée du sud du Brésil. Notamment, nous avons observé les interactions entre abeilles et fleurs dans les deux biotopes de la zone, la plaine côtière et la mangrove. Pour cela nous avons échantillonné les abeilles par des captures au filet entomologique et des piégeages dans des coupelles colorées. Nous avons dénombré 60 espèces d'abeilles appartenant aux familles *Apidae*, *Megachilidae* et *Halictidae*. La courbe de raréfaction des espèces d'abeilles s´est maintenue en hausse et les estimateurs de richesse montrent 84 et 104 espèces potentielles. Les familles *Colletidae* et *Andrenidae* n´ont pas été rencontrées. Des espèces d'abeilles cleptoparasites ont été collectées: *Leiopodus lacertinus* (Protepeolini), *Sphecodes* sp. (Halictini) et *Coelioxys* sp. (Megachilini). Des nids de *Trigona braueri, Tetragonisca angustula, Oxytrigona tataíra, Plebeia saiqui* (Meliponini), *Euglossa iopoecila* (Euglossini) et *Melitoma segmentaria* (Emphorini) ont été trouvés dans les arbres. Une espèce d'abeille de distribution restreinte, *Euglossa anodorhynchi* (Euglossini) et une nouvelle occurrence, *Paroxystoglossa brachycera* (Augochlorini), ont été recensées. L'apifaune est très similaire (coefficient de similarité) à celles déjà notées pour d'autres plaines côtières de la région. Les abeilles ont visité 49 espèces de plantes de 28 familles, spécialement *Asteraceae*, *Convolvulaceae* et *Anacardiaceae*. Des interactions d'abeilles ont été vérifiées avec des espèces botaniques de mangrove : *Avicennia schaueriana* Stapf & Leechm. ex Moldenke (*Acanthaceae*), *Laguncularia racemosa* (L.) CFGaertn. (*Combretaceae*) et *Talipariti pernambucense* Arruda (Bovini) (*Malvaceae*).

SUMMARY.— The present paper is a first characterization of apifauna richness in relation to flora in a protected area in southern Brazil. For that bee-plant interactions were observed in the two main habitats of the area: coastal plain and mangrove. Bees were sampled with entomological nets and pan traps. The survey resulted in 60 species of the families Apidae, Megachilidae and Halictidae. The bee species sampling sufficiency curve remained on the rise and the richness estimators showed 84 and 104 potential species. Colletidae and Andrenidae families were not found. Cleptoparasites bee species were sampled: *Leiopodus lacertinus (*Protepeolini*)*, *Sphecodes* sp. (Halictini) and *Coelioxys* sp. (Megachilini). Nests of *Trigona braueri, Tetragonisca angustula, Oxytrigona tataíra, Plebeia saiqui* (Meliponini), *Euglossa iopoecila* (Euglossini) and *Melitoma segmentaria* (Emphorini) were found in trees. A bee species with restricted distribution, *Euglossa anodorhynchi* (Euglossini) and a new occurrence, *Paroxystoglossa brachycera* (Halictidae, Augochlorini), were found. Bee fauna was very similar (coefficient of similarity) to that of other coastal plain environments in the study area. Bees visited 49 plant species of 28 families, especially Asteraceae, Convolvulaceae and Anacardiaceae. There were interactions of bees with plant species of mangrove habitats: *Avicennia schaueriana* Stapf & Leechm. ex Moldenke (Acanthaceae), *Laguncularia racemosa* (L.) C.F.Gaertn. (Combretaceae) and *Talipariti pernambucense* Arruda (Bovini) (Malvaceae).

The composition of bee communities in sandbank coastal plain zone environments in southern Brazil is poorly known and reveals, in general, an apifauna diversity with a mid species richness. Some work on this theme was performed in Santa Catarina State (SC) in dense lowland rain forest and sandbank formations (Mouga & Nogueira-Neto, 2015; Mouga *et al*., 2015), in Rio Grande do Sul State (RS), southwards of SC, in coastal plain environment (Truylio & Harter-Marques, 2007) and in two islands of Paraná State (PR), north of SC (Zanella, 1991; Schwarz Filho & Laroca, 1999).

Along the coast, mangrove fringes forests. It is a formation of shrub and tree species that live along shores, rivers and estuaries, on soft soils flooded twice daily by the tide, although mangrove species can spread far inland (Kathiresan & Bingham, 2001). Mangroves have their great diversity in Southeast Asia and only 12 species live in the Americas (Giri *et al.*, 2011). Species range in size from small bushes to 60-meter tall trees and most flowering occurs in late spring and early summer, with minor flowering all year (Alongi, 2002). There are some studies about bees on mangroves in Asia (Raju, 1990; Khrishnamurthy, 1990; Raju & Karyamsetty, 2008; Yao *et al.*, 2006; Almazol, 2010; Azmi *et al.*, 2012) but few in Brazil (Neves & Viana, 1997; Barth & Luz, 1998; Menezes *et al.*, 2008; Luz & Barth, 2011). Santa Catarina State is the natural southern frontier of mangroves in Brazil (Knie, 2002) but the utilization there of mangrove by bees, supposed to occur, had not been studied.

Mangroves being threatened by human use and because there is often a lack of bee pasture, we aimed to verify the apifauna richness in a mangrove formation in the southern part of Brazil and look there for interactions between bees and mangrove plant species. Thus, this work achieved an inventory of the bee community and their associated plants at the Caieira Natural Municipal Park (CNMP), which includes mangrove and tropical lowland rain forest, to assess the apifauna richness, to compare the situation there with other listings, to add new elements to species biogeography and biology, and to record foraging on flowers.

METHODOLOGY

STUDY AREA

The study was conducted in the CNMP (26° 18' 05" S, 48° 50' 38" W), a protected area located in Joinville, Santa Catarina State, along the Babitonga Bay, with vegetation of alluvial and lowland dense rain forest, including mangroves and sandbanks (Fig. 1) (Fundação do Meio Ambiente de Santa Catarina & Knie, 2002).

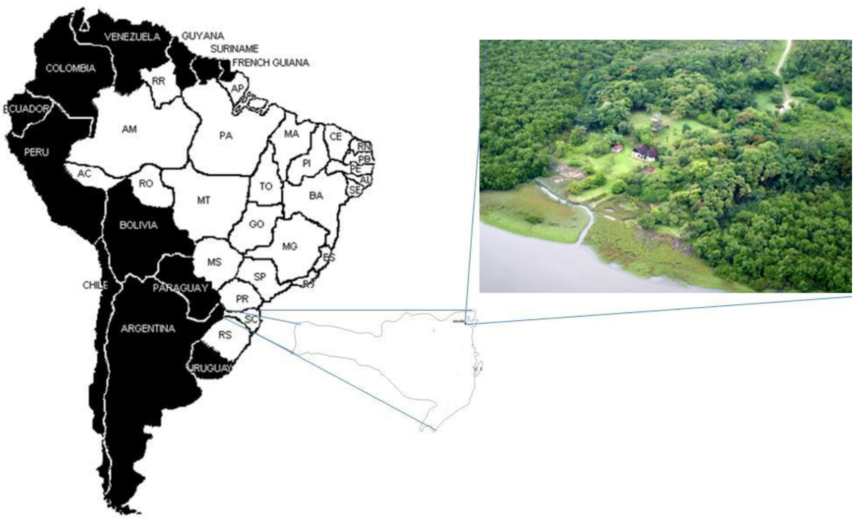

Figure 1.— Localization of CNMP at Joinville, state of Santa Catarina, southern Brazil.

The relief consists mainly of Quaternary sedimentary deposits, encompassing floodplains near the mouths of rivers, plans and alluvial ramps, featuring locally in rugged terrain in the transition between marine and continental ecosystems. The geomorphology is characterized, in part, by mangrove soil rich in organic matter originated from rivers and sea deposition during the tides, being for the most part, steady (*op. cit.*). The rainfall is about 2300 mm/year (Sandri, 2010) and the altitude does not exceed 10 m above sea level (Google Earth, 2013). Hydrographically, the park is bordered east and west by the rivers Cachoeira and Santinho. The place was constituted as a protected area in 2004, with a total surface of 1.28 km² (Joinville, 2004). The CNMP is set in a forest fragment that had ancient human occupancy (shell-mounds or *sambaquis*) (Tamanini, 1994) as well as recent past occupancy (lime extraction in XIX-XX centuries) (Vieira, 2010). The place has gone through a natural recovery since it became a preserved area. The park has two short trails covered with lawns which are kept cut and is open to visitors six days a week. There are no previous studies about the local bee species assembly although Fendrich (2012) cited for the place a few species of bees on some species of Melastomataceae.

METHOD

The study was performed from November 2013 to October 2014 (24 samplings), by two collectors, every two weeks, from 9:00 a.m. to 16:00 p.m. (sampling effort of 336 hours), running, at each sampling, the trails and the other areas, with access to flowering plants. The bees were collected following the method of Sakagami *et al.* (1967) with entomological nets swept over flowering plant for capture of flying bees or at the entrance of nests and with 12 Moericke pan traps (six different colors - yellow, red, green, blue, beige, orange - containing detergent with water) arranged in sunny sampling and collected at the end. All bees were sacrificed, separated in clear plastic bottles labeled with place, date, time of collection, identification number of the bee and of the plant. Plants visited by bees were collected and labeled with the same data for bees. Plants and bees which could be identified in the field to species level were not collected, but only recorded on field form for inclusion in the database and analysis. In the laboratory, bees were prepared and identified with taxonomic keys (Silveira *et al*., 2002 and others) and comparison with the reference collection of bees (CRABEU) of Univille Bees Laboratory (LABEL) as well by experts' consultation. The classification of bees followed Michener (2007). Plants vouchers were arranged as herbarium specimens and identified by experts (Herbarium of the Municipal Botanical Museum of Curitiba) or by comparison with material from Herbarium Joinvillea of Univille. The classification of plants followed APG III and Lista (2014). All materials are kept in LABEL. Data of each sample event (entomogical net and pan traps collecting) were added in a unique *per* day batch for analysis purposes (Krug & Alves dos Santos, 2008). Data were tabulated in Microsoft Excel 2010 software. A species accumulation curve was drawn (Krebs, 1989) and ecological indices were computed [richness estimators Jackknife 1 and 2 and Sørensen´s similarity (S) (Magurran, 2004)].

RESULTS

RICHNESS OF APIFAUNA

The families Apidae, Halicitidae and Megachilidae, which totaled 60 bee species from 14 tribes, were sampled (Table I).

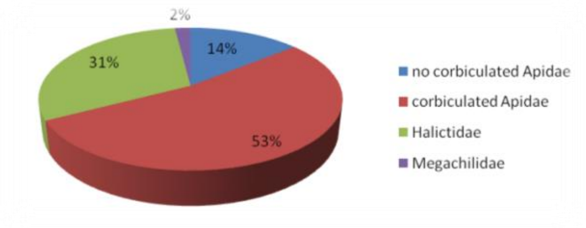

Figure 2.— Proportion of number of individuals per bee families at CNMP, Joinville, SC, southern Brazil.

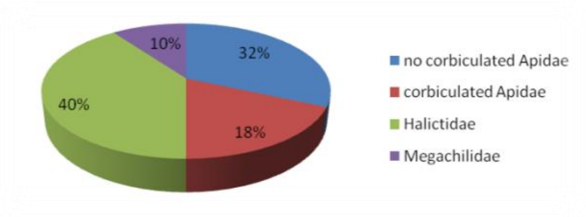

Figure 3.— Proportion of number of species per bee families at CNMP, Joinville, SC, southern Brazil.

Some taxa, mainly belonging to Halictidae, could not be identified to species level because there are no identification keys to many Brazilian species, a fact caused by the lack of taxonomic revisions, reported many times for places that are hotspots of biodiversity as is the case of Brazil (Marques & Lamas, 2006); added to this, Halictidae have their origin in the Gondwanian mainland, notably in southern South America, which increases enormously its richness and diversity (Silveira 2008). Thus, these genera were analysed and separated as morphospecies, following morphological descriptives of CRABEU (LABEL´s collection of bees), as do other studies performed in Brazil, for the same reason (Silveira *et al.,* 2006).

TABLE I

List of bee species sampled at CNMP, Joinville, SC, southern Brazil, and their abundance

Family	Tribe	Species	Abundance
Apidae	Apini	*Apis mellifera* Linnaeus, 1758	321
	Bombini	*Bombus morio* (Swederus, 1787)	86
	Euglossini	*Euglossa iopoecila* Dressler, 1982	2
		Euglossa anodorhynchi Nemésio, 2006	1
	Meliponini	*Trigona braueri* Friese, 1900	251
		Trigona spinipes (Fabricius, 1793)	70
		Oxytrigona tataira (Smith, 1863)	25
		Tetragonisca angustula (Latreille, 1811)	16
		Plebeia emerina (Friese, 1900)	15
		Plebeia saiqui (Friese, 1900)	13
		Paratrigona subnuda Moure, 1947	1
	Centridini	*Centris tarsata* Smith, 1874	2
		Centris (Melacentris) sp.	1
	Emphorini	*Melitoma segmentaria* (Fabricius, 1804)	25
	Eucerini	*Thygater analis* (Lepeletier, 1841)	2
	Protopeolini	*Leiopodus lacertinus* Smith, 1854	12
	Tapinotaspidini	*Paratetrapedia fervida* (Smith, 1879)	17
	Xylocopini	*Ceratina (Ceratinula)* sp. 06	41
		Ceratina (Crewella) sp. 08	31
		Xylocopa brasilianorum (Linnaeus, 1767)	27
		Xylocopa frontalis (Olivier, 1789)	23
		Ceratina (Ceratinula) sp. 02	9
		Ceratina (Ceratinula) sp. 07	9
		Ceratina (Crewella) maculifrons Smith, 1854	8
		Ceratina (Crewella) sp. 01	1
		Ceratina (Crewella) sp. 02	1
		Ceratina (Crewella) sp. 03	1
		Ceratina (Ceratinula) sp. 10	1
		Ceratina (Crewella) sp. 11	1
		Ceratina (Crewella) sp. 14	1
Halictidae	Augochlorini	*Augochlora (Oxystoglossella)* sp. 01	31
		Augochlora (Augochlora) sp. 01	13
		Augochlora (Augochlora) sp. 02	13
		Augochlora (Oxystoglossella) sp. 02	13
		Augochlora (Augochlora) sp. 03	12
		Augochlora (Augochlora) sp. 04	10
		Augochloropsis sp. 03	10
		Pereirapis rhizophila Moure, 1943	8
		Augochlora (Oxystoglossella) sp. 03	5
		Augochlorella ephyra (Schrottky, 1910)	3
		Pseudaugochlora gramínea (Fabricius, 1804)	2
		Augochlora (Augochlora) sp. 05	1
		Augochlora (Augochlora) sp. 16	1
		Augochlora (Oxystoglossella) sp. 06	1
		Augochlora sp.	1
		Augochlorella acarinata Coelho, 2004	1
		Augochloropsis sp. 04	1
		Augochloropsis sp. 07	1
		Augochloropsis sp. 08	1
		Augochloropsis sp. 09	1
		Paroxystoglossa brachycera Moure, 1960	1
	Halictini	*Dialictus* sp.	328
		Sphecodes sp.	3
		Caenohalictus cf. *incertus* (Schrottky, 1902)	1
Megachilidae	Anthidini	*Hypanthidium divaricatum* (Smith, 1854)	3
	Megachilini	*Megachile nudiventris* Smith, 1853	19
		Megachile cf. *susurrans* Haliday, 1836	3
		Megachile cf. *bertonii* Schrottky, 1908	3
		Coelioxys otomita Cresson, 1878	1

The family Apidae were predominant, referring to the number of individuals and species, as seen in Figures 2 and 3 respectively, where the tribes are separated as those with corbicula (Apini, Bombini, Euglossini, Meliponini) and those without corbicula (Centridini, Emphorini, Eucerini, Protopeolini, Tapinotaspidini and Xylocopini). Families Andrenidae and Colletidae were not sampled. The higher number of sampled individuals was found in the genera *Dialictus*, *Apis* and *Trigona.*

The sampling sufficiency was verified by the species accumulation curve that still showed ascension after one year of sampling (Fig. 4). The species richness estimators *Jackknife* 1 and *Jackknife* 2 indicate that, in the area, with the present data, it is possible to have a richness of 84 to 104 bee species, respectively.

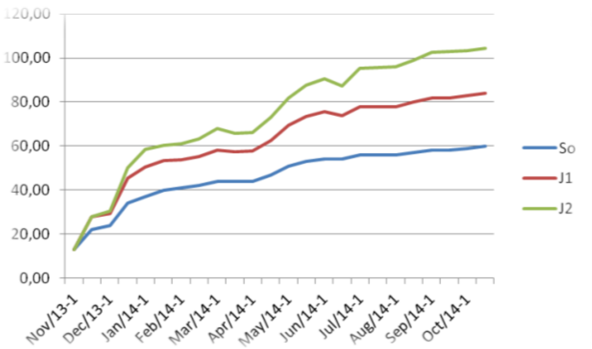

Figure 4.— Curves of sampling sufficiency and richness estimators of bee species at CNMP, Joinville, SC, southern Brazil. Legend: J1 = richness estimator *Jackknife* 1; J2 = richness estimator *Jackknife* 2; So = accumulation curve of observed species in the area and period of study.

COMPARISON WITH OTHER PLACES

The calculation of the Sørensen´s index indicated a greater similarity of the present study with works realized in the localities Vila da Glória (11 km far away) and Praia do Ervino (23 km far away), being 42% and 34% respectively (Tab. II).

TABLE II

Sørensen similarity índex, calculated for studies done in the region and local environments. Legend: DRF = Dense rain forest; Dist. = distance; Alt. =altitude

Authors	Year	Local	Description	Dist. (Km)	Alt. (m)	Geographic coordinates	Species	Sørensen
Mouga *et al.*	2015	Vila da Glória, São Francisco do Sul, SC	DRF lowland	11	5	26°14'45,89"S 48°42'34,32"O	60 25 equal	0,42
Mouga & Nogueira-Neto	2015	Praia do Ervino, São Francisco do Sul, SC	Sand Banks	23	1	26°23'25,46"S 48°34'57,78"O	51 19 equal	0,34
Zanella	1991	Ilha do Mel, PR	DRF lowland	96,66	1	25°33'14,77"S 48°16'51,23" O	78 21 equal	0,30
Dec & Mouga	2014	Joinville, SC	DRF submontane	20,9	90	26°17'29,86"S 49°00'04,79"O	49 16 equal	0,29
Oliveira & Mouga	2012	Joinville, SC	DRF lowland	8,79	12	26°15'08,45"S 48°51'27,09"O	64 18 equal	0,29
Kamke *et al.*	2011	Palhoça, SC	Sand Banks	149,15	5	27°39'06,81"S 48°40'21,67"O	64 17 equal	0,27
Steiner *et al.*	2010	Florianópolis, SC	DRF lowland	140,66	5	27°22'-27°50'S 48°25'–48°35'O	169 26 equal	0,23
Feja	2003	Florianópolis, SC	DRF lowland	140,66	5	27°22'–27°50'S 48°25'–48°35'O	130 19 equal	0,20
Laroca	1974	Parana coast	DRF lowland	100	900	25°28'41,18"S 49°12'15,65"O	256 27 equal	0,17

BIOGEOGRAPHY AND SPECIES BIOLOGY

Three bee families showed cleptoparasite species: *Leiopodus lacertinus (*Apidae, Protepeolini*)*, parasite of nests of *Melitoma segmentaria*; *Sphecodes* sp. (Halictidae, Halictini), cleptoparasite of *Dialictus* sp., and *Coelioxys* sp.(Megachilidae, Megachilini), parasite of nests of

Megachile genus. Six nests of social bee species were found at CNMP: *Trigona braueri* (Apinae, Meliponini), in the trunk of a dead palm tree (*Syagrus romanzoffiana*, Arecaceae*)*; *Tetragonisca angustula* (Apinae, Meliponini), in the trunk of *Schinus terebinthifolius* (Anacardiaceae); *Oxytrigona tataira* (Apinae, Meliponini), in a hollow of a tree (non identified species) approximately one meter from the ground; *Plebeia saiqui* (Apinae, Meliponini) in a crack of a stone wall holding an earth bank; *Euglossa iopoecila* (Apinae, Euglossini) in a hollow in a trunk of a wild fig tree **(***Ficus guaranitica*, Moraceae*)* and *Melitoma segmentaria*, (Apinae, Emphorini) with various nests in the mortar existing between the bricks of the lime kilns.

PLANT UTILIZATION BY BEES

The plants visited by bees totaled 49 species, of 28 families (Table III, with data for the bee species *Apis mellifera* disposed in a separated column).

TABLE III

List of plant bee species at CNMP, Joinville, SC, Brazil, with reference to sampled bee families
Legend: Total = number of individuals of sampled bees

Botanic family	Species	*A. mellifera*	Apinae	Halictinae	Megachilinae	Total
Acanthaceae	*Avicennia schaueriana* Stapf & Leechm. ex Moldenke	3	2	1		6
Anacardiaceae	*Schinus terebinthifolius* Raddi	27	23	7		57
Araliaceae	*Schefflera arborícola* (Hayata) Merr.	13	3			16
Arecaceae	*Syagrus romanzoffiana* (Cham.) Glassman	6				6
Asteraceae	*Crepis japonica* (L.) Benth.	4	42	63	3	112
Asteraceae	*Vernonia scorpioides* (Lam.) Pers.	50	5	10	4	69
Asteraceae	*Sphagneticola trilobata* (L.) Pruski	20	6	27	9	62
Asteraceae	*Vernonanthura phosphorica* (Vell.) H. Rob.	13	19	5	2	39
Asteraceae	*Mikania glomerata* Spreng.	6	2			8
Asteraceae	*Picrosia longifolia* D. Don		3	2		5
Asteraceae	*Taraxacum officinale* F.H. Wigg.			2		2
Bromeliaceae	*Aechmea nudicaulis* (L.) Griseb.		3			3
Bromeliaceae	*Vriesea friburgensis* Mez		2			2
Bromeliaceae	*Neoregelia* sp		1			1
Bromeliaceae	*Vriesea incurvata* Gaudich.			1		1
Cactaceae	*Rhipsalis* cf. *pachyptera* Pfeiff.	67	24		1	92
Cactaceae	*Rhipsalis bacífera* (J.S. Muell) Stearn	1	8			9
Campanulaceae	*Hippobroma longiflora* (L.) G. Don		4			4
Combretaceae	*Laguncularia racemosa* (L.) C.F. Gaertn.	3	8			11
Combretaceae	*Terminalia catappa* L.		6			6
Commelinaceae	*Commelina erecta* L.			7		7
Convolvulaceae	*Ipomoea cairica* (L.) Sweet		49	34		83
Convolvulaceae	*Ipomoea tiliacea* (Willd.) Choisy		1			1
Ericaceae	*Rhododendron simsii* Planch.		46	3		49
Fabaceae	*Mimosa bimucronata* (DC.) Kuntze	12	1			13
Fabaceae	*Inga marginata* Willd.	9				9
Fabaceae	*Dioclea violacea* Mart. ex Benth.	2	6			8
Fabaceae	*Desmodium incanum* (Sw.) DC.	1			1	2
Gesneriaceae	*Codonanthe gracilis* (Mart.) Hanst.		3			3
Lauraceae	*Persea americana* Mill.	5	28	1		34
Malvaceae	*Malvaviscus arboreus* Cav.		33			33
Malvaceae	*Talipariti pernambucense* (Arruda) Bovini	1	7			8
Malvaceae	*Sida rhombifolia* L.		2	2		4
Melastomataceae	*Tibouchina granulosa* (Desr.) Cogn.		10			10
Melastomataceae	*Miconia cinerascens* Miq.		2			2
Melastomataceae	*Tibouchina trichopoda* Baill.		1			1
Musaceae	*Musa paradisíaca* L.		10			10
Myrtaceae	*Eugenia uniflora* L.	13	1	1		15
Myrtaceae	*Psidium guajava* L.		1			1
Orchidaceae	*Cattleya* cf. *forbesii* Lindl.		1			1
Oxalidaceae	*Oxalis linarantha* Lourteig		3	1		4
Rosaceae	*Eriobotrya japonica* (Thunb.) Lindl.	37	2			39
Rutaceae	*Citrus reticulata* Blanco			1		1
Sapindaceae	*Allophylus edulis* (A. St.-Hil., A. Juss. & Cambess.) Hieron. ex Niederl.	1				1
Solanaceae	*Nicotiana tabacum* L.		7			7
Solanaceae	*Solanum americanum* Mill.	1				1
Verbenaceae	*Verbena litoralis* Kunth			3	1	4
Vitaceae	*Cissus verticillata* (L.) Nicolson & C.E. Jarvis		1			1
Zingiberaceae	*Hedychium coronarium* J. Koenig	9	75	3		87

The botanic families which attracted the greater quantity of bees were Asteraceae (represented by seven species, with 323 bees sampled), followed by Zingiberaceae (represented only by *Hedychium coronarium*, with 137 bees), and Convolvulaceae (with 110 bees in two species of the genus *Ipomoea)*. Few plants were not visited by Apidae. As this bee family was the most abundant, it developed more singular relations. In terms of richness of bee species that visited each family, Asteraceae interacted with 36 bee species, followed by Convolvulaceae (16) and Anacardiaceae (10). The plant species that attracted more bee species were *Ipomoea cairica* (Convolvulaceae, 16 bee species), *Sphagneticola trilobata* (Asteraceae, 14) and *Schinus terebinthifolius* (Anacardiaceae, 10) and those that attracted the greater number of individuals were *Hedychium coronarium* (Zingiberaceae, 137 bees), *Crepis japonica* (Asteraceae, 118) and *Ipomoea cairica* (109). In the present study, mainly the stingless bee *Trigona braueri* was sampled visiting the flowers of *Rhododendron simsii* (Ericaceae), a native species of Asia broadly utilized as ornamental. Other exotic species, as *Citrus reticulata* (Rutaceae) and *Terminalia catappa* (Combretaceae), didn´t have the same importance in terms of number of interactions, but diversified the community of foraging plants.

From all plants that established relations with the apifauna, 82 % are native from Brazil (Lista, 2014). Between native and exotic, 14 species are ornamental or have a potential to be and six species (two native and four exotic) are cultivated as fruitful. Several ruderal plants as *Sphagneticola trilobata*, *Crepis japonica* and *Vernonia scorpioides* (Asteraceae) contributed with a great number of interactions.

The plant species *Allophylus edulis* (Sapindaceae) and *Solanum americanum* (Solanaceae) were foraged only by *Apis mellifera*. Three individuals of the bee species *Bombus morio* were found, one at the entrance of the nest and two visiting flowers of *Ipomoea cairica*. The individuals presented *pollinia* adhered to dorsal surface of thorax, identified as *Cattleya* cf. *forbesii* (Orchidaceae).

About the interactions, 45 % occurred on flowers with nectar guides visible to the human eye and 41 % on flowers with strong scent. More than 50 % of bees have visited flowers that lack scents (to human nose), and among scented flowers, those more visited are flowers that lack nectar guides (to human eyes). So these traits seem not act as simple attractive traits.

Two plant species of mangrove, *Avicennia schaueriana (*Acanthaceae) and *Laguncularia racemosa* (Combretaceae) were visited by individuals of *Apis mellifera*. Besides that, *A. schaueriana* attracted *Trigona braueri* and *Augochlora (Augochlora)* sp. 04, and *L. racemosa* was visited by *Ceratina (Ceratinula)* sp. 07 and *Ceratina (Crewella)* sp. 08. A plant species intimately related to coastal environments and mangroves, *Talipariti pernambucense* (Malvaceae) (Lista, 2014), was visited by five species of bees: *Apis mellifera*, *Bombus morio*, *Ceratina (Crewella)* sp. 08, *Melitoma segmentaria* and *Trigona spinipes*.

DISCUSSION

RICHNESS OF BEES

The great quantity of sampled *Apis* and *Trigona* is explained by the fact that these taxa are eusocial, with fairly abundant nests, highly populated (Michener, 2007). The numbers of bee family representatives are interesting where Apidae (all of the highly social forms) may not be dominant as, in general, bee highly social forms are in great abundance wherever they occur (Michener, 2007). In Brazil, the introduction of *Apis mellifera scutellata* and its huge and fast dissemination have produced a distortion of the proportion of bee individuals sampled in many environments. The presence of *A. mellifera scutellata* has been recommended to monitor, aiming to accompany its intensity in the guilds of bee communities and propose measures in protected areas (Zanella 2004). The genus *Trigona,* on the other hand, is common in this part of the State, having been found in surveys realized in nearby places (Mouga *et al.*, 2012; Dec & Mouga, 2014; Mouga *et al.*, 2015*;* Mouga & Nogueira-Neto, 2015). The mentioned studies showed *T. spinipes* as the only species of the genus or, at least, more abundant than the other species of *Trigona*, while, in the present work, *T. braueri* was much more present. This fact can be attributed to the competition between the two species or to some adaptive advantage of *T. braueri* in sandbanks areas or mangrove. *Apis mellifera* had the same number of sampled individuals than the two species of *Trigona* together, a fact pointing the high adaptability of this polylectic species to diverse environments (Silveira *et al.*, 2002).

Another species that occurred in considerable numbers was *Bombus morio*, which is eusocial (Andersson, 1984), however it was sampled only during the summer months, mainly visiting flowers of *Hedychium coronarium*, an exotic species that attracts nectarivorous animals by its sweetish scent (Raguso, 2004) and whose interactions with *B. morio* have already been reported in other studies (Mouga & Krug, 2010).

About *Dialictus* species, which is rather abundant, we think that the high occurence, much higher than that of actual solitary species, may be due to the same reason mentionned by Eickwort (1986) who, in a work about the behaviour of *Dialictus lineatulus*, described a variable level of sociality according to the season of the year as, in summer, the species, considered no completely social, formed eusocial nests. It has to be reminded too that pan traps, an alternative sampling method for some species, among them *Dialictus*, can act as a selective method (Silveira *et al.*, 2002).

The diversity of the other bee *taxa*, Xylocopini (13 species), Augochlorini (21 species), stingless bees (seven species), Euglossinii (two species), Megachilidae (six species), among others, reveals the apifauna´s richness of the area, a protection zone established as an urban park of only 1,28 km^2. The absence of some groups of bees, namely Andrenidae and Colletidae, reported in other studies realized in nearby environments (Mouga *et al.*, 2015; Mouga & Nogueira-Neto, 2015), can be explained by the higher diversity and abundance of these groups in climatic conditions different from those which prevailed in this study (Michener, 2007).

Theoretically the total sampling of the species present in a place (number estimated by curves of sampling sufficiency and of richness indices), has to be attested by at least three specimens in all species. So, large numbers of rare species (represented by one or two specimens) tend to overestimate the estimated total number of species (Magurran 2004). As samplings lasted only one year, many seasonal animals and plants could not be collected with repetition and, besides that, a great part of CNMP is constituted of dense forest, where many bees forage out of samplers´reach (Silveira *et al.*, 2002).

COMPARISON WITH OTHER PLACES

Although the classic Sørensen index of compositional similarity is notoriously sensitive to sample size, especially for assemblages with numerous rare species (Chao *et al.*, 2005), it is often employed due to its rather plain formulation and allows getting a simple overview of the diversity and relative abundance of communities and their similarities (Wilms *et al*. 1997). The high ratio of species shared by lists of the different studies carried out in the same region is due to geographic and climatic similarities albeit the localities are separated by a body of water of considerable size, Babitonga Bay (1.567 km2 surface). The similar climatic conditions and floristic composition (Mouga *et al.*, 2015*;* Mouga & Nogueira-Neto, 2015*)* may have favoured the occupation of these spaces around the bay by the same bee species, which contoured Babitonga Bay along their way of dispersal, which would explain the similarity degree found.

BIOGEOGRAPHY AND SPECIES BIOLOGY

All species found in this study have been previously sampled in SC, by at least one of the surveys utilized for the Sørensen´s index calculation, with the exception of *Paroxystoglossa* *brachycera* which, according to Moure *et al.* (2013), is signaled only for Argentina and, in SC, was sampled only in an environment of transitional dense rain forest (Mouga *et al.*, 2014). *Euglossa anodorhynchi*, sampled in SC, in turn, shows a restricted distribution, reported by Moure *et al.* (2013) only for the states of SC and Paraná. The data obtained allow filling gaps in distribution patterns and confirm the importance of surveys of species as tools for monitoring and conservation (Lévêque, 1999).

The presence of nests and cleptoparasites bee species can be interpreted as an evidence of a favourable environment to bee life, offering foraging, structures for nesting and conditions for reproduction, since bees, both social and solitary, carefully choose the place for nesting (Potts & Willmer, 1997; Seeley & Buhrman, 2001), and because cleptoparasitism is associated with high rates of nesting (Alves-dos-Santos, 2009).

PLANT UTILIZATION BY BEES

The apifauna showed several levels of interaction with exotic plant species, invasive or ruderal, a remnant of the past anthropization of the study area. The ancient anthropic utilization of the place (Mouga, 1997) was demonstrated by the presence of some trees, such as avocado (*Persea americana*) and mandarine (*Citrus reticulata*), foraged by bees. According to Pyšek (1998), the presence of non-native plant species (introduced and naturalized) in the environment is renowned and due mainly to random or purposely spreading from cities, being a major pattern of anthropization. However, bees forage on them, as well as on native species since bee plants don´t need to be native to attract and feed native bees (Mouga *et al.*, 2015). On the other hand, the intensity of foraging on ruderal plants, such as *Sphagneticola trilobata* (common in open areas), shows bees may contribute with regeneration of altered environments by pollination of pioneer species that typically dominate disturbed areas (Oliveira & Mouga, 2012). The importance of bee foraging on an invasive species, *Hedychium coronarium*, suggests that, for the bees, the introduction of exotic plants don´t result mandatorily in a negative effect as this can raise the food offer, in spite of the fact that exotic plants can be a possible threat to the wild bee fauna, similarly to what happens with birds that ingest toxic fruits unknown by them (Agostini & Sazima 2003).

There were plants that were only foraged by *A. mellifera.* These species are native, produce flowers in great quantity but only one individual of this polylectic bee species has been seen on each of these plant species. Possibly, these events are a result of random first bee flower visits, which will not continue. According to Vaudo *et al.* (2014), the preferences of bees are dominated by the host-plants they visit first and these patterns are driven by the interplay between pollen abundance and quality.

Relations between bees and mangrove plant species haven´t been much studied in Brazil. Neves & Viana (1997) elaborated a survey of Euglossini bee species in a mangrove area in the state of Bahia and Venturieri *et al.* (2003) reported the bee species *Melipona fasciculata* showing a preference, for nesting, of trunks of *Avicennia nitida*, a plant species of northern mangrove of Brazil, the only region where this bee species is naturally abundant. None of these studies worked with visits of bees to flowers of plant species typical of mangrove. Mouga *et al.* (2015) recorded some interactions of bees with *Rhizophora mangle (*Rhizophoraceae), a species that didn´t show interactions with bees in this study, and with *Laguncularia racemosa*, a tree species found in this study.

CONCLUSION

The plant species present at the study area, a park with mangrove, this latter considered a habitat of low richness, offered, all year round, floral resources to bees that developed interactions even with mangrove plant species along their blooming times.

Obtained data add components to the understanding of the use by the apifauna of the southern border of mangroves along the Atlantic coast. The resource potential of this environment shows the importance of protecting mangrove as an apifauna refuge and a bee pasture.

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