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RESEARCH ARTICLE

THE APIFAUNA AND THE BEE FLOWERS IN THE *SERRA GERAL* RANGE IN SANTA CATARINA STATE, SOUTHERN BRAZIL

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ABSTRACT

Aiming to verify the diversity of bees and the visited flora in a protected zone of southern Brazil, on the *Serra Geral* mountain range, in Santa Catarina State (SC), situated in temperate climate, sampling collection was carried out with entomological nets on flowering plants in araucaria forests, during the period 2010-2012. We counted 74 species of bees belonging to the Colletidae, Andrenidae, Halictidae, Megachilidae and Apidae families, with 1,056 sampling hours and 2,208 verified individuals. New occurrences were recorded for SC (*Anthrenoides petuniae, Anthrenoides politus, Ceratina (Crewella) rupestris, Halictillus loureiroi, Hexantheda missionica, Megachile (Moureapis) nigropilosa, Megachile (Pseudocentron) framea, Megommation insigne, Thygater chaetaspis*) and for Brazil (*Lophopedia nigrispinnis, Paroxystoglossa brachycera, Psaenythia collaris*). One species with restricted occurrence in SC was found (*Ptilothrix relata*) as well as a threatened species (*Bombus bellicosus*). *Apis mellifera*, an exotic species, accounted for 57.6 1% of the sampled individuals. The bee species visited 172 botanical species, of 50 botanical families. The evaluated network measurements reveal a diversified web and a system with asymmetric interactions, with a predominance of general relations. The results obtained by this census unveal the extant bee communities and their structure, which can support the maintenance of the araucaria forest, a threatened environment.

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INTRODUCTION

The southeastern part of Santa Catarina State (SC), in southern Brazil, is characterized by the orographic configuration of the *Serra Geral* range, of mesozoic volcanic origin, a very rough terrain, with high altitude (between1002and 1822m above sea level) and pronounced seasonality due to the southern latitude (FALKENBERG, 2003). Climatic and soil features allow temperate agricultural activities and the region is scenic allowing for tourism activities (FERNANDES and OMENA, 2010). The Sao Joaquim National Park (SJNP)(49 300hectares, geographical coordinates 49°22 'to 49 39'S, 28°04 'to 28 °19'W) was created to protect this region (Figure 1).

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The SJNP includes different vegetational formations (SOUZA, 2004): the atlantic rain forest located on steep slopes in the branches of the *Serra Geral* at altitude below 1200m that presents a very complex composition due to the great variability of soils and climate with many Lauraceae species; the cloud forest located above 1200 m on the edges of the *Serra Geral* range periodically covered by fogs and characterized mainly by Myrtaceae median tortuous low dense trees whose trunks are covered by mosses and lichens; the araucaria forest located on the hillside, in the plateau and in the valleys, between 500 meters and 1400 m, composed of large *Araucaria angustifolia* (Bertol.) Kuntze 1898, that constitute the upper *stratum* and an equally dense understory with predominance of Myrtaceae, Aquifoliaceae and Lauraceae, interspersed with bamboos; the *faxinal f*orest located in the upper parts of *Serra Geral*, usually characterized by small size araucaria trees with meager, irregularly shaped other trees intermixed with fields of thick grasses; grass highlands with scattered vegetation and peat bogs mainly composed of mosses. Besides *Araucaria angustifolia,* the SJNP shelters one of the two species of *Podocarpus* existing in Brazil: *P. lambertii* Klotzsch ex Endl. Although SJNP is a park, it still includes several human settlements (farms, mainly of cattle and orchards) (BOLDRINI, 2009).

Bee species assemblies are closely related to flora, the latter determining their geographical distributions. Because of its sensitivity to environmental changes, bee diversity is considered to be an index for nature health. The bee species diversity of SC State includes more than 500 species being, biogeographically, one of the richest, due to the transition between tropical and temperate zone, including *taxa* of both (MOUGA, 2009). Aiming to obtain information about the biological richness of the apiforms, the ecological interactions between the bees and the flora and the biogeographic insertion of the apifauna, this study concerns the analysis of the bee-plant relations by the inventory of the bee species and their floral resources.

MATERIALS AND METHODS

Study area: The study was conducted at the higher part of SJNP, composed of araucaria, *faxinal* and cloud forests. The climate is CFb according to Koeppen (1948), with marked seasons and fluctuations (in winter, average minimum temperature -10^{o}C, average daily temperature 13^{o}C and maximum recorded temperature 31,4^{o}C; in summer, average maximum temperature 34^{o}C, average daily temperature 26^{o}C and minimum recorded temperature 20^{o}C) and the annual average temperature is 14,3^{o}C (CLIMERH, 2004). The winter often expands the trimester (June-July-August) and lasts from April to October. The rainfall is abundant and well distributed, with the annual index at 1614mm, the monthly average at 134mm, there are no drought periods and the rains are mainly concentrated in the spring (NIMER, 1979). Due to the rainfall rate and the air currents, the relative air humidity presents an annual average of 83,12% (EPAGRI, 1994). Fogs occur nearly every day all year long, frost at night fairly regularly (average of 55 frosts per year) and snow nearly every year (BURATTO *et al.,* 2010).

Data collection: Within the boundaries of SJNP, samplings were done from August 2010 to July 2012, from 06:00 to 18:00, running, during the field trips, several transects three kilometers long each approximately, in the higher parts of the SJNP. The relative size of the biotopes of the SJNP in depicted in Figure 2. The samplings included wild parts of the park as well as parts with human settlements. Apiforms specimens were sampled of flowering plants (wild and introduced) with entomological nets (SAKAGAMI *et al.,* 1967), prepared according to Michener *et al.* (1994) and identified with literature (MICHENER, 2000; SILVEIRA *et al.,* 2002; MELO and GONÇALVES, 2005; MOURE *et al.,* 2012) and the collaboration of experts (see Acknowledgements). There were records of date, location, time, temperature and relative humidity. Floral resources were photographed, collected, prepared and identified with literature and specialists (see Acknowledgements). Specimens of *Apis mellifera* Linnaeus, 1758, were not collected but recorded by quatitative estimate. The collected material is deposited in LABEL - Bee Laboratory of Univille. Information was incorporated into the database. Data was analyzed qualitatively and quantitatively. Data regarding bees and their associations with plants were tooled into spreadsheet MS Excel and R programs (DORMANN *et al.,* 2008), starting from the adjacent matrix, with presence and absence data of interaction between plants and bees species, resulting in a bipartite graphic that expresses the interaction network. Among all the available metrics to describe a network of quantitative interactions, the following were calculated, according to Dorman *et al*. (2009): the number of interactions, the network size, the connectance, the measure of network´s specialization level, the average degree for plants and animals species and the distribution of degrees. The number of observed interactions (E) is considered as the lines that are present in the network, after its construction. The network size is expressed by M = B. P (B and P are the number of interacting bees and plants in the habitat, respectively) and represent the number of possible interactions in the network. The connectance (C), which measures the proportion of connections that are actually observed, is the ratio between the number of observed interactions (E) and the number of possible interactions which, in turn, is given by the product of the number of bees (B) and plants (P) from the network: C = E/ B. P. For percentage values, the value of C was multiplied by 100. The measurement of the networks specialization level (H2) ranges from 0 to 1, revealing perfect specialization (1) or no specialization (0). Plants average degree was obtained through the arithmetic average from all plant species degrees, as degree is the number of interactions in which each species was involved. The same was done for bees. Degrees distribution was done graphically, in vertical bars representation, where x-axis represents the number of interactions established (degrees) and y-axis, the number of species that showed a certain degree, whether it is plant or animal. The nesting degree of the network was measured by the NODF index and calculated with the help of the program ANINHADO (GUIMARÃES and GUIMARÃES, 2006), using as a model of randomization (null model) the NODF (Coe), with 1000 randomizations (ALMEIDA NETO and ULRICH, 2011). At the end of the study, 44 days of field work and 1056 hours of sampling effort had been carried out.

RESULTS

Bees: A total of 2,208 bees were sampled, which are distributed in five families, 32 genera and 74 species (Table I).Some *taxa* 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 and LAMAS, 2006). Those species were analyzed and separated as morph species, 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). In terms of species richness, the descending sequence of the number of bee species by family was (separating the Apidae in corbiculate and no corbiculate): Halictidae (29) > no corbiculate Apidae (14 species)> corbiculate Apidae (11)> Andrenidae (10)> Megachilidae (7)> Colletidae (3). Among the bee species most sampled in terms of individuals (15 species), the decreasing sequence *per species* was *Apis mellifera*, *Trigona spinipes*, *Bombus pauloensis*, *Schwarziana quadripunctata*, *Bombus bellicosus*, *Augochlora (A.)* sp. 02, *Augochlora (A.)* sp. 03,*Lanthanomelissa betinae*, *Paroxystoglossa brachycera*, *Dialictus rhytidophorus*, *Plebeia saiqui,* *Plebeia emerina*, *Paroxystoglossa* sp. 02., *Paroxystoglossa* sp. 05, *Augochloropsis* sp. 02 (Figure 3). The other 59 species (from the total of 74 bee species sampled) were collected with up to

10 individuals. Several bee species were new records to SC, according to Moure *etal. (*2012): *Anthrenoides petuniae* Urban, 2005*, Anthrenoides politus* Urban, 2005*, Ceratina (Crewella) rupestris* Holmberg, 1884*, Halictillus loureiroi* (Moure, 1941)*, Hexantheda missionica* Ogloblin, 1948*, Megachile(Moureapis) nigropilosa* Schrottky, 1902*, Megachile(Pseudocentron) framea* Schrottky, 1913*, Megommationinsigne (*Smith, 1853)*, Thygater chaetaspis*Moure, 1941 while others have geographical distribution not yet indicated to Brazil (*Lophopedia nigrispinnis (*Vachal, 1909)*, Paroxystoglossa brachycera* Moure, 1960*, Psaenythiacollaris* Schrottky, 1906). A species of restricted occurrence was found, *Ptilothrix relata (*Holmberg, 1903), which has distribution, in Brazil, only for SC. In terms of endangeredbees, the species *Bombus bellicosus* Smith, 1879 was found although, according to Martins and Mello (2009), it was considered lost at its northeast limit.

Plants visited by bees: There were sampled 172 botanic species, distributed in 50 families (Table II, Figure 4). Eight species are endemic to Santa Catarina State, 53 are introduced in Brazil, 93 are native in Brazil and 18 are naturalized in Brazil. Several ornamental plant species (45) and some fruit species (10) were observed interacting with the bee species assembly. *Apis mellifera* was sampled on 97 plant species and was exclusive to 46 of these. In these 46, *Apis mellifera* was sampled on 24 native plant species (52,2%, being 18 species of Asteraceae), 20 introduced (43,5%, mainly Brassicaceae and Rosaceae), one endemic (2,2%, *Acca sellowiana*) and one naturalized (2,2%, *Veronica persica*). Native bee species were sampled on 126 plant species and were exclusive to 75 of these. In these 75, native bee species were sampled on 45 native plant species (60%, being 16 species of Asteraceae, 4 of Fabaceae, 3 of Solanaceae and varied others), 15 introduced (20%, 3 of Asteraceae and varied others), 3 endemic (4%, *Parodia haselbergii* subsp. *graessneri, Croton myrianthus, Petunia bonjardinensis*) and 12 naturalized (16%, 3 of Asteraceae and varied others).

Of the 172 plant species, 51 (29,7%) were visited both by *Apis mellifera* and by native bee species. The botanic families with more visited species were Asteraceae (69 species), Fabaceae (11), Solanaceae (10), Rosaceae (8), Lamiaceae (7). The most sought-after species by bees were: *Eschscholzia californica* Cham., *Senecio icoglossus* DC., *Solidago chilensis* Meyen, *Hypochaeris radicata* L., *Calendula officinalis* L. and *Verbena litoralis* Kunth. The rare plant species *Adesmia rocinhensis* Burkart (Fabaceae) (FLORA, 2016) was visited by bees as well as the typical or unusual species *Eryngium sanguisorba* Cham. and Schltdl.*(*Apiaceae), *Graphistylis serrana* (Zardini) B. Nord., *Jungia floribunda* Less. and *Graziellia serrata* (Spreng.) R.M. King and H. Rob.- the latter a anemocoric species - (Asteraceae), *Croton ceanothifolius* Baill. (Euphorbiaceae), *Mimosa scabrella* Benth. (Fabaceae), *Sisyrinchiumluzula* Klotzsch (Iridaceae) and *Colletia exserta* Klotzsch ex Reissek – this last, a threathened medicinal plant (Rhamnaceae). Endemic species of the state of Santa Catarina were visited by bees: *Passiflora urubicensis* Cervi (Passifloraceae), *Petunia bonjardinensis* T. Ando and Hashim. (Solanaceae*), Parodia haselbergii* subsp. *graessneri* (K. Schum.) Hofacker and P.J. Braun (Cactaceae), *Acca sellowiana* (O. Berg) Burret (Myrtaceae), *Leptostelma catharinense* (Cabrera) A. M. Teles and Sobral (Asteraceae), *Senecio conyzaefolius* Vell. (Asteraceae) *Croton myrianthus* Müll.Arg. (Euphorbiaceae) and *Salvia congestiflora* Epling (Lamiaceae). Some bee species (*Melipona bicolor, Melipona marginata, Melipona quadrifasciata, Plebeia emerina*) were collected on grain meal offered to birds, a bee species (*Plebeia emerina)* was collected at the entrance of the nest and several species (*Apis mellifera, Augochlora* sp. 02*, Augochlora* sp. 03, *Augochloropsis* sp. 02, *Bombus bellicosus, Bombus pauloensis, Melipona qudrifasciata, Paroxystoglossa brachycera, Plebeia emerina, Rhophitulus reticulatus, Trigona spinipes, Xylocopa bimaculata, Xylocopa augusti*) were sampled in flight.

Bee-plant interactions: Results were calculated and are presented with and without the presence of the introduced species *Apis melífera,* respectively. The total number of interactions observed was 2239 and 961, while the number of possible interactions of this network is 12.728 and 9.490; therefore, approximately 17,6 % and 10,1 % of the possible interactions were actually registered. The connectance, which indicates the proportion of possible interactions that are actually observed in the network, is of the order value of 0.173 and 0,101.The value of the measure of the network specialization (H2) was 0.5481539 and 0,5634201. In terms of the interactions observed for the bees, five social species, representing 6,8 % of the bee fauna, predominated: *Apis mellifera* (that visited 97 plant taxa, namely 56,4 %), *Bombus pauloensis* (44 plant taxa, 25,6 %), *Schwarziana quadripunctata* (28 plant taxa, 16,3 %), *Trigona spinipes* (23 plant taxa, 13,4 %) and *Bombus bellicosus* (12 plant taxa, 7 %). Many species were sampled only once. The degree of bees varied from 1 to 16 visited plant species (except *Apis mellífera* with 97 plant species) where the average degree for the bee community was equal to 1,68.

Twenty four bee species (27 %) visited more plants species than average and 54 (60,5 %) visited only one plant species.The plant species that had the largest number of connections in the network was *Hypochoeris brasiliensis* (Less) Griseb, interacting with 24 species of native bees and also with the exotic species *Apis melifera (*which represented 60 % of all visits to this plant) and, after, *Cunila galioides* Benth and *Baccharis trimera* (Less.) DC., all of the Asteraceae family. The degree of the plants ranged from 1 to 25, with the average degree for the plant community of 3.39. Twenty one of 172 plant species (25 %) received a number of species visitors above the average, while 29 (34 %) received only one bee species visit. In the bipartite graphs (Figures 5 and 6), which represent the bee-flower associations in the study area, it was observed that many plant species are visited by few bee species, while few bee species visit many plant species, showing a system with asymmetric interactions, shown by the value of nesting NODF = 11.40704 and 12.86731 (P <0.00) that was significant. The matrix representation of bipartite data (nestedness graphs) is represented in Figure 7.

DISCUSSION

Bees and plants – ecological data: In the SJNP, the several used transects of this study, running partly in less disturbed areas, partly in the vicinity of human settlements with its accompanying introduced vegetation, allowed the sampling of many species and, among them, *Apis mellifera*, one of such immigrants in this reserve. This species dominates in terms of number of individuals.

Table 1. Listofbeespeciesandassociatedplants. Legend: N=quantityofbeeindividuals; # =numberofthebeespecies in theinteractionnetwork;c=corbiculate;nc=no corbiculate.

#	Family	Species	Number of the plantspecies according to Table 2(quantity of bees)	N
51	Andrenidae	*Anthrenoidesalvarengai*Urban, 2007	53(1)	1
37	Andrenidae	*Anthrenoidesdensopunctatus*Urban, 2005	115(1), 171(1)	2
23	Andrenidae	*Anthrenoidesornatus*Urban, 2005	109(1), 171(3)	4
29	Andrenidae	*Anthrenoidespetuniae*Urban, 2005	162(2),171(1)	3
30	Andrenidae	*Anthrenoidespolitus*Urban, 2005	59(1), 112(1),171(1)	3
52	Andrenidae	*Anthrenoides cf. rodrigoi*Urban, 2005	109(1)	1
38	Andrenidae	*Psaenythiabergii*Holmberg, 1884	7(2)	2
39	Andrenidae	*Psaenythiacollaris*Schrottky, 1906	7(1),135(1)	2
53	Andrenidae	*Rhophitulusreticulatus (*Schlindwein& Moure, 1998)	132(1)	1
31	Andrenidae	*Rhophitulus*sp.	122(1),132(1),146(1)	3
54	Colletidae	*Actenosigynesfulvoniger (*Michener, 1989)	121(1)	1
55	Colletidae	*Belopria*sp. 2	108(1)	1
32	Colletidae	*Hexanthedamissionica*Ogloblin, 1948	125(1),132(1),162(1)	3
1	Apidaec	*Apismellifera*Linnaeus, 1758	1(8),2(5),3(6),4(11),6(59),7(16),9(3),11(11),13(2),14(6),15(23),16(31),17(11),18(10),19(11),20(1),21(11),23(42),24(6),25(17),27(6),28(1),29(20),30(7),31(6),33(62),35(1),37(26),39(20),40(26),41(3),42(3),43(28),4),46(6),50(11),54(1),55(7),57(3),59(40),60(1),61(2),64(1),65(1),66(46),69(1),70(2),71(6),72(47),74(1),75(9),76(28),77(2),78(1),79(39),80(37),81(10),83(1),84(24),87(6),90(1),91(15),92(1),97(1),103(5),104(26),108(29),109(3),111(5),115(11),116(53),120(1),126(2),129(1),134(82),136(1),137(2),138(1),139(1),147(1),149(24),150(50),151(41),152(1),153(20),154(2),155(2),157(4)159(11),161(2),163(2),164(6),166(6),167(3),169(1),171(20),	1271
8	Apidaec	*Bombusbellicosus*Smith, 1879	64(4),66(2), 114(1),115(3), 116(1), 139(2),140(1), 141(1),142(1), 143(1), 144(1),162(1), flying(1)	20
56	Apidaec	*Bombusmorio*(Swederus, 1787)	64(4),66(2), 114(1),115(3), 116(1), 139(2),140(1), 141(1),142(1), 143(1), 144(1),162(1), flying(1)	1
3	Apidaec	*Bombuspauloensis*Friese, 1913	34(2),35(1),36(3),38(2),40(2),43(5),48(1),55(1),57(1),61(1),64(1),66(7),70(2),71(2),72(1),75(6),76(18),84(2),89(40),92(3),99(2),100(3),101(1),102(1),104(2),105(1),107(1),108(4), 109(37), 115(13), 116(20), 118(16),119(1),120(1),122(1),125(1),128(1), 131(1),134(3),139(2),156(4),164(12),165(1),171(1), flying(4)	235
18	Apidaec	*Melipona bicolor* Lepeletier, 1836	12(1), 164(3),grainmeal (2)	6
24	Apidaec	*Meliponamarginata*Lepeletier, 1836	81(1),84(1),105(1),grainmeal(1)	4
19	Apidaec	*Meliponaquadrifasciata*Lepeletier, 1836	12(2),95(1),103(1),grainmeal (1)	5
11	Apidaec	*Plebeia emerina*(Friese, 1900)	7(7),40(1),111(1),134(1),nest entrance(1),grainmeal(1)	12
10	Apidaec	*Plebeia saiqui*(Friese, 1900)	3(1),59(1),63(1),82(6),85(2),103(2),105(1),127(1),146(3)	18
2	Apidaec	*Schwarzianaquadripunctata*(Lepeletier, 1836)	4(1),16(9),20(4),23(1),33(11),47(2),51(2),53(69),55(4),59(18),61(70),63(1),66(11),67(6),75(2),94(1),103(11),105(2),115(1),124(1),127(3),133(1), 136(1),145(6),148(5),160(1), 171(34)	278
4	Apidaec	*Trigonaspinipes* (Fabricius, 1793)	22(1),29(1),33(3),35(4),40(1),43(1),44(1),68(3),79(2),81(1),84(6),93(6),103(1),104(2),105(22),110(1),115(3),118(4),130(2),134(19),135(6),149(13), 152(2)	105
57	Apidaenc	*Ptilothrix relata* (Holmberg, 1903)	123(1)	1
40	Apidaenc	*Melissoptilathoracica* (Smith, 1854)	73(2)	2
20	Apidaenc	*Thygaterchaetaspis*Moure, 1941	120(5)	5
5	Apidaenc	*Lanthanomelissa*cf.*betinae*Urban, 1995	1(1),59(1),66(4),73(1),113(1),118(1),122(1),160(11),171(2)	23
21	Apidaenc	*Lophopedianigrispinnis*(Vachal, 1909)	73(1),134(4)	5
58	Apidaenc	*Ceratina (Ceratinula)* cf.*mulleri*Friese, 1910	107(1)	1
59	Apidaenc	*Ceratina (Ceratinula)* sp.8	7(1)	1
60	Apidaenc	*Ceratina (Crewella) rupestris*Holmberg, 1884	61(1)	1
41	Apidaenc	*Ceratina (Crewella)* sp.	61(1),118(1)	2
25	Apidaenc	*Ceratina (Crewella)* sp. 2	67(1)	1
33	Apidaenc	*Ceratina (Crewella)* sp. 3	29(1),135(1),170(1)	3
26	Apidaenc	*Ceratina (Rhysoceratina)* sp. 1	108(1),117(1),124(1),171(1)	4
27	Apidaenc	*Xylocopa (Dasyxylocopa) bimaculata*Friese, 1903	64(1),118(1),flying(2)	4
22	Apidaenc	*Xylocopa (Neoxylocopa) augusti*Lepeletier, 1841	109(2),flying(3)	5
61	Halictidae	*Augochloraamphitrite*(Schrottky, 1909)	67(1),115(1)	2
6	Halictidae	*Augochlora*sp. 2	56(1),66(8),63(7),91(1),115(1),118(4)	22
7	Halictidae	*Augochlora*sp.3	8(1),10(1),29(1),33(2),37(6),40(2),64(1),76(1),116(1),118(2),134(1),135(3)	22
62	Halictidae	*Augochlorella*sp. 1	171(1)	1
43	Halictidae	*Augochlorodes*sp. 1	52(1),131(1)	2
63	Halictidae	*Augochloropsis*sp. 1	51(1)	1
28	Halictidae	*Augochloropsis*sp. 2	96(1),118(1),125(2)	4
15	Halictidae	*Augochloropsis*sp. 3	61(1),66(2),98(1),105(1),125(1),171(3)	9
64	Halictidae	*Augochloropsis*sp. 4	61(1)	1
34	Halictidae	*Augochloropsis*sp. 5	51(1),86(1),171(1)	3

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65	Halictidae	*Augochloropsis*sp. 6	61(1)	1
66	Halictidae	*Augochloropsis*sp. 7	132(1)	1
67	Halictidae	*Augochloropsis*sp. 8	171(1)	1
35	Halictidae	*Megommation insigne (Smith, 1853)*	168(2)	2
12	Halictidae	*Paroxystoglossa*cf.*brachycera Moure, 1960*	37(2),51(1),53(1),61(3),66(1),146(1),171(3)	12
44	Halictidae	*Paroxystoglossa*sp. 1	60(1),113(1)	2
13	Halictidae	*Paroxystoglossa*sp. 2	10(1),32(1),35(1),37(1),41(1),58(1),61(1),67(1),135(4)	12
17	Halictidae	*Paroxystoglossa*sp. 3	61(5),62(1),171(1)	7
68	Halictidae	*Paroxystoglossa*sp. 4	37(1)	1
14	Halictidae	*Paroxystoglossa*sp. 5	61(9),171(3)	12
45	Halictidae	*Pseudaugochlora*sp.	62(1),81(1)	2
46	Halictidae	*Pseudagapostemoncyaneus*Moure &Sakagami, 1984	61(1),158(1)	2
69	Halictidae	*Pseudagapostemonfluminensis*Schrottky, 1911	64(1)	1
36	Halictidae	*Pseudagapostemonpruinosus*Moure &Sakagami, 1984	41(1),84(1),163(1)	3
47	Halictidae	*Caenohalictus*sp. 1	26(1),59(1)	2
9	Halictidae	*Dialictus*cf.*rhytidophorus*(Moure, 1956)	29(1),37(1),51(1),53(10),66(1),72(2),122(1),135(1),171(1)	19
16	Halictidae	*Dialictus*sp. 1	5(1),55(2),66(1),72(1),88(1),13(1),172(1)	8
48	Halictidae	*Halictillus*cf.*loureiroi (*Moure, 1941)	51(2)	2
70	Megachilidae	*Coelioxys (Acrocoelioxys)* sp. 1	61(1)	1
71	Megachilidae	*Megachile (Pseudocentron) framea*Schrottky, 1913	61(1)	1
49	Megachilidae	*Megachile*cf.*nigropilosaSchrottky, 1902*	33(1),135(1)	2
72	Megachilidae	*Megachile (Chrysosarus)* sp. 1	135(1)	1
50	Megachilidae	*Megachile (Moureapis) maculata*Smith, 1853	91(1),135(1)	2
73	Megachilidae	*Megachile (Moureapis) pleuralis*Vachal, 1909	49(1)	1
74	Megachilidae	*Megachile (Moureapis)* sp. 3	73(1)	1
	Total			2208

Table 2. List of plant species and associated beespecies. Legend: N = total number of bees sampled

Botanicfamily	**Species**	**NumberofthebeespeciesaccordingtoTable 1 (quantityofindividuals)**	**N**
Alismataceae	*Echinodorusgrandiflorus*(Cham. &Schltdl.) Micheli	1(8)	8
Alliaceae	*Alliumampeloprasum*L.	1(5)	5
Anacardiaceae	*Schinuspolygamous*(Cav.) Cabrera	1(6),10(1)	7
	*Schinusterenbinthifolus*Raddi	1(11), 2(1)	12
Apiaceae	*Eryngiumsanguisorba*Cham. &Schltdl.	16(1)	1
Araceae	*Zantedeschiaaethiopica*(L.) Spreng.	1(59)	59
Asphodelaceae	*Bulbinefrutescens*(L.) Willd.	38(2), 39(1), 1(16), 11(7), 59(1)	27
Asteraceae	*Achilleamillefolium*L.	7(1)	1
	*Arnica montana*L.	1(3)	3
	Aspiliamontevidensis(Spreng.) Kuntze	7(1), 13(1)	2
	Austroeupatoriumpicturatum(Malme) R.M. King & H. Rob.	1(11)	11
	Baccharidastrumtriplinervium(Less.) Cabrera	18(1), 19(2)	3
	*Baccharisanomala*DC.	1(2)	2
	Baccharisarticulata(Lam.) Pers.	1(6)	6
	*Baccharis calvescens*DC.	1(23)	23
	*Baccharis crispa*Spreng.	1(31),2(9)	40
	Baccharisdracunculifolia DC.	1(11)	11
	*Baccharismicrodonta*DC.	1(10)	10
	Baccharismilleflora DC.	1(11)	11
	*Baccharismyriocephala*DC.	1(1),2(4)	5
	*Baccharispseudomyriocephala*I.L. Teodoro	1(11)	11
	*Baccharissemiserrata*DC.	4(1)	1
	*Baccharis*cf.*trimera* (Less.) DC.	1(42), 2(1)	43

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	*Baccharisulicina*var.*multifida* (Griseb.) Kuntze	1(6)	6
	*Baccharisuncinella*DC.	1(17)	17
	Baccharis vulneraria Baker	47(1)	1
	*Barrosa candolleana*Steud.	1(6)	6
	*Bellisperennis*L.	1(1)	1
	*Bidensbipinnata*L.	1(20), 4(1), 33(1), 7(1), 9(1)	24
	Bidens pilosa L.	1(7)	7
	*Brachyscomemultifida*DC.	1(6)	6
	*Caleaunifiora*Less.	13(1)	1
	*Calendulaofficinalis*L.	1(62), 2(11), 4(3), 7(2), 49(1)	79
	Campovassouriacruciaae(Vell.) R.M. King & H. Rob.	3(2)	2
	*Centaureacyanus*L.	1(1), 3(1),4(4), 13(1)	7
	Chromolaenalaevigata(Lam.) R.M. King & H. Rob.	3(3)	3
	*Chrysanthemummyconis*L.	1(26), 7(6), 12(2),13(1), 68(1), 9(1)	37
	Chrysolaenaplatensis (Spreng.) H. Rob.	3(2)	2
	*Cichoriumintybus*L.	1(20)	20
	Cirsiumvulgare(Savi) Ten.	1(26), 3(2), 11(1), 4(1), 7(2)	32
	*Coreopsislanceolata*L.	1(3), 13(1), 36(1)	5
	Cyrtocymurascorpioides(Lam.) H. Rob.	1(3)	3
	*Dahliapinnata*Cav.	1(28), 3(5), 4(1)	34
	Galinsogaquadriradiata Ruiz &Pav.	4(1)	1
	Graphistylis serrana (Zardini) B. Nord.	1(2)	2
	Grazielia intermedia (DC.) R.M. King & H. Rob.	1(6)	6
	Grazieliaserrata(Spreng.) R.M. King & H. Rob.	2(2)	2
	*Helianthusdebilis*Nutt.	3(1)	1
	Helichrysumbracteatum(Vent.) Andrews	73(1)	1
	Heterothalamusalienus(Spreng.) Kuntze	1(11)	11
	Hypochaeris brasiliensis (Less.) Benth. &Hook. f.exGriseb.	2(2), 5(1), 63(1),34(1), 12(1), 9(1), 48(2)	9
	Hypochaerislutea (Vell.) Britton	43(1)	1
	*Hypochoerisradicata*L.	51(1), 2(69), 12(1), 9(10)	81
	*Jungia floribunda*Less.	1(1)	1
	**Leptostelmacatharinense (Cabrera)* A. M. Teles &Sobral	1(7), 3(1), 2(4), 16(2)	14
	Melampodiumdivaricatum(Rich.) DC.	6(1)	1
	Mikaniacordifolia (L. f.) Willd.	1(3), 3(1)	4
	Noticastrumdecumbens(Backer) Cuatrec.	13(1)	1
	Senecio brasiliensis (Spreng.) Less.	30(1), 1(40), 10(1), 2(18), 5(1), 47(1)	62
	* *Senecioconyzaefolius*Vell.	1(1), 44(1)	2
	*Senecioicoglossus*DC.	1(2), 3(1), 2(70), 60(1), 41(1), 25(2), 15(1), 64(1), 65(1),12(3), 13(1), 17(5), 14(9), 46(1), 70(1), 71(1)	101
	*Seneciojuergensii*Mattf.	17(1), 45(1)	2
	*Seneciooleosus*Vell.	10(1), 2(1), 6(7)	9
	*Seneciopinnatus*Poir.	1(1), 8(4),56(1), 3(1), 27(1), 7(1), 69(1)	10
	*Seneciopulcher*Hook. &Arn.	1(1)	1
	*Solidagochilensis*Meyen	1(46), 8(2), 3(7), 2(11), 5(4), 6(8), 42(1), 15(2), 12(1), 9(1), 16(1)	84
	Sommerfeltiaspinulosa (Spreng.) Less.	2(3), 13(1)	4
	Sonchusasper (L.) Hill	4(3)	3
	Sonchusoleraceus L.	1(1)	1
	*Symphyopappuslymansmithii*B.L. Rob.	1(2), 3(2)	4
	*Tagetes*cf.*erecta*L.	1(6), 3(2)	8
	Taraxacumofficinale F.H. Wigg.	1(42), 3(1), 9(2), 16(1)	46
	Tilesiabaccata (L.) Pruski	40(2), 5(1), 21(1), 74(1)	5
	*Trixislessingii*DC.	1(1)	1

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	Vernonanthuramontevidensis(Spreng.) H. Rob.	1(9), 3(6), 2(2)	17
	ZinniaelegansJacq.	1(28), 3(18), 7(1)	47
Bignoniaceae	*Lundianitidula*DC.	1(2)	2
	Pyrostegiavenusta(KerGawl.) Miers	1(1)	1
Boraginaceae	*Echiumplantagineum*L.	1(39), 4(2)	41
	Alyssummaritimum(L.) Lam.	1(37)	37
Brassicaceae	*Brassicaoleracea*L	1(10), 24(1), 4(1), 45(1)	13
	Brassica rapa L.	10(6)	6
	Eruca sativa Mill.	1(1)	1
	Raphanussativus L.	1(24), 3(2), 24(1), 4(6), 36(1)	34
Cactaceae	*Parodia haselbergii*subsp. *graessneri* (K. Schum.) Hofacker& P.J. Braun	10(2)	2
Caprifoliaceae	*Abeliagrandiflora*L.	42(1), 34(1)	2
	*Lonicerajaponica*Thunb.	1(6)	6
Caryophyllaceae	*Stellaria media* (L.) Vill.	16(1)	1
Convolvulaceae	*Ipomoeapurpurea*(L.) Roth	3(40)	40
Crassulaceae	*Echeveriaelegans*Rose	1(1)	1
Cucurbitaceae	*Cucurbita pepo*L.	1(1), 6(1), 50(1)	3
	*Cucurbita ficifolia*Bouché	1(15), 3(3)	18
Ericaceae	*Rhododendronsimsii*Planch.	4(6)	6
Escalloniaceae	*Escalloniabifida*Link & Otto	2(1)	1
Euphorbiaceae	*Crotonceanothifolius*Baill.	19(1)	1
	*Crotonmyrianthus*Müll. Arg.	28(1)	1
	*Euphorbiaheterophylla*L.	1(1)	1
	*Synadeniumgrantii*Hook. f.	15(1)	1
Fabaceae	*Adesmiarocinhensis*Burkart	3(2)	2
	Crotalariaspectabilis Roth	3(3)	3
	Desmodiumbarbatum (L.) Benth.	3(1)	1
	*Lotus corniculatus*L.	3(1)	1
	*Mimosa ramossima*Benth.	1(5), 19(1), 10(2), 2(11), 4(1)	20
	*Mimosa scabrella*Benth.	1(26), 3(2), 4(2)	30
	Senna neglecta(Vogel) H.S. Irwin &Barneby	3(1), 24(1), 10(1), 2(2), 4(22), 15(1)	28
	Sommerfeldtiaspinulosa(Spreng.) Less.	2(3), 25(1), 61(1)	5
	*Trifoliumpratense*L.	3(1), 58(1)	2
	*Trifoliumrepens*L.	55(1), 1(29), 3(4), 26(1)	35
	Vicia sativa L.	23(1), 52(1), 1(3), 3(37), 22(2)	44
Hemerocallidaceae	*Hemerocallis fulva* (L.) L.	4(1)	1
Hydrangeaceae	*Hydrangeamacrophylla* (Thunb.) Ser.	1(5), 11(1)	6
Iridaceae	*Sisyrinchiumluzula*Klotzsch	30(1)	1
	*Sisyrinchiumvaginatum*Spreng.	5(1),44(1), 16(1)	3
	*Cunilagalioides*Benth.	8(1)	1
Lamiaceae	*Lavanduladentata*L.	37(1), 1(11), 8(3), 3(13), 2(1), 4(3), 61(1), 6(1)	34
	*Lavandulaofficinalis*Chaix	1(53), 8(1), 3(20), 7(1)	75
	*Peltodonradicans*Pohl	26(1)	1
	*Plectranthusneochilus*Schltr.	3(16), 4(4), 5(1), 41(1), 27(1), 6(4), 7(2), 28(1)	30
	*Prunellavulgaris*L.	3(1)	1
	* *Salviacongestiflora*Epling	1(1), 3(1), 20(5)	7
Loasaceae	*Blumenbachiaurens*Urb.	54(1)	1
Lythraceae	*Cupheacarthagenensis* (Jacq.) J.F. Macbr	31(1), 3(1), 5(1), 9(1)	4
Malvaceae	*Pavoniadusenii*Krapov.	57(1)	2

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	*Sida rhombifolia*L.	2(1), 26(1)	2
Melastomataceae	*Tibouchinagracilis* (Bonpl.) Cogn.	32(1), 3(1), 28(2), 15(1)	5
Myrtaceae	*Accasellowiana* (O. Berg) Burret	1(2)	2
	Myrceugeniaovate (Hook. &Arn.) O. Berg	10(1), 2(3)	4
Nyctaginaceae	*Bougainvillea glabra*Choisy	3(1)	1
Oleaceae	*Jasminumpolyanthum*Franch	1(1)	1
	Jasminumsambac (L.) Aiton	4(2)	2
Onagraceae	*Ludwigiasericea*(Cambess.) H. Hara	3(1), 43(1)	2
Oxalidaceae	*Oxalisdebilis*Kunth	53(1), 31(1), 32(1), 66(1)	4
Papaveraceae	*Chelidoniummajus*L.	2(1)	1
	*Eschscholziacalifornica*Cham.	1(82), 3(5), 11(1), 4(19), 21(4),7(1), 72(1)	113
	*Papaversomniferum*L.	39(1), 4(6), 33(1), 7(3), 13(4), 9(1), 49(1), 50(1)	18
Passifloraceae	*Passiflora urubiciensis*Cervi	1(1), 2(1)	2
Plantaginaceae	*Antirrhinummajus*L.	1(2)	2
	Plantago major L.	1(1)	1
Plumbaginaceae	*Plumbagocapensis*Thunb.	1(1), 8(2), 3(2)	5
Poaceae	*Axonopuscompressus* (Sw.) P. Beauv.	8(1)	1
	*Cenchrusciliaris*L.	8(1)	1
	Echinochloa crus-galli (L.) P. Beauv.	8(1)	1
Polygonaceae	*Polygonumacuminatum*Kunth	8(1)	1
	*Polygonumrubricaule*Cham.	8(1)	1
Portulacaceae	*Portulacagrandiflora*Hook.	2(6)	6
Primulaceae	*Lysimachiaarvensis*(L.) U. Manns&Anderb.	31(1), 10(3), 12(1)	5
Ranunculaceae	*Clematis dioica* L.	1(1)	1
Rhamnaceae	*Colletiaexserta*KlotzschexReissek	2(5)	5
Rosaceae	*Maluspumila*Mill.	1(24), 4(13)	37
	*Prunuscerasifera*Ehrh.	1(50)	50
	Prunuspersica (L.) Batsch	1(41)	41
	*Prunusserrulata*Lindl.	1(1), 4(2)	3
	*Pyruscommunis*L.	1(20)	20
	*Pyrusmalus*L.	1(2)	2
	*Rosa x wichuraiana*Crépin.	1(2)	2
	*Rubusspectabilis*Pursh	3(4)	4
Salicaceae	*Salixmatsudana*Koidz.	1(4)	4
Scrophulariaceae	*Verbascumvirgatum*Stokes	46(1)	1
	*Veronica persica*Poir.	1(11)	11
Solanaceae	*Calibrachoadusenii*(R.E. Fr.) Stehmann&Semir	2(1), 5(11)	12
	*Cestrumcorymbosum*Schltdl.	1(2)	2
	*Petuniabonjardinensis*T. Ando &Hashim.	29(2), 32(1), 8(1)	4
	Petunia x hybrida	1(2), 36(1)	3
	*Physalisangulata*L.	1(6), 3(12), 18(3)	21
	*Solanummauritianum*Scop.	3(1)	1
	*Solanumramulosum*Sentdn.	1(6)	6
	*Solanumseaforthianum*Andrews	1(3)	3
	*Solanumvariabile*Mart.	35(2)	2
	*Solanumviarum*Dunal	1(1)	1
Tropaeolaceae	*Tropaeolummajus*L.	33(1)	1
Verbenaceae	*Verbena litoralis*Kunth	37(1), 23(3), 29(1), 30(1), 1(20), 3(1), 2(34), 5(2), 26(1),62(1), 15(3), 34(1), 67(1), 12(3), 17(1), 14(3), 9(1)	78
Violaceae	*Viola* cf.*odorata*L.	16(1)	1
	Nest entrance	11(1)	1
	Grainmeal	18(2), 24(1), 19(1), 11(1)	5
	Flying	8(1), 3(4), 27(2), 22(3)	10
total			2208

Figure 1.The SJNP in Santa Catarina State, southern Brazil.

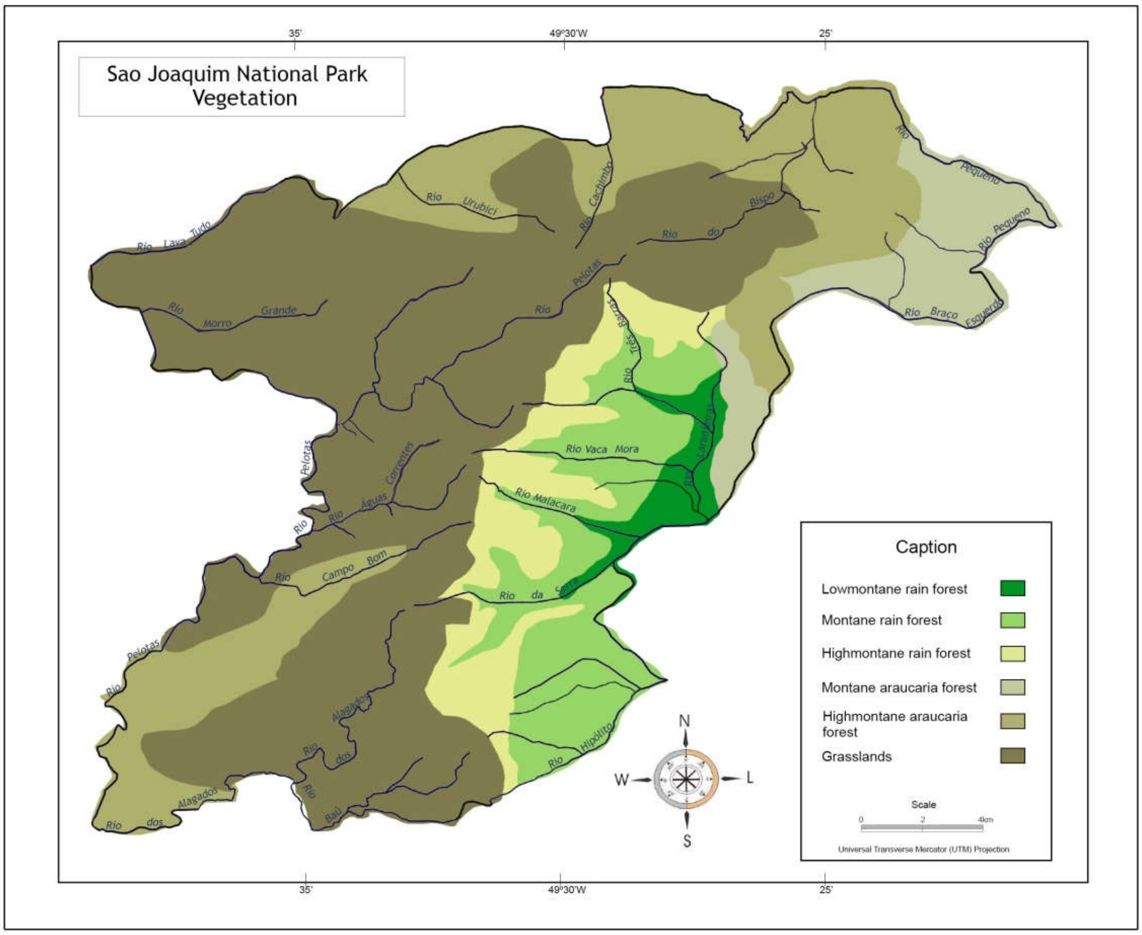


Figure 2. Map of the vegetation of the SJNP. Adapted from IBGE (1981).

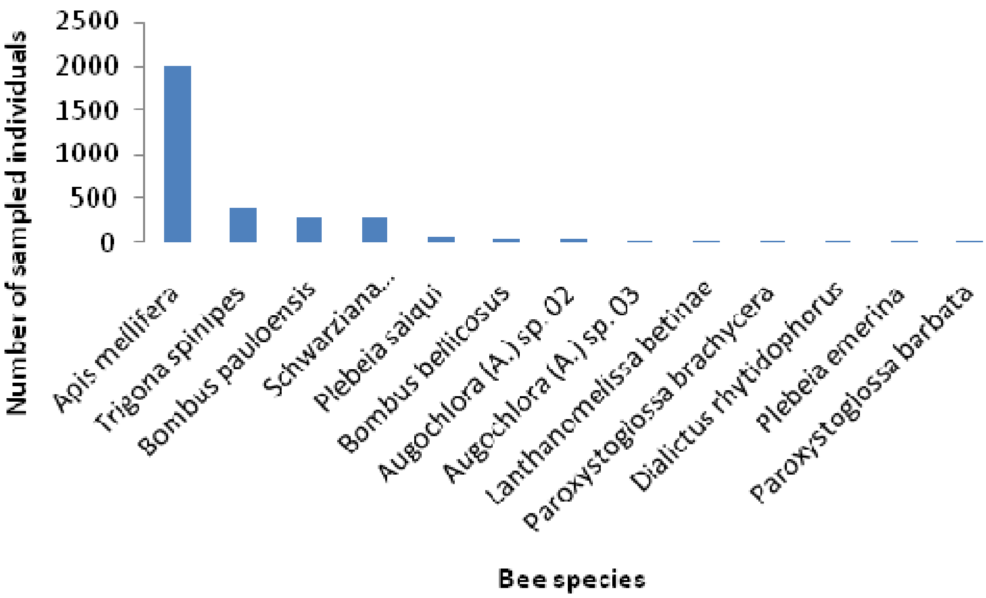


Figure 3. Abundance of the most sampled bee species at the SJNP.

Whether it has (had) an impact on the composition of the bee biodiversity is unclear but it can be seen that the introduction of the africanized honeybee did not cause the disappearance of other social bees, indigenous in Brazil, such as other social bee species (Trigonini, *Bombus pauloensis*) predominate in the sampled bee material. They are polylectic and were reported during most of the year, but differences in their preferences are of interest. On the other side, the number of specimens collected for each of the bee species varied and there are many species listed with less than 10 individuals collected. Several explanations are possible for their rareness: a species may be really rare, or may have a rather restricted time window for its flights (such as being the consequence of being oligolectic, the schedule for the collecting trips may explain the absence, etc.), or may nest far away from the track sampled. It is premature to make firm statements, because this will only be possible if a bee species is recorded rather frequently and its absence on the flowers of rather common plants is also known. Nevertheless, records on occurrence may be helpful for the formulation of questions that can be investigated in the future. There are farms in the reserve and the cattle have impact on the flora as bovids consume a great part of the grasses and of the vegetation of modest size (SOUZA, 2004). Further, as a consequence of the human settlements, there are quite many ornamentals and other introduced food sources. The high quantity of sampled specimens of *Apis mellifera* Linnaeus, 1758 is, additionally, probably derived from feral colonies and perhaps hived ones. All these facts constitute disturbances to the natural order that need to be addressed(FERNANDES and OMENA, 2010). The relative importance of honeybees in the environment is high. This species is polylectic, eusocial, with colonies with huge numbers of individuals and their presence disturb the picture as they may deplete food sources for wild species or they may scare away the other species through their odours and behaviour. About the interactions that occurred between bees and plants, some proved peculiar. *Passiflora urubiciensis*, endemic (MOREIRA *et al.,* 2011), with pharmacological and herbal potential (MUSCHNER *et al*., 2003), and *Petunia bonjardinensis,* threatened ornamental species restricted to SC and the neighbor State of *Rio Grande do Sul* (GERATS and STROMMER, 2009), were sampled with *Bombus bellicosus* (bee species threatened mentioned earlier) and *Anthrenoides petunia,* a typical altitude species. *Actenosigynes fulvoniger (*Michener, 1989), an oligolectic bee species, was noted on *Blumenbachia urens* Urb.(Loasaceae), a wild grassland species.*Mimosa scabrella* (*bracatinga*), a valuable tree species for environmental restoration and production of honeydew, by the natural association bees – mealbugs (WITTER *et al*.,2008), was intensively foraged by several bee species. These examples illustrate, among the different botanic formations present in the southern Brazil, the richness of the region in terms of endemic angiosperms (IGNACI *et al.,* 2014). Speaking of botanic families preferences, it is clear that Asteraceae was the most intensely sought after by the bee species. In open altitude environments, this family is characterized by significant diversity of *taxa* and is considered an important bee forage resource, due to its structural features (FALKENBERG, 2003). Social bees are polylectic, while many solitary bees can be polylectic and others oligolectic. Much of the patterns of flower visiting of the solitary bees is still unknown and, for this reason, it is important that both, bee and plant species, are recorded because oligolectic bee-plant relations are vulnerable: the disappearance of the plant would have as its consequence the disappearance of the bee. On the other side, the fact that there has been only*A. mellifera* in a third of the plant species sampled suggests an intense competitive effect (MOUGA *et al.,* 2012). Honeybees can disturb the figure as they may deplete food sources for wild species or may scare away the other species through their odors and behavior. The presence of this introduced bee species should be monitored, in a view to control invasive species in conservation units. Mutual dependences should be expected between the original fauna and the original vegetation. However, among the endemic plant species *Leptostelma catharinense* (Asteraceae), *Senecio conyzaefolius* (Asteraceae) and *Salvia congestiflora* (Lamiaceae), all of them were visited both by *Apis mellifera* and also by *Bombus pauloensis, Schwarziana quadripunctata, Dialictus* spp.; *Paroxystoglossa* sp. 1 and *Bombus pauloensis,* *Thygater chaetaspis*, respectively, that are relatively common bee species. As stated by Vásquez and Aizen (2006), it is rare that both flowering plants and floral visitors participate in reciprocally specific pollination interactions. On the other hand, there were plant species that were not visited by *Apismellifera*. These visits are of special interest, because original relationships can become visible. In this way, we noticed *Bombus pauloensis* (no corbiculate Apidae) as the only visitor of *Ipomoea purpurea* (Convovulaceae), of *Zinnia elegans, Dahlia pinnata* and *Vernoanthura montevidensis* (Asteraceae), of *Vicia sativa* and *Trifolium repens* (Fabaceae), of *Lavandula officinalis* and *Plecthranthus neochillus* (Lamiaceae) and of *Physalis angulata* (Solanaceae). The small Trigonini visit plants that are unrewarding for *Apis* and oligolectic bee species. In this way, we noticed *Schwarziana quadripunctata* (Meliponini) as the main visitor of many Asteraceae *(Baccharis crispa, Baccharis miriocephala, Calendula officinalis, Hypochaeris radicata, Senecio braziliensis, Senecio icoglossus*), Fabaceae (*Mimosa ramosissima*) and Portulacaceae (*Portulaca grandiflora*) and *Trigona spinipes* (Meliponini) was alone on *Centarea cyanus* (Asteraceae), *Rhondendrom simsii* (Ericaceae), *Senna neglecta* (Fabaceae), *Eschscholzia californica* (Papaveraceae) and *Malus pumila* (Rosaceae).

Limiting the comparison to the plant species with more than 40 bee visits recorded, we see that *Zantedeschia*, *Prunus ceracifera* and *Prunus persica* were visited by *Apis* only; *Baccharis crispa* and *Baccharis* cf. *trimera* predominantly by *Apis*, the same for *Taraxacum officinale*, *Echium plantagineum*, *Calendulaofficinalis*, *Senecio brasiliensis.* This dominance is less pronounced in the case of *Solidago chilensis*. *Zinnia elegans* and *Lavandula officinalis* were visited by *Apis* and *Bombus*, *Escholzia californica* by *Apis* and *Trigona spinipes*, and *Verbena litoralis* by *Apis* and *Schwarziana*. *Hypochoeris* was predominantly visited by *Schwarziana*, as was *Senecio icoglossus*; *Vicia sativa* and *Ipomoea* were exclusively visited by *Bombus*. So, these four species (*Apis mellifera*,*Schwarziana bipunctata*, *Bombus pauloensis* and *Trigona spinipes*) differ in body size, which may be connected to flight distances being different, or to some flowers being unrewarding for larger bees while attractive to smaller ones. It appears as if the four bee species are in separated niches, with some overlap between the species. There are some factors that could have influence on this pattern, such as where the colonies were located, that may play a role in the question of overlap, but that was not observed. It is intriguing to note that *Trigona spinipes* is hardly connected with the other three species and that *Senna neglecta* is an important plant for this species, lacking the other three species. The number of interactions observed was relatively high.

It is known that this number increases with species richness but at a relatively low rate that results in a low fraction of the possible interactions realized at high species richness values (VASQUEZ and AIZEN, 2006) and even levels off beyond 150 species (JORDANO *et al.,* 2006). Blüthgen (2012) mentions that a fraction of the unrecorded interactions cannot be accounted for and might be related to unknown factors which, among others, include chance effects, limited sampling effort, extremely low probability that the interaction actually occurs in nature despite an obvious cause. According to Olesen and Jordano (2002), the connectance is strongly and negatively associated to species richness so interactions rarify with increasing species richness and connectance decreases. Increasingly diverse communities have a lower number of central species and relatively simple communities have higher connectance (BASCOMPTE *et al.,* 2003). It has been observed that relatively high values of connectance are found in sub networks that only include a subset of the pollinator fauna (JORDANO, 1987), that could be this case, where only bees were searched. A few species contained the bulk of interactions, build the rest of the network around themselves and could be designed as central. These main plant-pollinators consist of a core of generalist species with a high density of interactions and the interactions of the core involve not only other generalists but also the more specialist species. Figures 5 and 6 are very dense due to the myriad of connections and would be even more denser if there were more observations of the number of interactions. In the matrix representation of the bipartite graph (Figure 7), it is possible to observe that there is a concentration of boxes on the left of a hypothetic curve (an isocline) which would mean a perfectly nested matrix.

As there is a low number of individuals recorded for many bee species, and the abundances of the plant species recorded were unknown, a large number of interaction cells in the matrix bees x plants remains empty. These almost empty fields result from the dominance in numbers of the four social species (*Apis mellifera*, *Schwarziana bipunctata*,*Bombus pauloensis* and *Trigona spinipes*), leading to almost devoid cells for the other bee-plant combinations. The way nodes (species) established links in the matrix and the interactions that didn't occur (the zeros in the matrix), give the matrix its characteristic sparse aspect, pointing to nestedness. So, this is not a perfectly nested matrix due to the fact that actual interactions are relatively rare as species-specific traits set limits to the possibilities of successful interactions. These traits are structural patterns that define the distribution of interactions throughout the network and arise mainly from biological constraints (phenology, etc...). According to Jordano *et al. (*2006), most species show, for the number of interactions recorded in studies, values greater than 5. In this study, numbers were, generally, lower and we consider that there is a real difficulty of assessing the totality of biotic interactions within highly diversified communities as most interactions are simply not observed and only a fraction of the maximum possible number actually occurs. The robustness of a network of interactions depends on the pattern of shared interactions and, from the perspective of connectivity distribution, plant-pollinator networks share many features due to ecological setting such as the influence of species loss, invasion by exotics or to overall simplification due to agricultural practices or human intervention (MEMMOTT *et al.,* 2004).

Faunistics and biogeopraphy: Sampling of several *taxa* of plants and bees, not yet reported in literature for the studied environment, has filled gaps in the knowledge about the bee flora and bee species communities in *Serra Geral* range, considered an enclave of araucaria forests (LEITE and KLEIN, 1990), in a region with high levels of biological diversity. The apifauna of southern Brazil is different from that of northernmost places (PINHEIRO-MACHADO, 2002) and some of the species reported to be typical of araucaria forest, according to Mouga *et al.* (2016), were found: *Psaenythia bergi* and *P. colaris* (Andrenidae); *Paroxystoglossa brachycera* and *Pseudagapostemon cyaneus* (Halictidae); *Megachile nigropilosa* (Megachilidae); *Lanthanomelissa betinae* (no corbiculate Apidae) and *Plebeia emerina* (corbiculate Apidae).

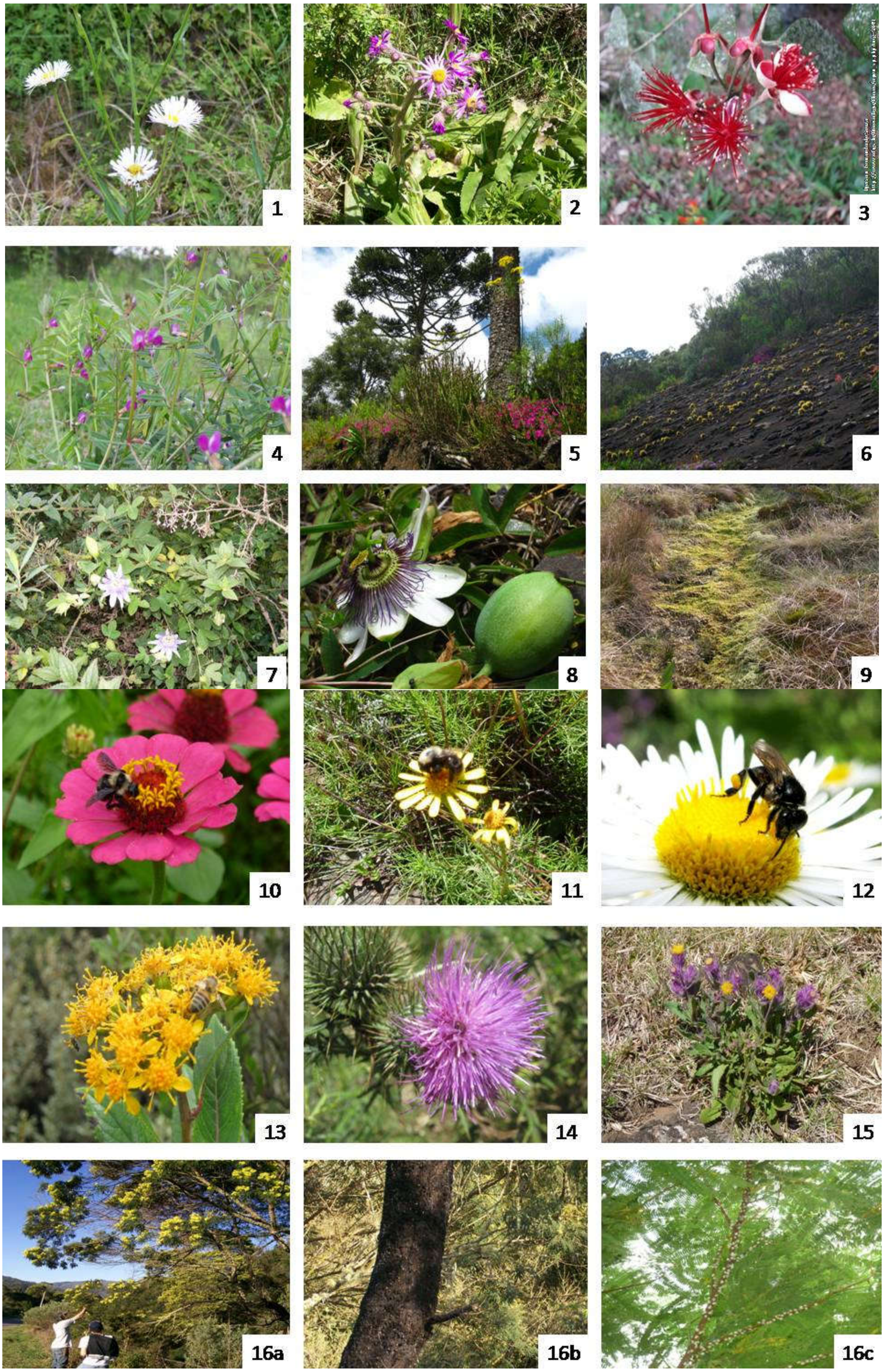


Figure 4. Some taxa of plant and associated bee species observed at SJNP, during 2010-2012. Legend: 1- *Leptostelma catharinense (*Asteraceae) 2 – *Senecio icoglossus (*Asteraceae) 3 – *Acca sellowiana*(Myrtaceae) 4 – *Vicia sativa (*Fabaceae) 5 – *Petunia bonjardinensis (*Solanaceae) 6 – *Parodia haselbergii* subsp. *graessneri (*Cactaceae) 7 – *Passiflora urubicensis (*Passifloraceae) 8 – *Passiflora urubicensis (*Passifloraceae) 9 - peatbogs; 10 – *Bombus pauloensis* (Apinae) on flower of *Zinnia elegans (*Asteraceae) 11 – *Bombus bellicosus*(Apinae) on flower of *Senecio pinnatus*(Asteraceae) 12 - *Schwarzianaquadripunctata* (Apinae) on flower of *Leptostelma maxima* (Asteraceae)13 - *Apis mellifera* (Apinae) on flower of *Graphistylis serrana*(Asteraceae) 14 - *Cirsiumvulgare* (Asteraceae) 15 - *Senecio conyzaefolius* (Asteraceae) 16 a- *Mimosa scabrella* (Fabaceae) 16 b- Tree trunk of *Mimosa scabrella* with mealbugs 16 c- Branches of *Mimosa scabrella* with mealbugs.

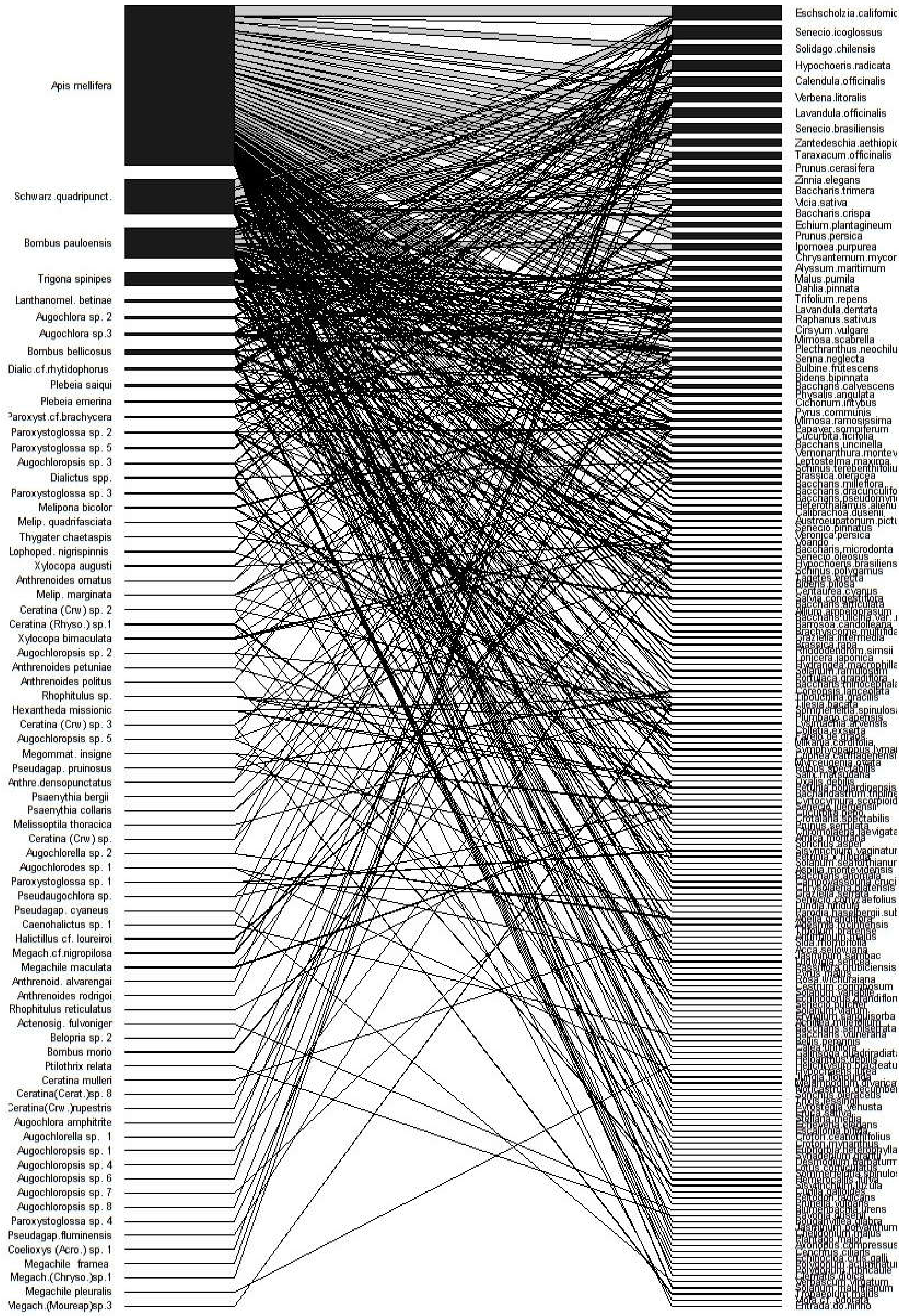


Figure 5. Interaction network between bees and plants at the SJPN, Santa Catarina State, Brazil, with *Apis mellifera.*On left, species of bees; on the right, species of plants. The number of lines and their thickness represent the strength of interaction between the species.

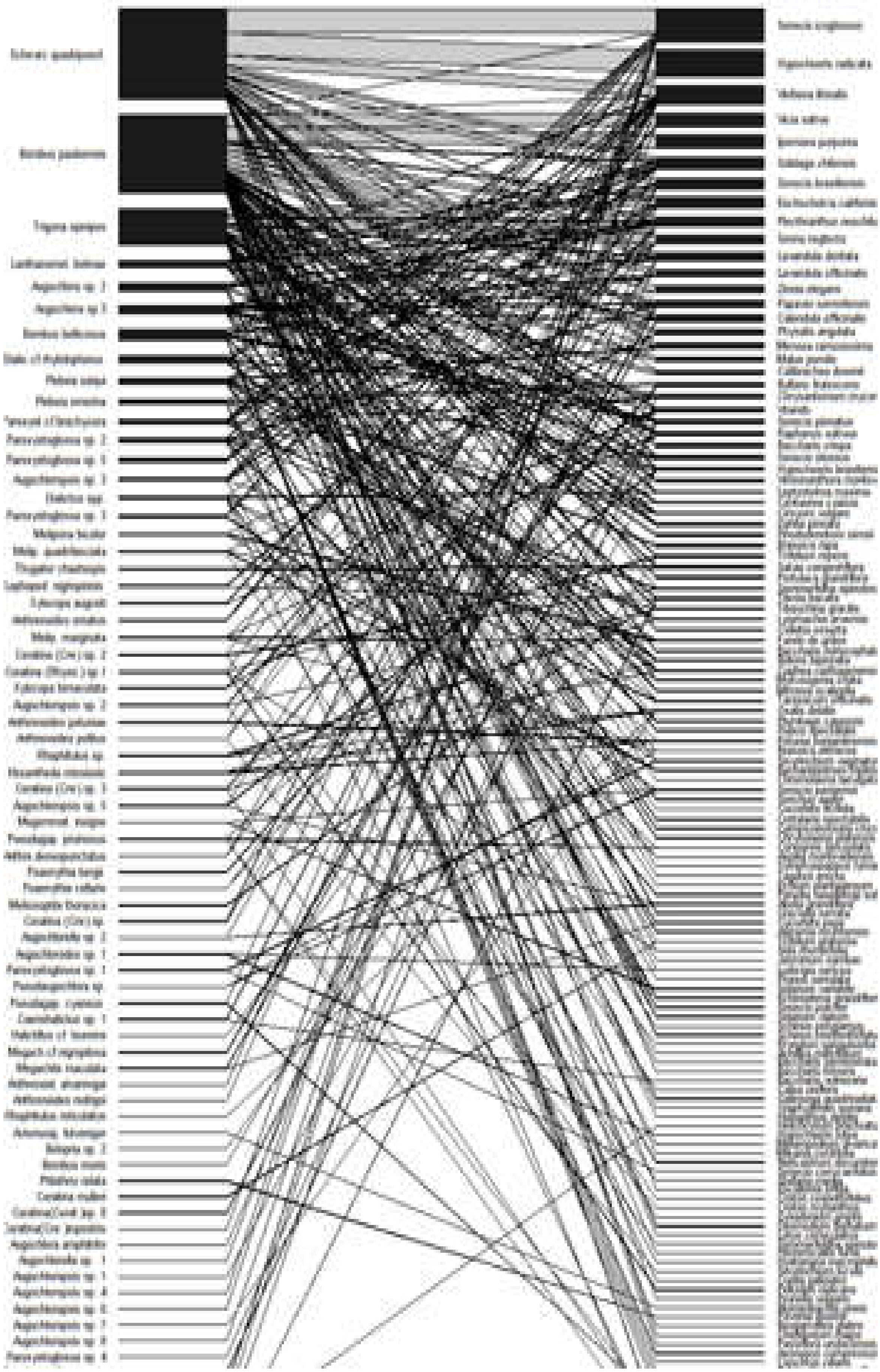
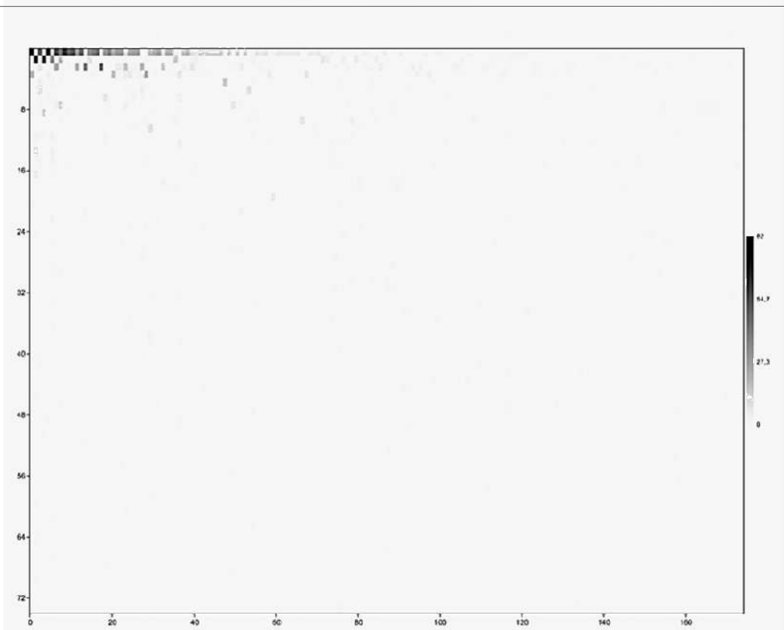


Figure 6. Interaction network between bees and plants at the SJPN, Santa Catarina State, Brazil, without *Apis mellífera.* On left, species of bees; on the right, species of plants. The number of lines and their thickness represent the strength of interaction between the species.



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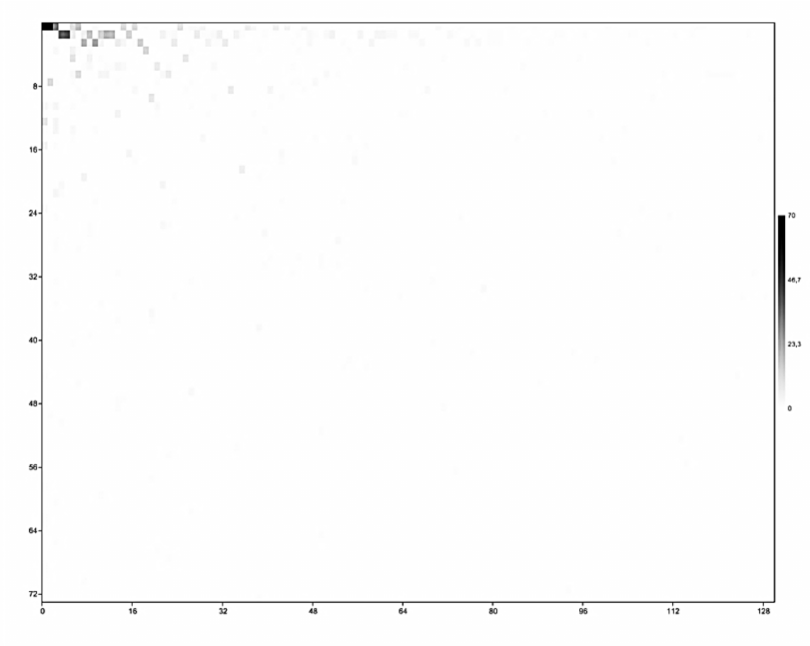

B.

Figure 7. Matrix representation of bipartite data (nestedness graphs). (a) With *Apis mellifera*; (b) without *Apis mellifera*. Rows represent plant species; columns represent bee species; black boxes indicate actually documented pairwise interactions

Figure 8. Araucaria forest advancing over high grasslands at SJNP.

The araucaria forests at the SJNP are nowadays developing in cold and humid climate (Cfb Koeppen classification, humid temperate) that exerts a marked action on the seasonality of bee community. The few bee species that hold activities throughout the year are of interest in terms of use as pollinators of winter agricultural crops (MOUGA and KRUG, 2010) and, also, in the context of climate change (VENTURIERI *et al.*, 2012). Current temperature and rainfall conditions in southern Brazil are favorable for forest development over grasslands (BEHLING, 2002), the advance of araucaria woods towards high grasslands being clearly observable (Figure 8) and would be achieved in some thousands years (DUARTE *et al.,* 2006), if it had not been run over by the advance of humans, as these formations have economic value (LEITE and KLEIN, 1990).

In pristine areas, there is a display of native plants in bloom whose flowers native visitors pollinate (KOPTUR, 2006). The fact that there are still many bee species foraging on the characteristic flora of araucaria forest is an evidence of the importance of this ecosystem. Unfortunately, these pristine areas are very rare nowadays and nonnative plants or pollinators are likely to join the natives in the scenario (BROWN *et al.,* 2002) although there are still large numbers of endemic plant *taxa* in araucaria forests (IGANCI *et al.,* 2013). Nowadays, the araucaria forest is a threatened environment. The results obtained by this work justify the useful activity of censuses as they unveal the situation of the apifauna with the presence of an introduced bee species. The knowledge about extant bee communities can help to understand its structure and support its maintenance.

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