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RESEARCH ARTICLE

Ants (Hymenoptera: Formicidae) of the Parque Estadual São Camilo, an isolated Atlantic Forest remnant in western Paraná, Brazil

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ABSTRACT. We provide a list for the ants collected in the leaf litter, soil and vegetation of the Parque Estadual São Camilo, an important conservation unit of Atlantic Forest in Paraná, Brazil, and one of the oldest in the state. We report 108 species, of which eight species and two genera represent new records for Southern Brazil. Seven species are reported for the first time in Paraná. Our work is the first ant list for the western limit of the state, and reveals a surprisingly high number of species considering the extension of the study area. We highlight the importance of integrating different sampling techniques to explore ant diversity, and to conduct baseline studies in protected areas to document biodiversity.

KEY WORDS. Biome, conservation, Malaise, pitfall, Winkler.

INTRODUCTION

Originally, the Brazilian Atlantic Forest encompassed a 1.5 million km² of the national territory, extending through most of the Brazilian coast and interior areas of Central and Southern regions (Ribeiro et al. 2011). However, the biome has suffered with a drastic habitat loss and fragmentation, mainly derived from anthropogenic activities. Currently, the extension of the Atlantic Forest in Brazil is nearly 0.28–0.30 million km², mainly represented by small, isolated and degraded fragments (Rosa et al. 2021a). Some of those fragments are located in protected areas of the country (Rosa et al. 2021b).

The state of Paraná, Southern Brazil, is covered by two of the six officially recognized Brazilian biomes (MMA 2021): the Atlantic Forest and the Cerrado. While the Cerrado is restricted to small, isolated fragments in the northern portion of the state (Oliveira and Feitosa 2021), the Atlantic Forest occupies most of Paraná's surface, including areas of semideciduous seasonal forests, ombrophilous forests with *Araucaria* and natural grasslands (Franco et al. 2021). One of the conservation unities stablished to protect the Atlantic Forest in the state is the Parque Estadual São Camilo (hereafter PESC), created in 1990 and once named Reserva Biológica de São Camilo (IAT 2022a). The park covers an area of 3.85 km² at the western limit of Paraná, near the border with Paraguay, representing only 0.0002% of the native fragments of the Atlantic Forest in the state (Cortez and Gonçalves 2015). The PESC is also a strategic point to link other preserved areas in at least 15 municipalities at the southwestern of the state (IAT 2022a). Nevertheless, the published studies aimed to report the biological diversity of PESC have been focused on a few taxa (i.e. fungus, plants, bats, bees and wasps) (Ferreira and Cortez 2012, Dias and Cortez 2013, Alves and Cortez 2014, da Silva Cruz and Cortez 2015, Cortez and Gonçalves 2015, Oliveira and Gonçalves 2017, Batista 2018, Silva-Filho et al. 2019). In addition, anthropic pressures as hunting activities, animal traps and pesticides in the immediate surroundings, and irregular plant extraction represent a threat for the maintenance and preservation of the park's biodiversity that need to be urgently addressed (IAT 2022b).

Insects play essential roles in the environment, mainly related to a high sensitivity to ecosystem alterations. Among the insects, ants (Hymenoptera, Formicidae) are a well-studied group in Brazil (Ramalho et al. 2020). Biomass and dominance of ants in terrestrial ecosystems make them crucial in processes of bioturbation, nutrient cycling, decomposition, seed dispersal and energy flow. Moreover, their importance as biological indicators and pest regulators has also been long recognized (Elizalde et al. 2020, Ribas et al. 2012).

One of the first steps to improve our understanding about biodiversity and how the ecosystems are being affected by anthropic activities is to identify the organisms inhabiting them

(Souza-Campana et al. 2019). In that sense, baseline studies, as species lists, are a powerful tool to do so (Camacho and Vasconcelos 2015). We here provided a list of the ant species in the Parque Estadual São Camilo based on four sampling techniques. Our findings revealed a high local richness, also including new geographic records of species and genera for the Paraná and Southern Brazil.

MATERIAL AND METHODS

Study site

The study area was the Parque Estadual São Camilo, located at 8 km of the central area of the municipality of Palotina, Paraná state (see Supplementary file Movie 1). The park has an average elevation of about 250 m average above sea level, and a Cfa climate type according to Köppen classification (IAT 2022b). The PESC is embedded in a broad matrix of anthropic use, and is covered by areas of submontane semideciduous seasonal forests interrupted by intermediate stages of plant succession, and pioneer formations with fluvio-lacustrine influence (IAT 2022b) (Fig. 1).

Experimental design

We established five sampling points at PESC at the semidecidual forest areas, two in the south limits of the park and three adjacent to the visitor's trail and the administrative center (Table 1, Fig. 1). We collected the ants under the collection permit IAT 21.19/15.713.531-7, at the second week of December 2020. Four techniques were employed, including non-baited epigean pitfall traps, Winkler extractors of leaf litter, free hand-collection in vegetation and soil strata, and a flight interception Malaise trap. Our study was a rapid survey, the sampling was not standardized, and there were no replicates. All the techniques, except by the Malaise trap, were employed in the first point, Winkler and hand-collection in the second point, Malaise and hand-collection in the third point, hand-collection in the fourth point, and pitfall and Winkler in the fifth point. The pitfall traps consisted in 25 plastic 200 ml cups containing a solution of water and liquid unscented soap, with the opening positioned at the ground level. We kept the traps in the field for 48 hours, after that, we removed them and sorted the ants (Lasmar et al. 2017). We randomly selected areas to implement the Winkler technique as described by Fisher (1999), except by the ant sorting, which was carried out with ants still alive in white trails. After collecting 31 sifted litter samples, we transported them to our field lab at the PESC administrative center, and sorted the specimens until ant activity ceased. We performed hand-collection of ants in soil and vegetation strata. The Malaise trap was installed adjacent to the visitor's trail of the park, and kept in field for 72 hours

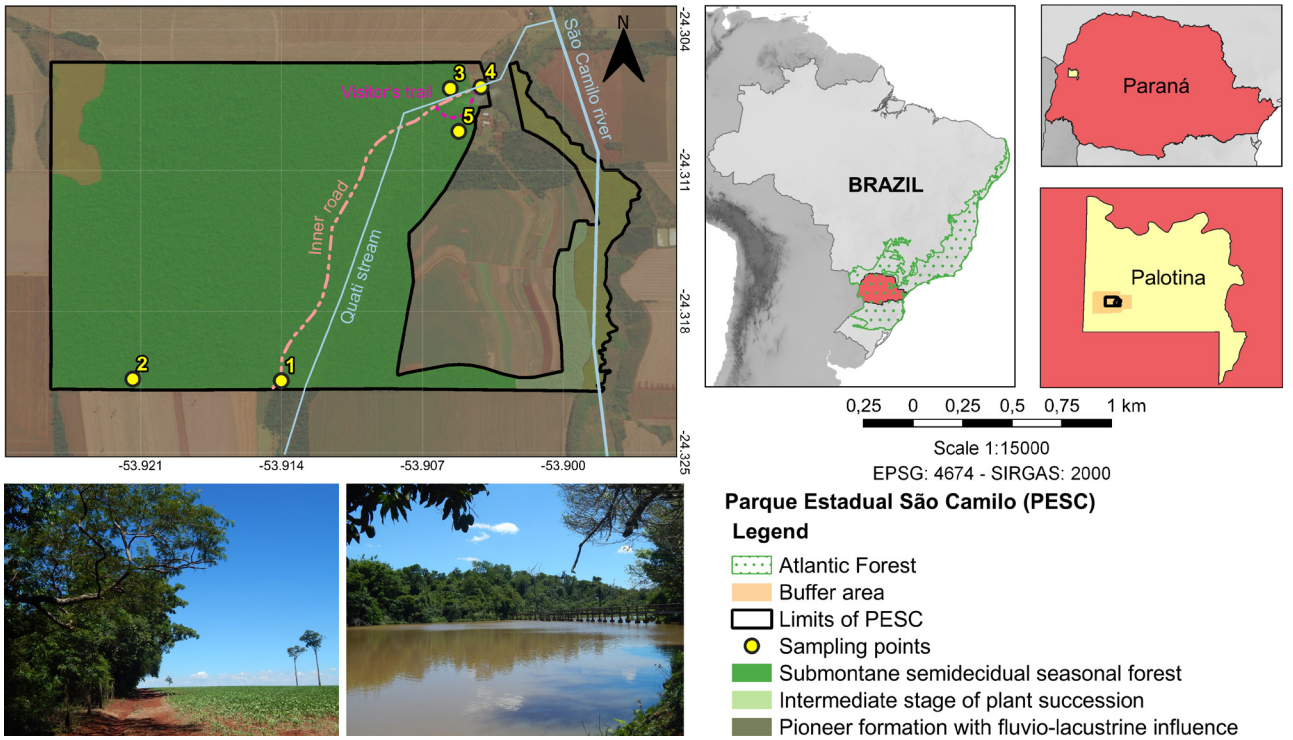

Figure 1. Map showing the collection points indicated by yellow circles at Parque Estadual São Camilo, Palotina, Paraná state, Southern Brazil. The photos show the main environments explored, and the green filled polygons depict the vegetation cover of the park. Photos: N. Ladino, 8–11/12/2020.

Table 1. Collection points at Parque Estadual São Camilo, Palotina, PR. Brazil.

Point number	Point name	Description	Coordinates	Elevation (m)
			Latitude (S), Longitude (W)	
1	Limit 1	Park's limit, after the inner road	-24.321467 -53.914033	329
2	Limit 2	Park's limit, before the inner road	-24.321397 -53.921367	323
3	Trail 1	Restricted access trail	-24.306951 -53.905590	288
4	Station	Visitor's center	-24.306864 -53.904087	287
5	Trail 2	Visitor's trail	-24.309035 -53.905160	283

(Montgomery et al. 2021). All samples were stored in vials with ethanol at 100%, and transported to the Laboratório de Sistemática e Biologia de Formigas at the Universidade Federal do Paraná, where the ants were separated in morphospecies, dry-mounted, pinned, and labelled.

Ant identification

We firstly identified the ants to the genus level using Baccaro et al. (2015). For the identification of species, we used specific taxonomic publications (Gonçalves 1961, Watkins 1976, Kugler and Brown 1982, Mackay and Mackay 2010, Longino 2013, Johnson and Cover 2015, Ortiz et al. 2019, Oliveira et al. 2021). For the identification of *Rogeria* species we consulted Otávio Guilherme Morais Silva (Museu Paraense Emílio Goeldi). For the identification of *Odontomachus* and *Pachycondyla* species we consulted unpublished keys provided by Eder Cleyton Barbosa de França and Frederico Rottgers Marcineiro (Universidade Federal do Paraná). For the species of *Pheidole* we used the interactive key as implemented in the Lucid platform, provided by John T. Longino (https://sites.google.com/site/newworldpheidole/home), along with Wilson's monography (2003), and AntWeb (2022). We listed the unidentified ants as morphospecies and deposited vouchers of all collected specimens at the Entomological Collection Padre Jesus Santiago Moure (DZUP), at Universidade Federal do Paraná, Curitiba, Brazil. The new records for Paraná state and Southern Brazil were determined by the revision of taxonomic works and ant surveys carried out in this region, together with the information provided by Antmaps.org (Janicki et al. 2016).

Data treatment

We elaborated a dataset including specimens records by subfamily, genus, species, collection point, and sampling technique. The dataset was analyzed in the R environment with the R Base package (R Core Team 2020), and the graph relating the number of species by genus in each subfamily was made with the ggplot2 package (Wickham 2016). Our list was compared with other records for ants in the region (see Golias et al. 2018, Holdefer et al. 2017, Franco and Feitosa 2018, Martins et al. 2019, Franco et al. 2021, Oliveira and Feitosa 2021). We elaborated a map of the study area in Brazil with the collection points established at PESC in QGIS v.3.16.7 (QGIS 2021), the vegetation cover was retrieved from IAT (2022b). Also, provided a time-lapse video derived from aerial images of changes in land cover over time in Palotina, obtained in Google Earth Pro, v. 7.3.4.8248, as supplementary material (see Supplementary file Movie 1). High-resolution photos from new ant genera records were elaborated with a Zeiss Axiocam 305 camera coupled to a Zeiss Stereo Discovery V20 stereomicroscope. Parameters of brightness and contrast were enhanced in Adobe Photoshop CC2014, and the figure plates were elaborated in Adobe Illustrator 2020.

RESULTS

We recorded 108 species at PESC, distributed in 41 genera and eight subfamilies (Table 2, Fig. 2). Ten species were exclusively collected with pitfall traps, 29 with Winkler extractors, three with Malaise and 12 by hand-collection, from which seven were solely found in vegetation. *Pheidole* was the richest genus with 27 species (25.2%), followed by *Solenopsis* with eight (7.5%) and *Camponotus* with seven (6.5%). We reported the species *Rasopone ferruginea* (Smith, 1858), *Thaumatomyrmex mutilatus* Mayr, 1887, *Pheidole lucretii* Santschi, 1923, *Brachymyrmex santschii* Menozzi, 1927 and *Carebara brevipilosa* Fernández, 2004 for the first time in Paraná; while we firstly recorded *Anochetus bispinosus* (Smith, 1858), *Rogeria scobinata* Kugler, 1994, *Solenopsis iheringi* Forel, 1908, *Strumigenys hyphata* (Brown, 1953), and *Wasmannia iheringi* for Southern Brazil (Figs 3–11).

DISCUSSION

We present here the first list of the ants occurring in the Parque Estadual São Camilo, Paraná, increasing the number of species formerly recorded for the state. We found that less than 30 species listed in the PESC are shared with other areas of the state based on previous studies on ant diversity in Paraná (Holdefer et al. 2017, Franco and Feitosa 2018, Golias et al. 2018, Martins et al. 2019, Franco et al. 2021, Oliveira and Feitosa 2021).

Different works have cited the advantages of combining sampling techniques for rapid ant surveys (e.g. Delabie et al. 2020, Salata et al. 2020). This approach has a positive impact on the reported richness, collection of different ant guilds, and the comprehension of the community structure of ants (Delabie et al. 2020, Salata et al. 2020). Implementing the four sampling techniques applied here was crucial to achieve the results we present, once ants establish their nests and forage in different substrates (Soares and Schoereder 2001). Among the outcomes of using these sampling techniques we outstand that

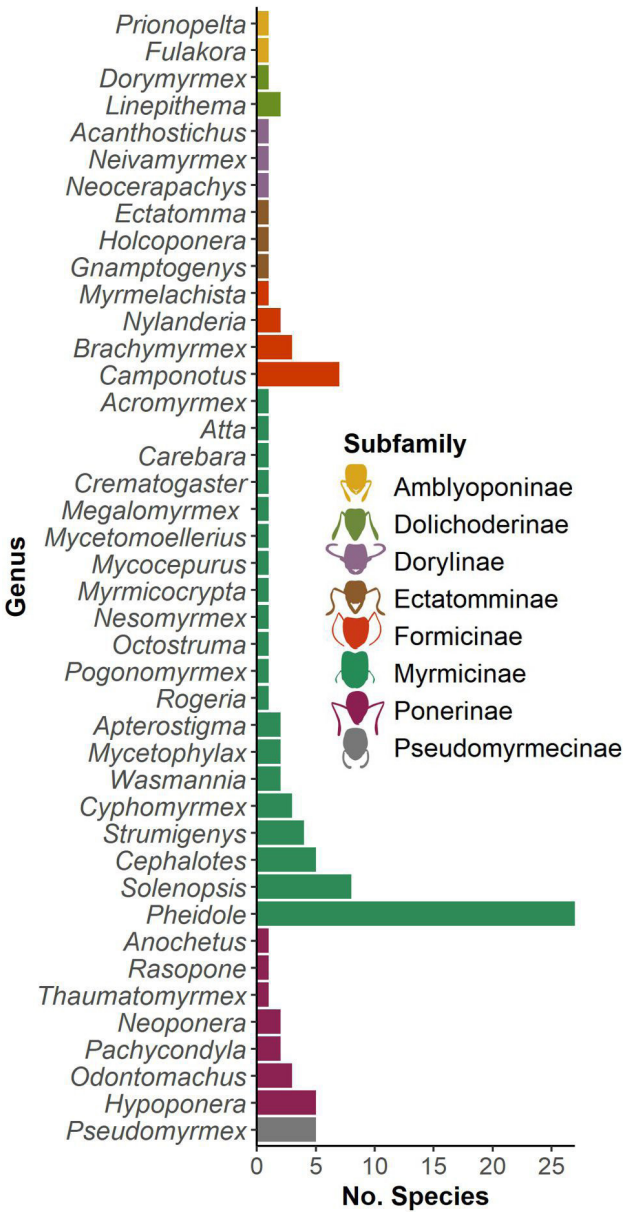

Figure 2. Number of ant species per genus recorded in the Parque Estadual São Camilo, Palotina, PR, Brazil.

the epigean pitfall and Winkler techniques were effective to reveal ants inhabiting or foraging in the soil, litter and rotten wood. On the other hand, species of *Cephalotes* and *Nesomyrmex*, two exclusively arboreal ant genera listed here, were obtained only by hand-collection, once we did not use any technique to explore the arboreal ant fauna. Moreover, the single species of *Neivamyrmex* and *Neoponera marginata* (Roger, 1861), two taxa known by their nomadic habits, were also exclusively captured by hand-collection. In fact, trails of *N. marginata* were widely spread along the PESC visitors trail, but we fail to record the species at the collection points established (see Supplementary file Movie 2). Finally, the Malaise trap allowed us to register a great representativity of ant queens and males. Otherwise, those individuals would have been difficult to capture, since most techniques aimed to collect ants on our study are focused on workers.

The ants recorded in PESC where collected inside a fragment of submontane semidecidual seasonal forest in an advanced stage of recovery (IAT 2022b, Cortez and Gonçalves 2015). This forest type was once considered one of the richest in Brazil in terms of wood volume per unit of area due to a fertile soil derived from basalt (IAT 2022b). Also, the high humidity and wide range substrates for nesting and forage as mold, leaf litter and well-developed roots provide conditions that favor the establishment of ant colonies (Inkotte et al. 2022). Ants in these environments are more prone to be captured with Winkler extractors, which could explain the higher number of exclusive species obtained with this technique in our study. The prevalence of species of *Pheidole*, *Solenopsis* and *Camponotus* in our list is an expected outcome. Together, these taxa account for nearly 40% of the number of ant species collected here and correspond to genera known by their high diversity worldwide. *Pheidole* is the richest ant genera, with around 150 species recognized in Brazil (Casadei-Ferreira et al. 2020). *Camponotus* and *Solenopsis* include species commonly sampled in ant inventories, and stand out for their diversity and complex taxonomy, particularly in South America (Pacheco et al. 2013, Mackay 2019).

Among the new records made here, our discovery of *C. brevipilosa*, *R. ferruginea* and *T. mutilatus* in the PESC filled the occurrence gap for these three genera in Southern Brazil. The southernmost occurrence for this species before ours was recorded in Misiones, Argentina (Hanisch et al. 2018). *Rasopone ferruginea* was already known from Santa Catarina and Rio Grande do Sul, but has never been reported to Paraná until now (Cantarelli et al. 2015, Martins et al. 2019). This species is exclusively Neotropical, and the southernmost limit of its distribution is Formosa, Argentina (Leponce et al. 2004, Theunis et al. 2005). The unprecedent record of *T. mutilatus* was rather expected in Paraná, since neighboring states also reported its presence (Brandão et al. 1991, Kempf 1975, Ulysséa et al. 2011, Demetrio et al. 2017). Outside Brazil, the southernmost records of *T. mutilatus* include Paraguay (Wild 2007) and Misiones, Argentina (Hanisch et al. 2015). Before our work, *A. bispinosus* was only known from the states of Central and Northern Brazil (Brown 1978). Thus, our finding constitutes the southernmost record for the distribution of this species in South America. Similarly, *S. hyphata* was also known so far by a few states Central-North Brazil. Despite the few records in Brazil, the occurrence of *W. iheringi*, *S. iheringi* and *R. scobinata* was not surprising, since these species have been collected in São Paulo, a state that borders Paraná to the north (Kugler 1994, Longino and Fernández 2007, Pacheco et al. 2013). Also, *S. iheringi* and *R. scobinata* have been reported in Paraguay

Figures 3–11. Full-face, lateral and dorsal view of the new genera records for the Paraná state and Southern Brazil according to the survey carried out in the Parque Estadual São Camilo, Palotina: (3–5) *Carebara brevipilosa*; (6–8) *Rasopone ferruginea*; (9–11) *Thaumatomyrmex mutilatus*. Scale: 0.2 mm.

and states of north Argentina (Kugler 1994, Wild 2007, Pacheco et al. 2013, Hanisch et al. 2015, 2018). Some works published in the last decade have reported the presence of *Brachymyrmex santschii* in Southern Brazil, but solely in Santa Catarina (da Silva 1999, Favretto et al. 2013, Ulysséa et al. 2011). Nevertheless, the most recent taxonomic revision of *Brachymyrmex* report this species for Costa Rica and Panamá (Ortíz-Sepúlveda et al. 2019). Finally, the species *Pheidole lucrettii* was only known from Santa Catarina state until our work (Ulysséa et al. 2011), and we here expand its distribution to the north.

We reported an important contribution to the knowledge of ants from Southern Brazil, and added taxonomic novelties for the ant diversity in Paraná (Table 2, Fig. 2, Figs 3–11). Still, we are certain that the ant diversity of the region remains underestimated. The PESC represents a refuge for biodiversity, and one of the last forest fragments of considerable size in Palotina (Cortez and Gonçalves 2015). Considering this, a greater sampling effort and the publication of taxonomic works could lead to more species reported to this area. Our results are evidence of the historical lack of ant surveys in the state, which can be related to the low amount or even the absence of ant specialists based in Paraná institutions so far (Andrade and Feitosa 2020). Complementary to this, the current scenario of systematic dismantling of environmental policies enhanced by the current Brazilian government, suggest a disheartening panorama for the maintenance of ecosystem services within the country biomes (Lira et al. 2021).

Table 2. List of ants of the Parque Estadual São Camilo, Palotina, PR, Brazil, discriminated by collection point and sampling technique: pitfall (P), Winkler (W), Malaise (M), and hand-collection (H; S: soil, V: vegetation). New records for the Paraná state are indicated by one asterisk (*), and new records for Southern Brazil are indicated by two asterisks (**).

Subfamily/Taxon	Technique				
	P	W	M	H	
				S	V
Amblyoponinae					
Fulakora sp. 1		X			
Prionopelta amabilis Borgmeier, 1949		X			
Dolichoderinae					
Dorymyrmex brunneus Forel, 1908					X
Linepithema iniquum (Mayr, 1870)	X				
Linepithema micans (Forel, 1908)	X	X			
Dorylinae					
Acanthostichus sp.			X		
Neivamyrmex bohlsi (Emery, 1896)					X
Neocerapachys sp.			X		
Ectatomminae					
Ectatomma edentatum Roger, 1863	X	X			
Holcoponera striatula (Mayr, 1884)		X			
Gnamptogenys sulcata (Smith, 1858)	X				
Formicinae					
Brachymyrmex admotus Mayr, 1887	X	X			X
Brachymyrmex santschii Menozzi, 1927 *	X	X	X		X
Brachymyrmex sp.		X			
Camponotus ager (Smith, 1858)	X		X		X
Camponotus atriceps (Smith, 1858)	X	X			X
Camponotus cingulatus Mayr, 1862	X	X			
Camponotus crassus Mayr, 1862			X		X
Camponotus sericeiventris (Guérin-Méneville, 1838)			X		
Camponotus sp. 1		X	X		X
Camponotus zenon Forel, 1912	X	X	X		X
Myrmelachista gagatina Emery, 1894			X		X
Nylanderia sp. 1	X	X			
Nylanderia sp. 2		X			
Myrmicinae					
Acromyrmex subterraneus (Forel, 1893)	X	X			X
Apterostigma gr. *pilosum* sp. 1	X				
Apterostigma wasmannii Forel, 1892	X	X			
Atta sexdens (Linnaeus, 1758)	X				X
Carebara brevipilosa Fernández, 2004 *	X	X			
Cephalotes atratus (Linnaeus, 1758)					X
Cephalotes clypeatus (Fabricius, 1804)					X
Cephalotes eduarduli (Forel, 1921)					X
Cephalotes maculatus (Smith, 1876)	X				X
Cephalotes pusillus (Klug, 1824)	X		X		X
Crematogaster evallans Forel, 1911	X		X		X
Cyphomyrmex minutus Mayr, 1862	X	X			X
Cyphomyrmex sp. 1	X				
Cyphomyrmex sp. 2		X			
Megalomyrmex drifti Kempf, 1961		X			
Mycetomoellerius sp.		X			
Mycetophylax sp.		X			

Continues

Table 1. Continued.

Subfamily/Taxon	Technique				
	P	W	M	H	
				S	V
Mycetophylax strigatus (Mayr, 1887)		X			
Mycocepurus smithii (Forel, 1893)	X	X			
Myrmicocrypta sp.	X	X			
Nesomyrmex spininodis (Mayr, 1887)					X
Octostruma balzani (Emery, 1894)	X	X			
Pheidole brevicona Mayr, 1887	X	X			
Pheidole fimbriata Roger, 1863		X			
Pheidole gertrudae Forel, 1886	X	X			
Pheidole gr. *diligens* sp.1					X
Pheidole gr. *flavens*	X	X			
Pheidole gr. *flavens* sp. 1	X	X			
Pheidole gr. *flavens* sp. 2		X			
Pheidole gr. *flavens* sp. 3		X			
Pheidole gr. *flavens* sp. 4		X			
Pheidole jelskii Mayr, 1884	X	X			X
Pheidole lucretii Santschi, 1923 *	X				
Pheidole pr. *rufipilis*	X	X			X
Pheidole radoszkowskii Mayr, 1884	X				
Pheidole subarmata Mayr, 1884	X	X			
Pheidole triconstricta Forel, 1886		X			
Pheidole sp. 1		X			
Pheidole sp. 2		X			
Pheidole sp. 3	X	X			
Pheidole sp. 4	X				
Pheidole sp. 5	X	X	X		X
Pheidole sp. 6	X				
Pheidole sp. 7	X	X			
Pheidole sp. 8	X				X
Pheidole sp. 9	X				
Pheidole sp. 10		X			
Pheidole sp. 11		X			
Pheidole sp. 12		X			
Pogonomyrmex naegelii Emery, 1878				X	
Rogeria scobinata Kugler, 1994 **		X			
Solenopsis iheringi Forel, 1908 **	X	X			
Solenopsis sp. 1	X	X			
Solenopsis sp. 2	X	X			
Solenopsis sp. 4		X			
Solenopsis sp. 5		X			
Solenopsis sp. 6				X	
Solenopsis sp. 7	X	X			
Solenopsis sp. 8	X				
Strumigenys denticulata Mayr, 1887		X			
Strumigenys elongata Roger, 1863	X	X			
Strumigenys hyphata (Brown, 1953) **		X			
Strumigenys louisianae Roger, 1863	X				
Wasmannia auropunctata (Roger, 1863)	X	X			X
Wasmannia iheringi Forel, 1908 **	X	X			
Ponerinae					
Anochetus bispinosus (Smith, 1858) **		X			
Hypoponera foreli (Mayr, 1887)		X			
Hypoponera sp. 1	X	X			
Hypoponera sp. 2		X			

Continues

Table 1. Continued.

Subfamily/Taxon	Technique				
	P	W	M	H	
				S	V
Hypoponera sp. 3	X	X			
Hypoponera sp. 4		X			
Neoponera marginata (Roger, 1861)				X	
Neoponera villosa (Fabricius, 1804)			X		X
Odontomachus chelifer (Latreille, 1802)	X				X
Odontomachus haematodus (Linnaeus, 1758)				X	
Odontomachus meinerti Forel, 1905		X			
Pachycondyla harpax (Fabricius, 1804)	X	X			
Pachycondyla striata Smith, 1858	X				X
Rasopone ferruginea (Smith, 1858) *		X			
Thaumatomyrmex mutilatus Mayr, 1887 *		X	X		
Pseudomyrmecinae					
Pseudomyrmex gracilis (Fabricius, 1804)		X	X		
Pseudomyrmex gr. *pallidus* sp. 1			X		X
Pseudomyrmex gr. *pallidus* sp. 2				X	
Pseudomyrmex phyllophilus (Smith, 1858)		X	X		X

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LITERATURE CITED

Andrade PL, Feitosa RM (2020) Coleção Entomológica Padre Jesus Santiago Moure: um novo centro de referência para a formação de sistematas de formigas (Hymenoptera: Formicidae). Boletim do Museu Paraense Emílio Goeldi, Ciências Naturais 15(1): 277–288. https://doi.org/10.46357/bcnaturais.v15i1.244

Alves CR, Cortez VG (2014) Gasteroid Agaricomycetidae (Basidiomycota) from São Camilo State Park, Paraná, Brazil. Revista Brasileira de Biociências 12(1): 26. http://www.ufrgs.br/seerbio/ojs/index.php/rbb/article/view/2632

AntWeb (2022) AntWeb. v. 8.75.3. California Academy of Science. Available online at: http://www.antweb.org [Accessed: 04/01/2022]

Baccaro FB, Feitosa RM, Fernández F, Fernandes IO, Izzo TJ, Souza JLP, Solar RRC (2015) Guia para os gêneros de formigas do Brasil. INPA, Manaus, 388 pp. https://doi.org/10.5281/zenodo.32912

Batista SC (2018) Assembleia de morcegos (Mammalia, Chiroptera) do Parque Estadual de São Camilo, Paraná, Brasil. MSc. Dissertation, Universidade Federal do Paraná, Brazil. Available online at: https://www.acervodigital.ufpr.br/handle/1884/55748?show=full

Brandão CRF, Diniz JLM, Tomotake EM (1991) *Thaumatomyrmex* strips millipedes for prey: a novel predatory behaviour in ants, and the first case of sympatry in the genus (Hymenoptera: Formicidae). Insectes Sociaux 38(4): 335–344. https://doi.org/10.1007/BF01241869

Brown WL (1978) Contributions toward a reclassification of the Formicidae. Part VI. Ponerinae, tribe Ponerini, subtribe Odontomachiti. Section B. Genus *Anochetus* and bibliography. Studia Entomologica 20: 549–638.

Camacho GP, Vasconcelos HL (2015) Ants of the Panga Ecological Station, a Cerrado reserve in central Brazil. Sociobiology 62(2): 281–295. https://doi.org/10.13102/sociobiology.v62i2.281-295

Cantarelli EB, Fleck MD, Granzotto F, Corassa JN, D'Avila M (2015) Diversidade de formigas (Hymenoptera:Formicidae) da serrapilheira em diferentes sistemas de uso do solo. Ciência Florestal 25(3): 607–616. https://doi.org/10.5902/1980509819612

Casadei-Ferreira A, Economo EP, Feitosa RM (2020) Additions to the taxonomy of *Pheidole* (Hymenoptera: Formicidae) from the southern grasslands of Brazil. Revista Brasileira de Entomologia 64(4): e20200068. https://doi.org/10.1590/1806-9665-RBENT-2020-0068

Cortez VG, Gonçalves RB (2015) Guia da biodiversidade de Palotina. Editora UFPR, Curitiba, 232 pp.

da Silva Cruz K, Cortez VG (2015) *Xylaria* (Xylariaceae, Ascomycota) in the Parque Estadual de São Camilo, Paraná, Brazil. Acta Biológica Paranaense 44: 1–4.

da Silva RR (1999) Formigas (Hymenoptera: Formicidae) do oeste de Santa Catarina: histórico das coletas e lista atualizada das espécies do Estado de Santa Catarina. Biotemas 12(2): 75–100. https://doi.org/10.5007/%25x

Delabie J, Koch E, Dodonov P, Caitano B, DaRocha W, Jahny B, Leponce M, Majer J, Mariano C (2020) Sampling and Analysis Methods for Ant Diversity Assessment. In: Santos JC, Fernandes GW (Eds) Measuring Arthropod Biodiversity. Springer, Cham, 13–54. https://doi.org/10.1007/978-3-030-53226-0_2

Demétrio MF, Silvestre R, Souza PR, Aoki C (2017) Checklist of ants (Hymenoptera, Formicidae) from Mato Grosso do Sul, Brazil. Iheringia, Série Zoologia 107: e2017126. https://doi.org/10.1590/1678-4766e2017126

Dias RL, Cortez VG (2013) New records of *Pluteus* (Agaricales) from Paraná State, Brazil. Mycosphere 4: 937–943. https://doi.org/10.5943/mycosphere/4/5/6

Elizalde L, Arbetman M, Arnan X, Eggleton P, Leal IR, Lescano MN, Saez A, Werenkraut V, Pirk GI (2020) The ecosystem services provided by social insects: traits, management tools

and knowledge gaps. Biological Reviews 95(5): 1418–1441. https://doi.org/10.1111/brv.12616

Favretto MA, dos Santos EB, Geuster CJ (2013) Entomofauna do oeste do estado de Santa Catarina, Sul do Brasil. EntomoBrasilis 6(1): 42–63. https://doi.org/10.12741/ebrasilis.v6i1.271

Ferreira AJ, Cortez VG (2012) Lepiotoid Agaricaceae (Basidiomycota) from São Camilo State Park, Paraná State, Brazil. Mycosphere 3(6): 962–976. https://doi.org/10.5943/mycosphere/3/6/11

Fisher BL (1999) Improving inventory efficiency: a case study of leaf-litter ant diversity in Madagascar. Ecological Applications 9(2): 714–731. https://doi.org/10.1890/1051-0761(1999)009[0714:IIEACS]2.0.CO;2

Franco W, Feitosa RM (2018) First standardized inventory of ants (Hymenoptera: Formicidae) in the natural grasslands of Paraná: New records for Southern Brazil. Papéis Avulsos de Zoologia 58: e20185812. https://doi.org/10.11606/1807-0205/2018.58.12

Franco W, Vasconcelos HL, Feitosa RM (2021) Patterns of Ant Diversity in the Natural Grasslands of Southern Brazil. Neotropical Entomology 50: 725–735. https://doi.org/10.1007/s13744-021-00886-y

Golias HC, Lopes J, Delabie JHC, de Azevedo F (2018) Diversity of ants in citrus orchards and in a forest fragment in Southern Brazil. EntomoBrasilis 11(1): 01–08. https://doi.org/10.12741/ebrasilis.v11i1.703

Gonçalves CR (1961) O gênero *Acromyrmex* no Brasil (Hym. Formicidae). Studia Entomologica 4: 113–180.

Hanisch PE, Calcaterra LA, Leponce M, Achury R, Suarez AV, Silva RR, Paris CI (2015) Check list of ground-dwelling ant diversity (Hymenoptera: Formicidae) of the Iguazú National Park with a comparison at regional scale. Sociobiology 62(2): 213–227.

Hanisch PE, Suarez AV, Tubaro PL, Paris CI (2018) Co-occurrence patterns in a subtropical ant community revealed by complementary sampling methodologies. Environmental Entomology 47(6): 1402–1412. https://doi.org/10.1093/ee/nvy143

Holdefer DR, Lutinski JA, Garcia FRM (2017) Does organic management of agroecosystems contribute to the maintenance of the richness of ants? Semina: Ciências Agrárias 38(6): 3455–3468. https://doi.org/10.5433/1679-0359.2017v38n6p3455

IAT (2022a) Instituto Água e Terra. https://www.iat.pr.gov.br/Pagina/Conheca-os-Parques-do-Parana

IAT (2022b) Instituto Água e Terra. http://www.iat.pr.gov.br/Pagina/Plano-de-Manejo-Parque-Estadual-de-Sao-Camilo

Inkotte J, Bomfim B, da Silva SC, Valadão MBX, da Rosa MG, Viana RB, Rios Polliana DA, Gatto A, Pereira RS (2022) Linking soil biodiversity and ecosystem function in a Neotropica savana. Applied Soil Ecology 169: 104209. https://doi.org/10.1016/j.apsoil.2021.104209

Janicki J, Narula N, Ziegler M, Guénard B, Economo EP (2016) Visualizing and interacting with large-volume biodiversity data using client-server web-mapping applications: The design and implementation of antmaps.org. Ecological Informatics 32: 185–193.

Johnson RA, Cover SP (2015) A taxonomic revision of the seed-harvester ant genus *Pogonomyrmex* (Hymenoptera: Formicidae) on Hispaniola. Zootaxa 3972(2): 19. https://doi.org/10.11646/zootaxa.3972.2.5

Kempf WW (1975) A revision of the Neotropical ponerine ant genus *Thaumatomyrmex* Mayr (Hymenoptera: Formicidae). Studia Entomologica 18: 95–126.

Kugler C (1994) A revision of the ant genus *Rogeria* with description of the sting apparatus (Hymenoptera: Formicidae). Journal of Hymenoptera Research 3:17–89.

Kugler C, Brown WL (1982) Revisionary and other studies on the ant genus *Ectatomma*, including the description of two new species. Search Agriculture 24: 1–8.

Lasmar CJ, Queiroz ACM, Rabello AM, Feitosa RM, Canedo-Júnior EO, Schmidt FA, Cuissi RG, Ribas CR (2017) Testing the effect of pitfall-trap installation on ant sampling. Insectes Sociaux 64: 445–451. https://doi.org/10.1007/s00040-017-0558-7

Leponce M, Theunis L, Delabie JH, Roisin Y (2004) Scale dependence of diversity measures in a leaf-litter ant assemblage. Ecography 27(2): 253–267. https://doi.org/10.1111/j.0906-7590.2004.03715.x

Lira PK, Portela RCQ, Tambosi LR (2021) Land-Cover Changes and an Uncertain Future: Will the Brazilian Atlantic Forest Lose the Chance to Become a Hopespot? In: Marques MCM, Grelle CEV (Eds) The Atlantic Forest. Springer, Cham, 233–251.

Longino JT (2013) A revision of the ant genus *Octostruma* Forel 1912 (Hymenoptera, Formicidae). Zootaxa 3699(1): 1–61. https://doi.org/10.11646/ZOOTAXA.3699.1.1

Longino JT, Fernández F (2007) Taxonomic review of the genus *Wasmannia*. Memoirs of the American Entomological Institute 80: 271–289.

Mackay WP (2019) New World Carpenter Ants of the Hyperdiverse genus *Camponotus*. Lambert Academic Publishing, El Paso, vol. 1, 412 pp.

Mackay WP, Mackay EE (2010) Systematics and biology of the New World ants of the genus *Pachycondyla* (Hymenoptera: Formicidae). Edwin Mellen Press, Lewiston, 642 pp.

Martins MFO, Thomazini MJ, Baretta D, Brown GG, da Rosa MG, Zagatto MR, Santos A, Nadolny HS, Cardoso GBX, Niva CC, Bartz ML, Feitosa RM (2019) Accessing the subterranean ant fauna (Hymenoptera: Formicidae) in native and modified subtropical landscapes in the Neotropics. Biota Neotropica 20: e20190782. https://doi.org/10.1590/1676-0611-BN-2019-0782

MMA (2021) Biomas. Ministério do Meio Ambiente, Brasília. https://antigo.mma.gov.br/biomas.html [Accessed: 04/01/2022]

Montgomery GA, Belitz MW, Guralnick RP, Tingley MW (2021) Standards and Best Practices for Monitoring and Benchmarking Insects. Frontiers in Ecology and Evolution 8: 579193. https://doi.org/10.3389/fevo.2020.579193

Oliveira AM, Powell S, Feitosa RM (2021) A taxonomic study of the Brazilian turtle ants (Formicidae: Myrmicinae: *Cephalotes*). Revista Brasileira de Entomologia 65(3): e20210028. https://doi.org/10.1590/1806-9665-RBENT-2021-0028

Oliveira AM, Feitosa RM (2021) Save the survivors: the remarkable ant diversity of the last protected fragment of savanna in Southern Brazil. Insectes Sociaux 68: 49–58. https://doi.org/10.1007/s00040-020-00804-2

Oliveira PS, Gonçalves RB (2017) Trap-nesting bees and wasps (Hymenoptera: Aculeata) in a Semidecidual Seasonal Forest fragment, southern Brazil. Papéis Avulsos de Zoologia 57: 149–156. https://doi.org/10.11606/0031-1049.2017.57.13

Ortíz-Sepúlveda CM, Van Bocxlaer B, Meneses AD, Fernández F (2019) Molecular and morphological recognition of species boundaries in the neglected ant genus *Brachymyrmex* (Hymenoptera: Formicidae): toward a taxonomic revision. Organisms Diversity & Evolution 19(3): 447–542. https://doi.org/10.1007/s13127-019-00406-2

Pacheco JA, Mackay WP, Lattke J (2013) The systematics and biology of the New World thief ants of the genus *Solenopsis* (Hymenoptera: Formicidae). Edwin Mellen Press, New York, 501 pp.

QGIS (2021) QGIS Geographic Information System. QGIS Association. http://www.qgis.org

R Core Team (2020) R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, v. 3.6.3. https://www.R-project.org/

Ramalho M, Martins C, Moreau CS (2020) Myrmecology: majority of females only within the colony. Boletim do Museu Paraense Emílio Goeldi-Ciências Naturais 15(1): 17–26. https://doi.org/10.46357/bcnaturais.v15i1.241

Ribas CR, Campos RBF, Schmidt FA, Solar RRC (2012) Ants as Indicators in Brazil: A Review with Suggestions to Improve the Use of Ants in Environmental Monitoring Programs. Psyche 2012: 636749. https://doi.org/10.1155/2012/636749

Ribeiro MC, Martensen AC, Metzger JP, Tabarelli M, Scaran F, Fortin M-J (2011) The Brazilian Atlantic Forest: a shrinking biodiversity hotspot. In: Zachos F, Habel J (Eds) Biodiversity hotspots: distribution and protection of conservation priority areas. Springer, Berlin, 405–433.

Rosa MR, Brancallon PHS, Crouzeilles R, Tambosi LR, Piffer PR, Lenti FEB, Hirota M, Santiami E, Metzger JP (2021a) Hidden destruction of older forests threatens Brazil's Atlantic Forest and challenges restoration programs. Science Advances 7(4): eabc4547. https://doi.org/10.1126/sciadv.abc4547

Rosa TF, Camarota F, Zuanon LA, Tito R, Maravalhas JB, Powell S, Vasconcelos HL (2021b) The effects of high-severity fires on the arboreal ant community of a Neotropical savanna. Oecologia 196: 951–961. https://doi.org/10.1007/s00442-021-04922-x

Salata S, Kalarus K, Borowiec L, Trichas A, Kujawa K (2020) How estimated ant diversity is biased by the sampling method? A case study of Crete: a Mediterranean biodiversity hotspot. Biodiversity and Conservation 29(9): 3031–3050. https://doi.org/10.1007/s10531-020-02014-5

Silva-Filho AGS, Seger C, Cortez VG (2019) *Panaeolus* (Agaricales) from Western Paraná state, South Brazil, with a description of a new species, *Panaeolus sylvaticus*. Edinburgh Journal of Botany 76(2): 297–309. https://doi:10.1017/S0960428619000064

Soares SM, Schoereder JH (2001) Ant-nest distribution in a remnant of tropical rainforest in southeastern Brazil. Insectes Sociaux 48(3): 280–286. https://doi.org/10.1007/PL00001778

Souza-Campana DR, Carvalho ACN, Canali M, Silva OGM, Morini MSC, Fujihara RT (2019) A rapid survey of ground-dwelling ants (Hymenoptera: Formicidae) in an urban park from state of São Paulo, Brazil. Brazilian Journal of Biology 80: 682–684. https://doi.org/10.1590/1519-6984.221831

Theunis L, Gilbert M, Roisin Y, Leponce M (2005) Spatial structure of litter-dwelling ant distribution in a subtropical dry forest. Insectes Sociaux 52(4): 366–377. https://doi.org/10.1007/s00040-005-0822-0

Ulysséa MA, Cereto CE, Rosumek FB, da Silva RR, Lopes BC (2011) Updated list of ant species (Hymenoptera, Formicidae) recorded in Santa Catarina State, southern Brazil, with a discussion of research advances and priorities. Revista Brasileira de Entomologia 55(4): 603–611. https://doi.org/10.1590/S0085-56262011000400018

Watkins JF (1976) The identification and distribution of New World Army Ants. Baylor University Press, Waco, Texas, 109 pp.

Wickham H (2016) ggplot2: Elegant Graphics for Data Analysis. Springer, Cham, 260 pp. https://doi.org/10.1007/978-3-319-24277-4

Wild AL (2007) A catalogue of the ants of Paraguay (Hymenoptera: Formicidae). Zootaxa 1622(1): 1–55. https://doi.org/10.11646/ZOOTAXA.1622.1.1

Wilson EO (2003) *Pheidole* in the New World: a dominant, hyperdiverse ant genus. Harvard University Press, Cambridge, vol. 1, 820 pp.

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Supplementary material 1
Supplementary file Movie 1. Evolution of the surrounding area of Parque Estadual São Camilo along time, with details of vegetation covering and urban expansion.
Authors: N Ladino, RM Feitosa.
Data type: Geographical data.

Link: https://doi.org/10.1590/S1984-4689.v39.e22001

Supplementary material 2
Supplementary file Movie 2. Record of a nest migration event of *Neoponera marginata* (Formicidae: Ponerinae) in one of the trails of Parque Estadual São Camilo.
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