



RESEARCH ARTICLE - ANTS

How the Choice of Habitat and Sampling Technique Affects Biodiversity Knowledge: The Case of *Cylindromyrmex* (Hymenoptera, Formicidae) in the Atlantic Forest

JORGE L.P. SOUZA^{1,2,5}, RICARDO E. VICENTE^{1,3,4}, PEDRO R. BARTHOLOMAY¹

1 - Instituto Nacional da Mata Atlântica (INMA), Santa Teresa, Espírito Santo, Brazil

2 - Programa de Pós-Graduação em Zoologia, Universidade Federal Do Amazonas (UFAM), Manaus, Amazonas, Brazil

3 - Instituto Nacional de Pesquisa do Pantanal (INPP), Cuiabá, Mato Grosso, Brazil

4 - Museu Paraense Emílio Goeldi (MPEG), Belém, Pará, Brazil

5 - Programa de Pós-Graduação em Ecologia de Biomas Tropicais, Universidade Federal de Ouro Preto (UFOP), Ouro Preto, Minas Gerais, Brazil

Article History

Edited by

Jacques Hubert C. Delabie, UESC/CEPLAC, Brazil

Received 03 May 2023

Initial acceptance 31 October 2023


Final acceptance 17 November 2023

Publication date 23 February 2024

Keywords

Ants; biomonitoring; Dorylinae; collecting methods; taxonomy; urban diversity.

Corresponding author

Jorge L.P. Souza 
 Instituto Nacional da Mata Atlântica
 Av. José Ruschi nº 4, CEP: 29650-000
 Santa Teresa, Espírito Santo, Brasil.
 E-Mail: souza.jorge@gmail.com

Abstract

The Atlantic Forest is a biodiversity hotspot, and myrmecologists broadly study its numerous habitats. Even so, much of its biodiversity remains to be discovered, and the choice of collection methods and habitats to be explored directly affect the results obtained, especially in the case of species with cryptic habits, such as *Cylindromyrmex* ants. The ant subfamily Dorylinae has 11 genera registered in the Neotropics, with *Cylindromyrmex* Mayr, 1870 being a lineage to the region. The present study reports new records of three *Cylindromyrmex* species in 13 municipalities located in the Atlantic Forest in southeastern Brazil. It also describes the effect of sampling techniques and habitats on species records. The 78 examined herein specimens belong to the species *C. brasiliensis* Emery, 1901, *C. brevitarsus* Santschi, 1925, and *C. longiceps* André, 1892, and were collected manually or with Malaise traps. Records are distributed along the Espírito Santo state, with a tendency towards higher records in municipalities with mountainous habitats. All records in this region of the Atlantic Forest are associated with the hottest months and with the highest rainfall, suggesting a possible preference for nuptial flights in the summer. Most records of the three *Cylindromyrmex* species occurred in forested areas (93%), whereas few records belong to urban areas (7%). Although manual collections and Malaise traps are not widely used in research or surveys of ant diversity, these techniques could potentially reveal essential findings for ant ecology.

Introduction

The Atlantic Forest is recognized as a biodiversity hotspot, although its area has been substantially reduced over the years (Ribeiro et al., 2011; Resende et al., 2018). It is also the most well-studied biome in Brazil by myrmecologists (Feitosa et al., 2022; Lewinsohn et al., 2022; Schmidt et al., 2022; Queiroz et al., 2023), with numerous ant biodiversity projects executed in Brazilian states still containing Atlantic Forest remnants (e.g., FAPESP 2008). An extensive database of Atlantic Forest ants was recently published as a data paper;

it is a compilation of ant distribution data between 1886 and 2020 (Silva et al., 2022). Even with these extensive efforts over the years, knowledge gaps remain to be filled, such as occurrence records of *Cylindromyrmex* Mayr, 1870 species in the state of Espírito Santo. The genus has been recorded in the surrounding states, which makes its presence likely in Espírito Santo (Baccaro et al., 2015).

Ant diversity surveys are directly affected by the choice of sampling methods, separately or in combination (Souza et al., 2012; Vicente et al., 2016; Souza & Araujo, 2020). Pitfall traps and Winkler extractors are the most commonly used



methods, and one of their advantages versus other methods is obtaining a high diversity of ants (Souza et al., 2012; Gomes et al., 2018; Przybyszewski et al., 2020; Schmidt et al., 2022). Species that nest or inhabit underground strata, hollow stems in the canopy, and, in general, are not commonly seen foraging on the soil surface or in the litter are usually not collected with these techniques (Prado et al., 2016; Vicente et al., 2019). Another factor that directly affects ant surveys is the environments in which they are carried out. Researchers have dedicated years to studying which mechanisms affect and structure assemblages in different habitats and scales (Levin, 1992; McGill, 2010). Ant species do not respond equally to these changes. One of the reasons for their ecological success is the diversity of mechanisms they use in different microhabitats, especially when it comes to feeding and nesting (Hölldobler & Wilson, 1990). Variations in the environmental gradient within the same habitat, between habitats, and even domains generate different responses in the distribution of ant morphological and functional metrics (e.g., richness, abundance, and composition) (Guilherme et al., 2019; Rosenberg et al., 2023; Schultheiss et al., 2022).

Among the 27 Dorylinae genera, *Cylindromyrmex* has an exclusively Neotropical lineage with 13 species (ten living and three extinct) (De Andrade, 1998; Borowiec, 2016), distributed from Mexico to Uruguay (De Andrade, 1998; Quiroz-Robledo, 2003; Janicki et al., 2016; Guénard et al., 2017). *Cylindromyrmex* ants are seemingly associated with termites, at least in part, either as theirinquilines (Wheeler, 1936; Overall & Bandeira, 1985) or as predators of them (De

Andrade, 1998; Borowiec, 2016). Another hypothesis raised by some researchers is that these ants are invasive foragers of arboreal ant nests since the only complete nest series containing brood and reproductives are known only from wood, apparently (Fernández & Escobar, 1997; De Andrade, 1998; Mariano et al., 2004).

In this study, we use *Cylindromyrmex* as an example to describe the effect of habitat choices and collection techniques on species records. Also, we here report records of *Cylindromyrmex* species in southeastern Brazil, and following previous reports, we confirm their distribution along the Atlantic Forest.

Material and Methods

Database

We initially verified the distribution of *Cylindromyrmex* in Brazil using the Atlantic Forest and database (Silva et al., 2022). Additionally, we consulted other databases that compile information on ant distribution: 1. AntWeb.org (2022) and 2. antmaps.org (Janicki et al., 2016; Guénard et al., 2017) to confirm the presence or absence of *Cylindromyrmex* for the state of Espírito Santo.

We also used data compiled by Silva et al. (2022) to verify the total number of ant species records in different habitats and with diverse sampling techniques. Due to the high number of these and their combinations (70), Figures 1 and 2, with information on species records from Brazil and Espírito Santo, show only those with the highest values.

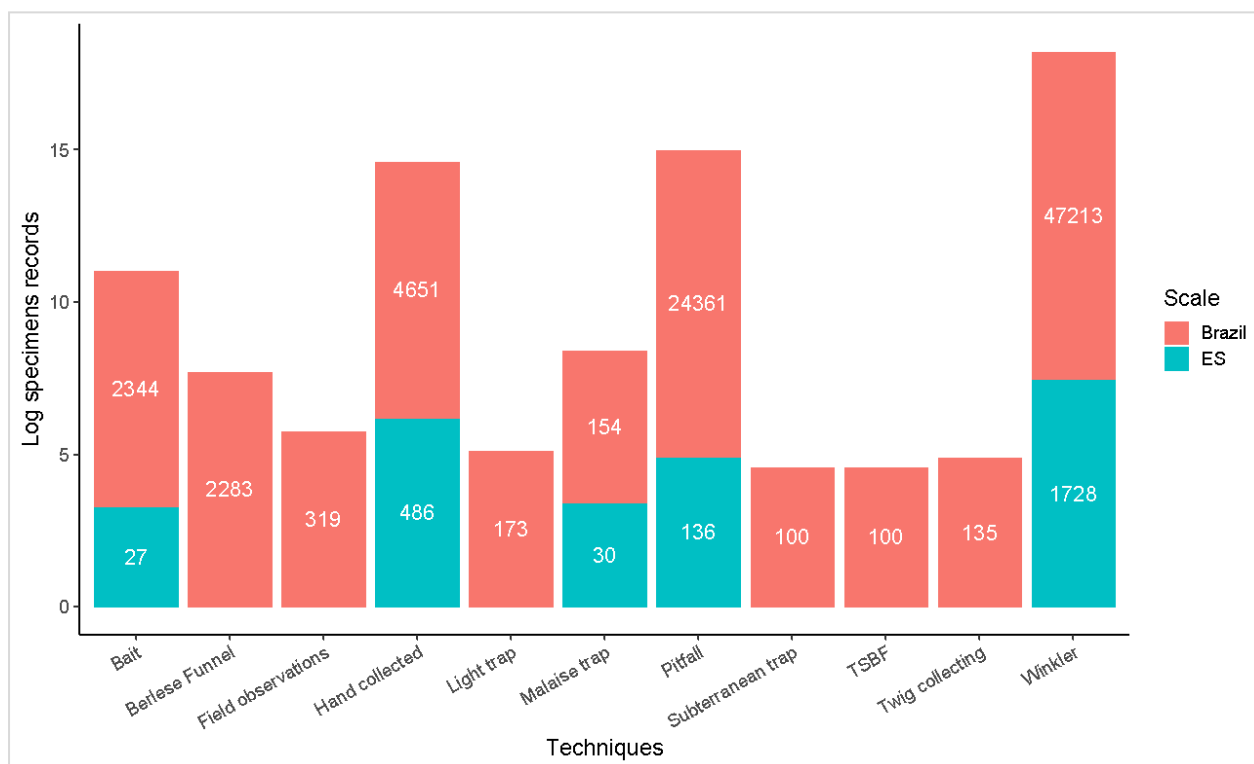


Fig 1. Number of ant species records in Brazil (red bars) and in the Espírito Santo state (green bars) for the main sampling techniques. The Y-axis is on a logarithmic scale, with raw values inside the bars. Data from Silva et al. (2022).

We also removed species records that were obtained through a combination of sampling techniques or lacked information (NA) about them. We adopted a similar procedure for the considered habitats.

Entomological Collections

To verify whether there were specimens of *Cylindromyrmex* collected in Espírito Santo deposited in collections, we examined samples deposited in the entomological collection of the Federal University of Espírito Santo (UFES) and entomological collection and the Hymenoptera collection of the Museu de Zoologia da Universidade de São Paulo (MZSP). When found, specimens of *Cylindromyrmex* were then identified to species whenever possible.

Collected specimens

We manually collected *Cylindromyrmex* specimens in an urban area surrounded by remnants of tropical ombrophilous forest in the Atlantic Forest corridor at Santa Teresa, a mountainous region of Espírito Santo. We identified the specimens using available taxonomic keys by Brown (1975) and De Andrade (1998, 2001) while also comparing our material with that preserved in the collection of the Universidade Federal do Espírito Santo (UFES). The material of such collection was previously identified by specialists (Rodrigo Feitosa and John Latke). Voucher specimens were deposited in the Invertebrate Collection of the Instituto Nacional da Mata Atlântica (INMA).

Results

The Winkler technique showed Brazil's most species records, followed by pitfall trapping, manual collection, and baits (Figure 1). The Winkler technique accumulated approximately 48% more records than pitfall traps and 90% more records than manual collection. When considering only Espírito Santo, we found a similar pattern, with the Winkler technique showing the highest amount of records, followed by manual collection and pitfall trapping (Figure 1). The Winkler technique accumulated about 72% more records than manual collection and 92% more records than pitfall trapping.

The vast majority of species records in Brazil belong to forested, natural habitats. The forest phytophysiognomies with the highest records were Cerrado and Restinga. The urban areas showed only 601 records; 1.5% of the records were found in secondary forests, the most species-rich habitats in Brazil (Figure 2). We found a similar pattern in Espírito Santo, with natural habitats dominating the number of records. However, in that state, ant species had an elevated value in Restinga habitats (Figure 2).

Seventy-eight *Cylindromyrmex* specimens were recorded for the Atlantic Forest in Espírito Santo. These were distributed in 13 localities (Figure 3) and sampled manually or with Malaise traps between September and January, which are the rainiest seasons in the state (Table 1).

Among the total number of individuals registered for Espírito Santo, five (7%) were manually collected in the city of Santa Teresa, a mountainous region located at the central

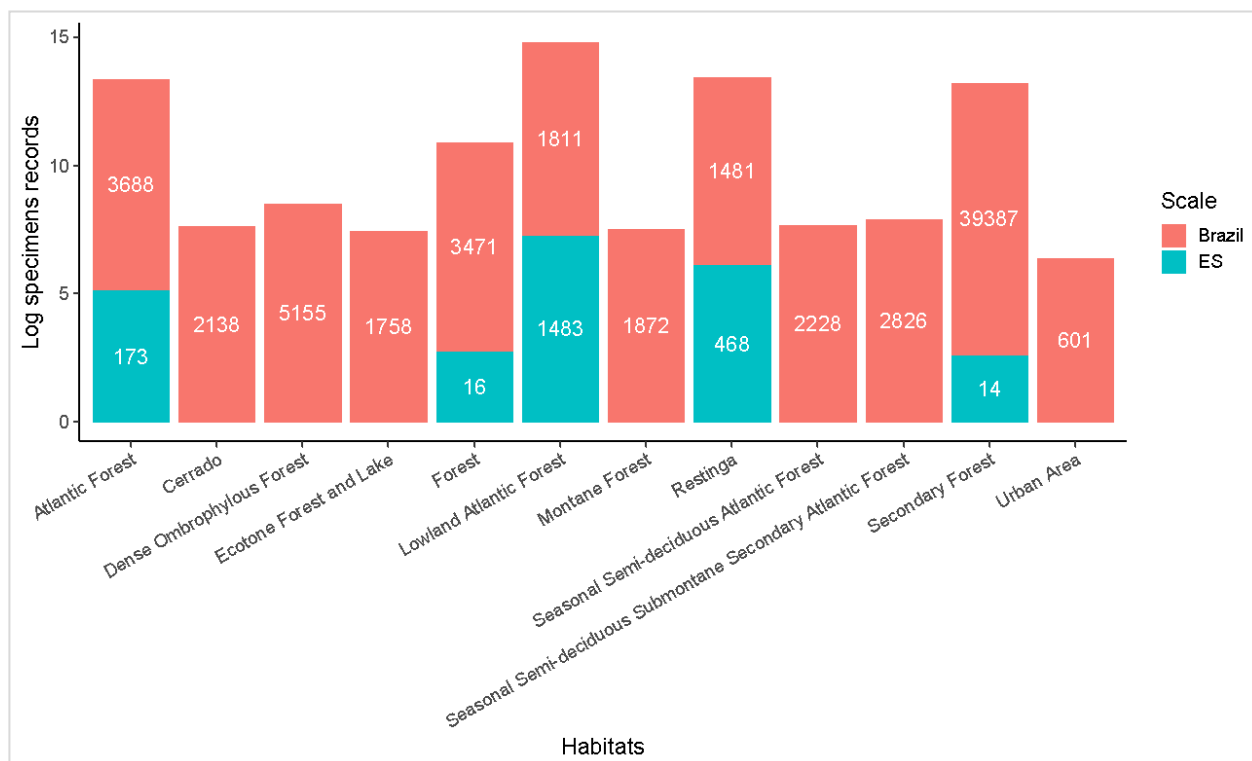


Fig 2. Number of ant records in Brazil (red bars) and in the Espírito Santo state (green bars) showing some of the main habitat and biome types. The Y-axis is on a logarithmic scale, with raw values inside the bars. Data from Silva et al. (2022).

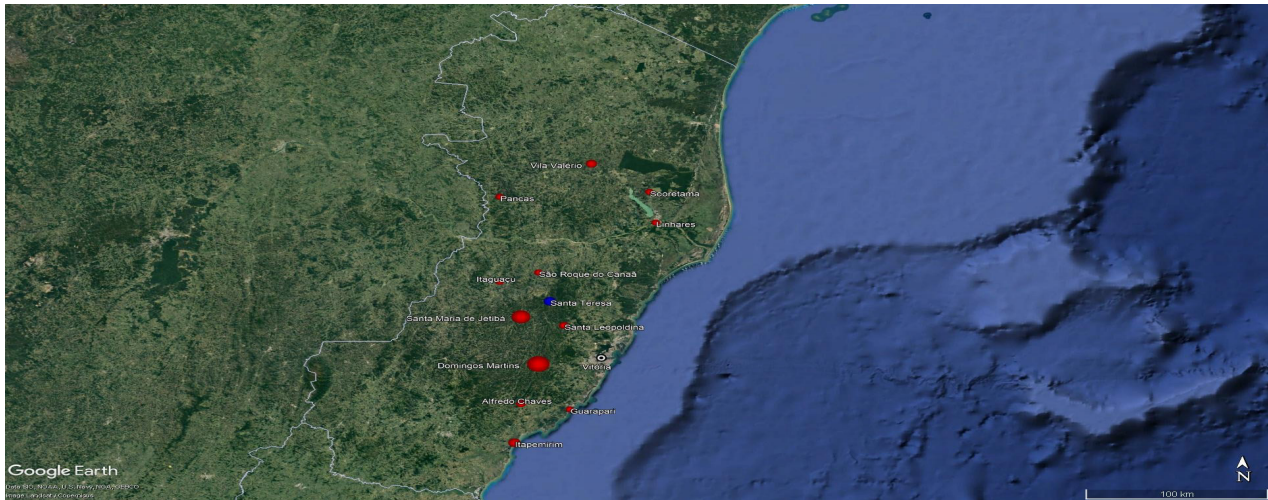


Fig 3. The geographic location of municipalities with records of *Cylindromyrmex* species in Espírito Santo. Red points represent Malaise trap sampling, and blue points represent manual collections. Each point size is visualized relative to the total number of records in the municipality. Data from Silva et al. (2022).

corridor of the Atlantic Forest. These specimens were collected in an urban habitat and identified as *C. brevitarsus* Santschi, 1925, and *C. longiceps* André, 1892 (Figure 4; Table 1).

Most *Cylindromyrmex* records (71) for Espírito Santo come from Malaise trap samples deposited in entomological

collections, covering several phytophysionomies. We registered 50 males, 19 queens, and six workers. Males were identified as genus only. The species recorded in Malaise traps were *C. brasiliensis* Emery, 1901, *C. brevitarsus*, and *C. longiceps* (Table 1).

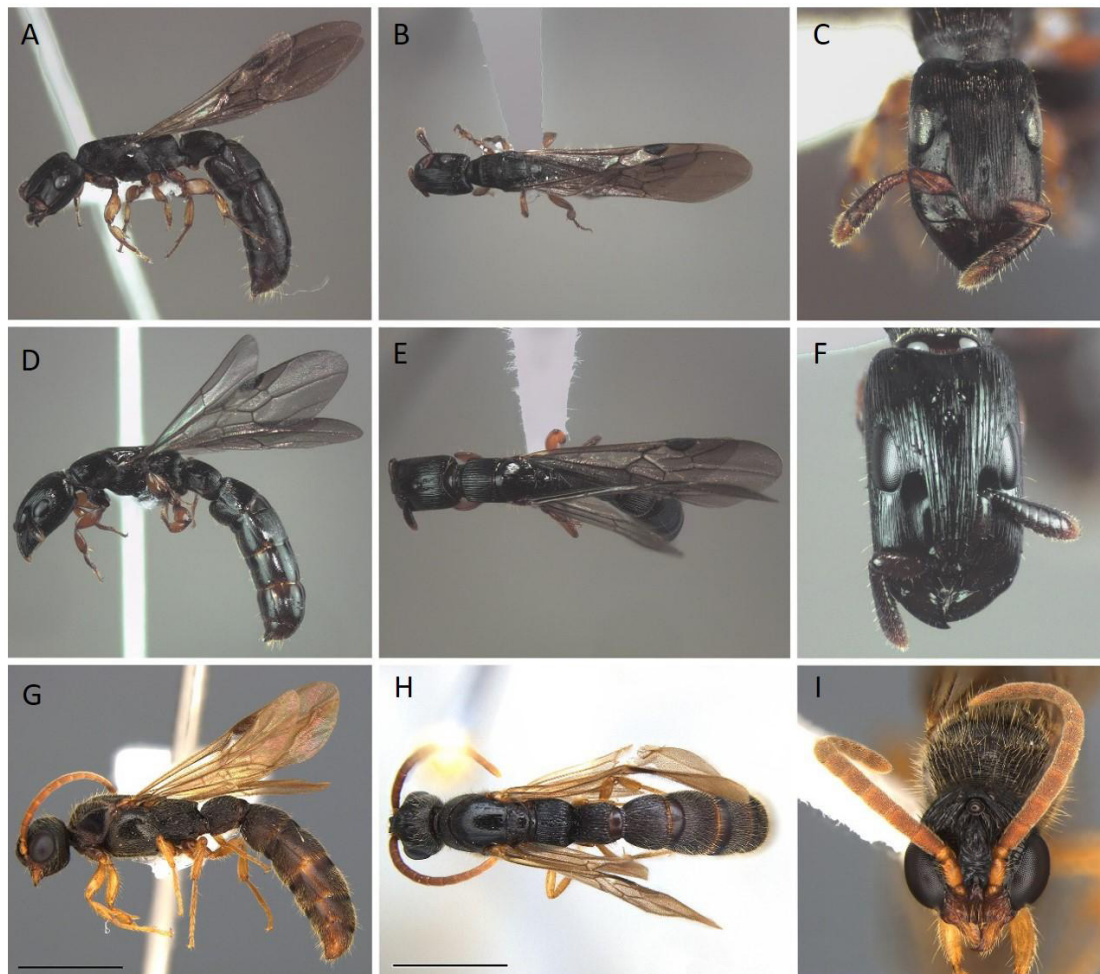


Fig 4. Photos of *Cylindromyrmex longiceps* (A: Lateral view, B: Dorsal view, C: Head in frontal view) and *Cylindromyrmex brevitarsus* (D: Lateral view, E: Dorsal view, F: Head in frontal view) sampled in Santa Teresa, ES and deposited in MBML; and *Cylindromyrmex* sp. (male) (G: Lateral view, H: Dorsal view, I: Head in frontal view) sampled in Linhares, ES, and deposited in MZSP. Scale bar = 2mm.

Discussion

*Confirmed *Cylindromyrmex* records in Espírito Santo*

As far as we know, this is the first study to list *Cylindromyrmex* species in Espírito Santo, and we also confirm and expand the genus distribution in Brazil. Although the Atlantic Forest is the most extensively studied Brazilian biome in regards to ant diversity and distribution in the last two centuries (Feitosa et al., 2022; Schmidt et al., 2022; Silva et al., 2022; Queiroz et al., 2023), some genera (e.g., *Acanthostichus*, *Leptanilloides*, *Neocerapachys*, *Sphinctomyrmex*) classified by some specialists as “probably present”, have not yet been found in the region (Antmaps, 2022; Baccaro et al., 2015). Among these was *Cylindromyrmex*, which until 2015 had its distribution status in Espírito Santo as “probable” (Baccaro et al., 2015, p. 154). However, Azevedo et al. (2015) finally confirmed it as occurring in this state. Unfortunately, this work was published in a journal with low recognition by the international academic community, significantly restricting the dissemination of their findings. So much so that until today, AntMaps, AntWeb, AntWiki, and the data paper by Silva et al. (2022) have yet to update the records of this genus for Espírito Santo.

This case seems to be more common than we imagine. A few years ago, a similar situation occurred with the male caste of *Martialis heureka*, Rabeling & Verhaagh, 2008. There were specimens deposited in the entomological collection of the National Institute for Amazonian Research (INPA), but they were only officially described 30 years after being collected (Boudinot, 2015). In the case of the registration of *Cylindromyrmex* for Espírito Santo, the time between collections and official registration was shorter (21 years) but still quite long. The absence or reduced number of professionals working on updating and computerizing Brazilian biological collections, together with research published in journals of low international relevance, appears to contribute to this kind of situation.

Sampling techniques and habitat type: do they matter for species discovery

Since *Cylindromyrmex* species are either predators and/orinquilines of termites, and colonies are found primarily on cavities and hollow branches, this increases the difficulty of collecting some of its species. In this study, we obtained records of *Cylindromyrmex* species using the Malaise flight interception trap and manual collection of ants. Also, we obtained information from collections in urban habitats, where biodiversity inventories are usually neglected. We recorded the three species of *Cylindromyrmex*, *C. brasiliensis*, *C. brevitarsus*, and *C. longiceps*, from samples of Malaise traps from different areas of the Atlantic Forest of Espírito Santo, usually associated with rural habitats or within the area of a nature reserve, deposited in entomological collections.

Cylindromyrmex brevitarsus and *C. longiceps* were also collected manually in an urban habitat surrounded by Atlantic Forest remnants.

The use of multiple sampling techniques can be helpful due to their complementary effect in better representing the studied fauna (Olson, 1991; Bestelmeyer et al., 2000), with some sampling techniques, however, having redundant effects (Parr & Chown, 1999; Souza et al., 2012). The collecting of ant species in Brazil is associated with the massive use of Winkler extractors, pitfall traps, and baits (Silva et al., 2022), which in recent decades have been considered by specialists as the most common ant sampling techniques (Alonso & Agosti, 2000; Bestelmeyer et al., 2000; Delabie et al., 2000). Similarly, in Espírito Santo, most ant records were obtained using these techniques. However, there is also a pronounced use of manual collection and Malaise traps, the only techniques where we found records of *Cylindromyrmex* species in the state. In general, Malaise trapping is not the most efficient in terms of assessing ant diversity (Delabie & Reis, 2000; Queiroz et al., 2023), but it can be helpful in ant inventories, especially in tropical forests, where flight nuptials appear to have wide frequencies and durations (Kaspari et al., 2001a, b). Furthermore, flight interception traps are profitable for capturing species with more cryptic habits, such as *Cylindromyrmex* (Delabie & Reis, 2000), which are rarely seen on the surface of the soil or leaf litter and are more associated with the hypogeic stratum or hollow branches in the canopy for nesting and forage (Wheeler, 1936; Overal & Bandeira, 1985; De Andrade, 1998; Borowiec, 2016). In Espírito Santo, the majority of *Cylindromyrmex* records (93%) occurred with alates in the Malaise trap, concentrated in the hottest months of the year according to other states (Delabie & Reis, 2000), reinforcing the usefulness of this trap in inventories and studies of ant phenology.

The Atlantic Forest and the Cerrado are the domains best studied by myrmecologists in Brazil (Feitosa et al., 2022; Lewinsohn et al., 2022; Queiroz et al., 2023; Schmidt et al., 2022). Not surprisingly, the vast majority of species records in Brazil compiled by Silva et al. (2022) have occurred in forested habitats. Urban areas have few species records as compared to other habitats studied. The state of Espírito Santo follows the same pattern, with forest habitats dominating the number of ant species records. Still, the situation in urban habitats is more extreme, as no records were computed. Urban habitats surrounded by forests or urban forest fragments are often neglected in biodiversity studies (Savard et al., 2000; Santos, 2016), although there are reports that these areas can function as essential repositories of wildlife (Souza & Araújo, 2020). The situation has improved in recent decades with increased studies in urban habitats (Stringer et al., 2009; Santos, 2016; Perfecto & Philpott, 2023). In our study, 67% of *Cylindromyrmex* species recorded for Espírito Santo were collected manually in urban habitats, evidencing the potential biodiversity these places can harbor.

Table 1. Geographic location, collection dates, sampling techniques, and voucher collections of *Cylindromyrmex* specimens collected in Espírito Santo, Brazil.

Collection code	Voucher Number	Genus	Species	Caste	Determined	Collection date	County	Latitude	Longitude	Technique
UFES-ENTOMOLOGIA	63883	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Male	Souza, 2023	11/26/2004	Domingos Martins	20°22'17"S	40°39'29"W	Malaise
UFES-ENTOMOLOGIA	63884	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Male	Souza, 2023	11/26/2004	Domingos Martins	20°22'17"S	40°39'29"W	Malaise
UFES-ENTOMOLOGIA	63885	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Male	Souza, 2023	11/26/2004	Domingos Martins	20°22'17"S	40°39'29"W	Malaise
UFES-ENTOMOLOGIA	64434	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Male	Souza, 2023	11/26/2004	Domingos Martins	20°22'17"S	40°39'29"W	Malaise
UFES-ENTOMOLOGIA	64443	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Male	Souza, 2023	11/26/2004	Domingos Martins	20°22'17"S	40°39'29"W	Malaise
UFES-ENTOMOLOGIA	64464	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Male	Souza, 2023	11/26/2004	Domingos Martins	20°22'17"S	40°39'29"W	Malaise
UFES-ENTOMOLOGIA	64464	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Male	Souza, 2023	11/26/2004	Domingos Martins	20°22'17"S	40°39'29"W	Malaise
UFES-ENTOMOLOGIA	64467	<i>Cylindromyrmex</i>	<i>brasiliensis</i>	Worker	Souza, 2022	11/26/2004	Domingos Martins	20°22'17"S	40°39'29"W	Malaise
UFES-ENTOMOLOGIA	64468	<i>Cylindromyrmex</i>	<i>brasiliensis</i>	Worker	Souza, 2022	11/26/2004	Domingos Martins	20°22'17"S	40°39'29"W	Malaise
UFES-ENTOMOLOGIA	64470	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Male	Souza, 2023	11/26/2004	Domingos Martins	20°22'17"S	40°39'29"W	Malaise
UFES-ENTOMOLOGIA	64471	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Male	Souza, 2023	11/26/2004	Domingos Martins	20°22'17"S	40°39'29"W	Malaise
UFES-ENTOMOLOGIA	64479	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Male	Souza, 2023	11/26/2004	Domingos Martins	20°22'17"S	40°39'29"W	Malaise
UFES-ENTOMOLOGIA	64483	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Male	Souza, 2023	11/26/2004	Domingos Martins	20°22'17"S	40°39'29"W	Malaise
UFES-ENTOMOLOGIA	64484	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Male	Souza, 2023	11/26/2004	Domingos Martins	20°22'17"S	40°39'29"W	Malaise
UFES-ENTOMOLOGIA	64485	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Male	Souza, 2023	11/26/2004	Domingos Martins	20°22'17"S	40°39'29"W	Malaise
UFES-ENTOMOLOGIA	64486	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Male	Souza, 2023	11/26/2004	Domingos Martins	20°22'17"S	40°39'29"W	Malaise
UFES-ENTOMOLOGIA	64490	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Male	Souza, 2023	11/26/2004	Domingos Martins	20°22'17"S	40°39'29"W	Malaise
UFES-ENTOMOLOGIA	64498	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Male	Souza, 2023	11/26/2004	Domingos Martins	20°22'17"S	40°39'29"W	Malaise
UFES-ENTOMOLOGIA	64504	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Male	Souza, 2023	11/26/2004	Domingos Martins	20°22'17"S	40°39'29"W	Malaise
UFES-ENTOMOLOGIA	64505	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Male	Souza, 2023	11/26/2004	Domingos Martins	20°22'17"S	40°39'29"W	Malaise
UFES-ENTOMOLOGIA	64537	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Male	Souza, 2023	11/26/2004	Domingos Martins	20°22'17"S	40°39'29"W	Malaise
UFES-ENTOMOLOGIA	64610	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Male	Souza, 2023	11/26/2004	Domingos Martins	20°22'17"S	40°39'29"W	Malaise
UFES-ENTOMOLOGIA	64636	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Male	Souza, 2023	11/26/2004	Domingos Martins	20°22'17"S	40°39'29"W	Malaise
UFES-ENTOMOLOGIA	64700	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Male	Souza, 2023	11/26/2004	Domingos Martins	20°22'17"S	40°39'29"W	Malaise
UFES-ENTOMOLOGIA	64816	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Male	Souza, 2023	11/26/2004	Domingos Martins	20°22'17"S	40°39'29"W	Malaise
UFES-ENTOMOLOGIA	66753	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Queen	Souza, 2022	11/19/2010	Itapemirim	20°57'02"S	41°03'20"W	Malaise

Table 1. Geographic location, collection dates, sampling techniques, and voucher collections of *Cylindromyrmex* specimens collected in Espírito Santo, Brazil. (Continuation)

Collection code	Voucher Number	Genus	Species	Caste	Determined	Collection date	County	Latitude	Longitude	Technique
UFES-ENTOMOLOGIA	67453	<i>Cylindromyrmex</i>	<i>brasiliensis</i>	Worker	Souza, 2022	10/8/2007	Alfredo Chaves	20°27'53"S	40°42'35"W	Malaise
UFES-ENTOMOLOGIA	68743	<i>Cylindromyrmex</i>	<i>longiceps</i>	Male	Souza, 2023	11/29/2002	Santa Maria de Jetibá	20°04'27"S	40°44'51"W	Malaise
UFES-ENTOMOLOGIA	69227	<i>Cylindromyrmex</i>	<i>brasiliensis</i>	Male	Souza, 2023	11/5/2007	Santa Leopoldina	20°04'55"S	40°35'39"W	Malaise
UFES-ENTOMOLOGIA	69228	<i>Cylindromyrmex</i>	<i>brasiliensis</i>	Male	Souza, 2023	11/5/2007	Santa Leopoldina	20°04'55"S	40°35'39"W	Malaise
UFES-ENTOMOLOGIA	69234	<i>Cylindromyrmex</i>	<i>brasiliensis</i>	Queen	Souza, 2022	11/5/2007	Santa Leopoldina	20°04'55"S	40°35'39"W	Malaise
UFES-ENTOMOLOGIA	74601	<i>Cylindromyrmex</i>	<i>brasiliensis</i>	Worker	Lattke, 2013	10/14/2009	Alfredo Chaves	20°33'S	40°48'W	Malaise
UFES-ENTOMOLOGIA	76169	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Queen	Souza, 2022	10/14/2009	Alfredo Chaves	20°33'S	40°48'W	Malaise
UFES-ENTOMOLOGIA	78032	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Queen	Souza, 2022	12/6/2011	Sooretama	19°03'18"S	40°08'43"W	Malaise
UFES-ENTOMOLOGIA	82220	<i>Cylindromyrmex</i>	<i>brasiliensis</i>	Worker	Lattke, 2013	9/22/2008	Itaguaçu	19°48'S	40°48'W	Malaise
UFES-ENTOMOLOGIA	89843	<i>Cylindromyrmex</i>	<i>brasiliensis</i>	Worker	Souza, 2022	11/9/2006	Guarapari	20°36'S	40°25'W	Malaise
UFES-ENTOMOLOGIA	94639	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Male	Souza, 2023	11/29/2002	Santa Maria de Jetibá	20°04'28"S	40°44'51"W	Malaise
UFES-ENTOMOLOGIA	94645	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Male	Souza, 2023	11/29/2002	Santa Maria de Jetibá	20°04'28"S	40°44'51"W	Malaise
UFES-ENTOMOLOGIA	94646	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Male	Souza, 2023	11/29/2002	Santa Maria de Jetibá	20°04'28"S	40°44'51"W	Malaise
UFES-ENTOMOLOGIA	94647	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Male	Souza, 2023	11/29/2002	Santa Maria de Jetibá	20°04'28"S	40°44'51"W	Malaise
UFES-ENTOMOLOGIA	95165	<i>Cylindromyrmex</i>	<i>longiceps</i>	Male	Souza, 2023	11/29/2002	Santa Maria de Jetibá	20°02'31"S	40°41'51"W	Malaise
UFES-ENTOMOLOGIA	95166	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Male	Souza, 2023	11/29/2002	Santa Maria de Jetibá	20°02'31"S	40°41'51"W	Malaise
UFES-ENTOMOLOGIA	95167	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Male	Souza, 2023	11/29/2002	Santa Maria de Jetibá	20°02'31"S	40°41'51"W	Malaise
UFES-ENTOMOLOGIA	95171	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Male	Souza, 2023	11/29/2002	Santa Maria de Jetibá	20°02'31"S	40°41'51"W	Malaise
UFES-ENTOMOLOGIA	95745	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Male	Souza, 2023	11/29/2002	Santa Maria de Jetibá	20°04'28"S	40°44'51"W	Malaise
UFES-ENTOMOLOGIA	95746	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Male	Souza, 2023	11/29/2002	Santa Maria de Jetibá	20°04'28"S	40°44'51"W	Malaise
UFES-ENTOMOLOGIA	95747	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Male	Souza, 2023	11/29/2002	Santa Maria de Jetibá	20°04'28"S	40°44'51"W	Malaise
UFES-ENTOMOLOGIA	95748	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Male	Souza, 2023	11/29/2002	Santa Maria de Jetibá	20°04'28"S	40°44'51"W	Malaise
UFES-ENTOMOLOGIA	95749	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Male	Souza, 2023	11/29/2002	Santa Maria de Jetibá	20°04'28"S	40°44'51"W	Malaise
UFES-ENTOMOLOGIA	95751	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Male	Souza, 2023	11/29/2002	Santa Maria de Jetibá	20°04'28"S	40°44'51"W	Malaise
UFES-ENTOMOLOGIA	95752	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Male	Souza, 2023	11/29/2002	Santa Maria de Jetibá	20°04'28"S	40°44'51"W	Malaise
UFES-ENTOMOLOGIA	95753	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Male	Souza, 2023	11/29/2002	Santa Maria de Jetibá	20°04'28"S	40°44'51"W	Malaise

Table 1. Geographic location, collection dates, sampling techniques, and voucher collections of *Cylindromyrmex* specimens collected in Espírito Santo, Brazil. (Continuation)

Collection code	Voucher Number	Genus	Species	Caste	Determined	Collection date	County	Latitude	Longitude	Technique
UFES-ENTOMOLOGIA	95754	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Male	Souza, 2023	11/29/2002	Santa Maria de Jetibá	20°04'28"S	40°44'51"W	Malaise
UFES-ENTOMOLOGIA	100112	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Queen	Souza, 2022	11/19/2010	Itapemirim	20°56'29"S	41°03'06"W	Malaise
UFES-ENTOMOLOGIA	100225	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Queen	Souza, 2022	11/19/2010	Itapemirim	20°57'02"S	41°03'20"W	Malaise
UFES-ENTOMOLOGIA	101861	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Queen	Souza, 2022	11/19/2010	Itapemirim	20°57'02"S	41°03'20"W	Malaise
UFES-ENTOMOLOGIA	102001	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Queen	Souza, 2022	11/19/2010	Itapemirim	20°56'29"S	41°03'06"W	Malaise
UFES-ENTOMOLOGIA	102012	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Queen	Souza, 2022	11/19/2010	Itapemirim	20°56'29"S	41°03'06"W	Malaise
UFES-ENTOMOLOGIA	102075	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Queen	Souza, 2022	11/19/2010	Itapemirim	20°57'02"S	41°03'20"W	Malaise
UFES-ENTOMOLOGIA	103671	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Queen	Souza, 2022	1/24/2003	Pancas	19°13'10"S	40°46'24"W	Malaise
UFES-ENTOMOLOGIA	106332	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Queen	Souza, 2022	1/24/2003	Pancas	19°13'10"S	40°46'24"W	Malaise
UFES-ENTOMOLOGIA	119417	<i>Cylindromyrmex</i>	<i>longiceps</i>	Male	Souza, 2022	9/14/2011	Vila Valério	18°58'S	40°27'W	Malaise
UFES-ENTOMOLOGIA	119422	<i>Cylindromyrmex</i>	<i>longiceps</i>	Queen	Lattke, 2013	9/14/2011	Vila Valério	18°58'S	40°27'W	Malaise
UFES-ENTOMOLOGIA	119443	<i>Cylindromyrmex</i>	<i>longiceps</i>	Male	Souza, 2022	9/14/2011	Vila Valério	18°58'S	40°27'W	Malaise
UFES-ENTOMOLOGIA	2015	<i>Cylindromyrmex</i>	<i>longiceps</i>	Male	Souza, 2023	9/14/2011	Vila Valério	18°58'S	40°27'W	Malaise
UFES-ENTOMOLOGIA	127271	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Queen	Souza, 2022	10/8/2012	Santa Leopoldina	20°10'14"S	40°34'56"W	Malaise
UFES-ENTOMOLOGIA	132432	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Queen	Souza, 2022	9/14/2011	Vila Valério	18°58'S	40°27'W	Malaise
UFES-ENTOMOLOGIA	142724	<i>Cylindromyrmex</i>	<i>brasiliensis</i>	Male	Souza, 2022	12/10/2012	Santa Teresa	19°54'29"S	40°33'19"W	Malaise
UFES-ENTOMOLOGIA	146192	<i>Cylindromyrmex</i>	<i>brasiliensis</i>	Male	Souza, 2022	12/10/2012	Santa Teresa	19°54'29"S	40°33'19"W	Malaise
UFES-ENTOMOLOGIA	150136	<i>Cylindromyrmex</i>	<i>brasiliensis</i>	Male	Souza, 2022	11/2/2007	São Roque do Canaã	19°48'17"S	40°45'52"W	Malaise
MZSP	67500	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Male	Prado, 2022	9/28/2009	Linhares	19°26'14"S	40°04'49"W	Malaise
MZSP	67501	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Male	Prado, 2022	9/28/2009	Linhares	19°26'14"S	40°04'49"W	Malaise
INMA-MBML	3083	<i>Cylindromyrmex</i>	<i>brevitarsus</i>	Queen	Souza, 2022	11/16/2020	Santa Teresa	19°56'9"S	40°36'0"W	Manual
INMA-MBML	3084	<i>Cylindromyrmex</i>	<i>longiceps</i>	Queen	Souza, 2022	11/30/2021	Santa Teresa	19°56'9"S	40°36'0"W	Manual
INMA-MBML	3132	<i>Cylindromyrmex</i>	<i>longiceps</i>	Queen	Souza, 2022	10/29/2022	Santa Teresa	19°56'9"S	40°36'0"W	Manual
INMA-MBML	3133	<i>Cylindromyrmex</i>	<i>longiceps</i>	Queen	Souza, 2022	12/9/2022	Santa Teresa	19°56'9"S	40°36'0"W	Manual
INMA-MBML	3134	<i>Cylindromyrmex</i>	<i>longiceps</i>	Queen	Souza, 2023	1/17/2023	Santa Teresa	19°56'9"S	40°36'0"W	Manual

There is a good chance that ant data is likely “hidden” in entomological collections because it is not digitally available in full in any publicly accessible repository. Alternatively, some of these data are published in scientific journals that, for various reasons (e.g., Publications of species records in journals not indexed in international search databases; journals with dubious reputation), are not accessible via international search engines by most researchers. Factors like these create obstacles to biodiversity knowledge in one of the most studied biomes by myrmecologists over the last few decades. It is important to emphasize that we are not criticizing the curators and researchers, as they are at the end of the curation and publication process. The lack of funding for science due to multiple cuts over the years (Escobar, 2015; 2019; Angelo, 2017) contributes considerably to these knowledge gaps about Brazilian biodiversity.

Conclusion

In this study, we show evidence of how the choice of sampling techniques associated with unexplored habitats can reveal hidden facets of ant biodiversity. Although the Malaise trap and manual collection are not the most efficient techniques regarding richness, abundance, and composition for ant biodiversity inventories, both techniques can be useful for collecting ants with more reclusive foraging and nesting habits. These techniques, whenever possible, should be associated with other collection methods for a better overview of ant diversity. Furthermore, habitats such as urban environments surrounded by forest remnants can function as important repositories of biodiversity and should not be neglected in biodiversity inventories. Finally, we suggest that collection curators and researchers work together so that primary collection data is in secure, publicly accessible repositories. We also propose that researchers exercise caution when publishing their results so that they are readily available to the public in quality scientific journals.

Acknowledgments

We appreciate the support provided by Marcelo Tavares and his team in providing access to specimens in the UFES entomological collection. This study was supported by the National Council for Scientific and Technological Development (CNPq, Programa de Capacitação Institucional – PCI/INMA) of the Brazilian Ministry of Science, Technology and Innovation (MCTI). JLPS was supported by a CNPq PCI/INMA (300886/2022-5) post-doctoral scholarship. REV was supported by the CNPq PCI/INMA (318064/2021-9) and CNPq/MPEG (302057/2023-4) post-doctoral scholarships. PRB was supported by the CNPq PCI/INMA (306711/2022-2) post-doctoral scholarship.

Authors' Contribution

JLPS: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing-Original Draft and Writing-Review & Editing.

REV: Writing-Review & Editing.

PRB: Conceptualization, Data curation, and Writing-Review & Editing.

Statements and Declarations

The authors attest that all funding sources for this study have been included in the acknowledgments section. They also certify no conflict of interest related to the information and data used in this manuscript.

References

- Alonso, L.E. & Agosti, D. (2000). Biodiversity studies, monitoring, and ants: an overview. In: Agosti, D., Majer, J.D., Alonso, L.E., Schultz, T.R. (Eds.), *Ants: Standard Methods for Measuring and Monitoring Biodiversity*. Smithsonian Institution Press, Washington, DC, USA, pp. 1-8.
- Angelo, C. (2017). Brazilian scientists reeling as federal funds slashed by nearly half. *Nature*, 2017: 21766. <https://doi.org/10.1038/nature.2017.21766>
- AntMaps. Online at <https://antmaps.org>. (accessed date: 18 October 2022).
- AntWeb. Version 8.81. California Academy of Science, online at <https://www.antweb.org>. (accessed date: 18 October 2022).
- AntWiki: The Ants - Online. Online at <https://www.antwiki.org>. (accessed date: 18 October 2022).
- Azevedo, C.O., Molin, A.D., Pentead-Dias, A., Macedo, A.C.C., Rodriguez, V.B., Dias, B.Z.K., Waichert, C., Aquino, D., Smith, D.R., Shimbori, E.M., Noll, F.B., Gibson, G., Onody, H.C., Carpenter, J.M., Lattke, J.E., Ramos, K.S., Williams, K., Masner, L., Kimsey, L.S., Tavares, M.T., Olmi, M., Buffington, M.L., Ohl, M., Sharkey, M., Johnson, N.F., Kawada, R., Gonçalves, R.B., Feitosa, R.M., Heydon, S., Guerra, T.M., Silva, T.S.R. & Costa, V. (2015). Checklist of the genera of Hymenoptera (Insecta) from Espírito Santo state, Brazil. *Boletim do Museu de Biologia Mello Leitão*, 37: 313-343.
- Baccaro, F.B., Feitosa, R.M., Fernández, F., Fernandes, I.O., Izzo, T.J., Souza, J. L.P. & Solar, R.R.C. (2015). *Guia para os gêneros de formigas do Brasil*, pp 388, Editora INPA. <https://doi.org/10.5281/zenodo.32912>
- Bestelmeyer, B.T., Agosti, D., Alonso, L.E., Brandão, C.R.F.R., Brown, W.Jr., Delabie, J.H.C., Silvestre, R., Majer, J.D. & Schultz TR, (2000). Field techniques for the study of ground-living ants: an overview, description, and evaluation. In: Agosti D, Majer J, Alonso E, Schultz TR (Ed.) *Ants, Standard Methods for Measuring and Monitoring Biodiversity*, Washington, DC: Smithsonian Institution, pp 122-144

- Borowiec, M.L. (2016). Generic revision of the ant subfamily Dorylinae (Hymenoptera: Formicidae). *ZooKeys*, 608: 1-280. <https://doi.org/10.3897/zookeys.608.9427>
- Boudinot, B.E. (2015). Contributions to the knowledge of Formicidae (Hymenoptera, Aculeata): a new diagnosis of the family, the first global male-based key to subfamilies, and a treatment of early branching lineages. *European Journal of Taxonomy*, 120: 1-62. <https://doi.org/10.5852/ejt.2015.120>
- Brown, W.L.Jr. (1975). Contributions toward a reclassification of the Formicidae. V. Ponerinae, tribes Platythyreini, Cerapachyini, Cylindromyrmecini, Acanthostichini, and Aenictogitini. *Search, Agriculture, Entomology*, 5: 1-115
- De Andrade, M.L. (1998). Fossil and extant species of *Cylindromyrmex* (Hymenoptera: Formicidae). *Revue Suisse de Zoologie*, 105: 581-664. <https://doi.org/10.5962/bhl.part.80052>
- De Andrade, M. L. (2001). A remarkable Dominican amber species of *Cylindromyrmex* with Brazilian affinities and additions to the generic revision (Hymenoptera: Formicidae). *Contributions to Entomology = Beiträge Zur Entomologie*, 51: 51-63. <https://doi.org/10.21248/contrib.entomol.51.1.51-63>
- Delabie, J.H.C., Fisher, B.L., Majer, J.D. & Wrigth, I.W., (2000). Sampling effort and choice of methods. In: Agosti, D., Majer, J.D., Alonso, L.E. & Schultz, T.R. (Eds.), *Ants Standard Methods for Measuring and Monitoring Biodiversity*. Smithsonian Institution Press, Washington, pp. 145-154.
- Delabie, J.H.C. & Reis, Y.T. (2000). Sympatry and mating flight synchrony of three species of *Cylindromyrmex* (Hymenoptera, Formicidae) in southern Bahia, Brazil, and the importance of Malaise trap for rare ants' inventory. *Revista Brasileira de Entomologia*, 44: 109-111
- Escobar, H. (2015). Fiscal crisis has Brazilian scientists scrambling. *Science*, 349: 909-910. <https://doi.org/10.1126/science.349.6251.909>
- Escobar, H. (2019). Brazilian scientists lament 'freeze' on research budget. *Science*, 364: 111. <https://doi.org/10.1126/science.364.6436.111>
- Feitosa, R.M., Camacho, G.P., Silva, T.S., Ulysséa, M.A., Ladino, N., Oliveira, A.M., ... & DaRocha, W. (2022). Ants of Brazil: an overview based on 50 years of diversity studies. *Systematics and Biodiversity*, 20: 2089268. <https://doi.org/10.1080/14772000.2022.2089268>
- Gomes, C.B., Souza, J.L.P. & Franklin, E. (2018). A comparison between time of exposure, number of pitfall traps and the sampling cost to capture ground-dwelling poneromorph ants (Hymenoptera: Formicidae). *Sociobiology*, 65: 138-148. <https://doi.org/10.13102/sociobiology.v65i2.1207>
- Guénard, B., Weiser, M., Gomez, K., Narula, N. & Economo E.P. (2017). The global ant biodiversity informatics (GABI) database: a synthesis of ant species geographic distributions. *Myrmecological News*, 24: 83-89. https://doi.org/10.25849/myrmecol.news_024:083
- Guilherme, D.R., Souza, J.L.P., Franklin, E., Pequeno, P.A.C.L., Chagas, A.C. das & Baccaro, F.B. (2019). Can environmental complexity predict functional trait composition of ground-dwelling ant assemblages? A test across the Amazon Basin. *Acta Oecologica*, 99: 103434. <https://doi.org/10.1016/j.actao.2019.05.004>
- Hölldobler, B., & Wilson, E. O. (1990). *The ants*. Harvard University Press. Cambridge. 732 pp. <https://doi.org/10.1007/978-3-662-10306-7>
- Janicki, J., Narula, N., Ziegler, M., Guénard, B. & Economo E.P. (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. <https://doi.org/10.1016/j.ecoinf.2016.02.006>
- Kaspari M., Pickering J., Longino J.T. & Windsor D. (2001a). The phenology of a Neotropical ant assemblage: Evidence for continuous and overlapping production. *Behavioral Ecology and Sociobiology*, 50: 382-390. <https://doi.org/10.1007/s002650100378>
- Kaspari M., Pickering J. & Windsor D. (2001b). The reproductive flight phenology of a Neotropical ant assemblage. *Ecological Entomology*, 26: 245-257. <https://doi.org/10.1046/j.1365-2311.2001.00320.x>
- Leach, W.E. (1815). *Entomology*. in: Brewster, D. (ed.) *The Edinburgh encyclopedia*. Edinburgh: William Blackwood, Volume 9, pp 57-172
- Levin, S.A. (1992). The Problem of Pattern and Scale in Ecology: The Robert H. MacArthur Award Lecture. *Ecology*, 73: 1943-1967. <https://doi.org/10.2307/1941447>
- Lewinsohn, T.M., Agostini, K., Lucci Freitas, A.V. & Melo, A.S. (2022). Insect decline in Brazil: an appraisal of current evidence. *Biology Letters*, 18: 20220219. <https://doi.org/10.1098/rsbl.2022.0219>
- Mariano, C.S.F., Delabie, J.H.C. & Pompolo, S.G. (2004). Nota sobre uma colônia e o cariótipo da formiga neotropical *Cylindromyrmex brasiliensis* Emery (Hymenoptera: Formicidae: Cerapachyinae). *Neotropical Entomology*, 33: 267-269. <https://doi.org/10.1590/S1519-566X2004000200020>
- Mcgill, B.J. (2010). Matters of scale. *Science*, 328: 575-576. <https://doi.org/10.1126/science.1188528>
- Olson, D.M. (1991). A comparison of the efficacy of litter sifting and pitfall traps for sampling leaf litter ants (Hymenoptera, Formicidae) in a tropical wet forest, Costa Rica. *Biotropica*, 23: 166-172. <https://doi.org/10.2307/2388302>
- Overall, W.L. & Bandeira, A.G. (1985). Nota sobre hábitos de *Cylindromyrmex striatus* Mayr, 1870, na Amazônia

- (Formicidae, Ponerinae). *Revista Brasileira de Entomologia*, 29: 521-522.
- Parr, C. & Chown, S. (2001). Inventory and bioindicator sampling: testing pitfall and Winkler methods with ants in a South African savanna. *Journal of Insect Conservation*, 5: 27-36. <https://doi.org/10.1023/A:1011311418962>
- Perfecto, I. & Philpott, S.M. (2023). Ants (Hymenoptera: Formicidae) and ecosystem functions and services in urban areas: a reflection on a diverse literature. *Myrmecological News*, 33: 103-122. https://doi.org/10.25849/myrmecol.news_033:103
- Prado, L.P., Vicente, R.E., Silva, T.S.R. & Souza, J.L.P. (2016). *Strumigenys fairchildi* Brown, 1961 (Formicidae, Myrmicinae): first record of this rarely collected ant from Brazil. *Check List*, 12: 1922. <https://doi.org/10.15560/12.4.1922>
- Przybyszewski, K.R., Silva, R.J., Vicente, R.E., Freitas, J.V.G., Pereira, M.J.B., Izzo, T.J. & Tonon, D.S. (2020). Can baited pitfall traps for sampling dung beetles replace conventional traps for sampling ants? *Sociobiology*, 67: 376-387. <https://doi.org/10.13102/sociobiology.v67i3.5201>
- Queiroz, A.C.M., Marques, T.G., Ribas, C.R., Cornelissen, T.G., Nogueira, A., Schmidt, F.A., Feitosa, R.M., Sobrinho, T.G., Quinet, Y., Baccaro, F.B., Ulysséa, M.A., Vargas, A.B., Morini, M.S.C., Souza, J.L.P., Paolucci, L.N., Dáttilo, W., Del-Claro, K., Lange, D., Santos, J.C., Silva, R.R., Campos, R.B.F., Albuquerque, E.Z., Izzo, T., Rabello, A.M., Solar, R.R.C., Soares, S.A., Carvalho, K.S., Moraes, A.B., Torezan'silingardi, H.M., Nahas, L., Dos Santos, I.A., Costa'milanez, C.B., Esteves, F., Frizzo, T., Harada, A.Y., Darocha, W. & Diehl-Fleig, E. (2023). Ant diversity decreases during the dry season: A meta-analysis of the effects of seasonality on ant richness and abundance. *Biotropica*, 55: 29-39. <https://doi.org/10.1111/btp.13158>
- Quiroz-Robledo, L.N. (2003). First record of genus *Cylindromyrmex* Mayr for Mexico. *Folia Entomologica Mexicana*, 42: 295-296.
- Rezende, C.L., Scarano, F.R., Assad, E.D., Joly, C.A., Metzger, J.P., Strassburg, B.B.N., Tabarelli, M., Fonseca, G.A. & Mittermeier, R.A. (2018). From hotspot to hopespot: An opportunity for the Brazilian Atlantic forest. *Perspectives in Ecology and Conservation*, 16: 208-214. <https://doi.org/10.1016/j.pecon.2018.10.002>
- Ribeiro, M.C., Martensen, A.C., Metzger, J.P., Tabarelli, M., Scarano, F. & Fortin, M.J. (2011). The Brazilian Atlantic forest: A shrinking biodiversity hotspot. In: Zachos, F., Habel, J. (eds) *Biodiversity hotspots*. Springer, Berlin, Heidelberg. pp 405-434. https://doi.org/10.1007/978-3-642-20992-5_21
- Rosenberg, Y., Bar-On, Y.M., Fromm, A., Ostikar, M., Shoshany, A., Giz, O. & Milo, R. (2023). The global biomass and number of terrestrial arthropods. *Science Advances*, 9: 1-13. <https://doi.org/10.1126/sciadv.abq4049>
- Santos, M.N. (2016). Research on urban ants: approaches and gaps. *Insectes Sociaux*, 63: 359-371. <https://doi.org/10.1007/s00040-016-0483-1>
- Savard, J.P., Clergeau, P. & Mennechez, G. (2000). Biodiversity concepts and urban ecosystems. *Landscape and Urban Planning*, 48: 131-142. [https://doi.org/10.1016/S0169-2046\(00\)00037-2](https://doi.org/10.1016/S0169-2046(00)00037-2)
- Schmidt, F.A., Ribas, C.R., Feitosa, R.M., Baccaro, F.B., de Queiroz, A.C.M., Sobrinho, T.G., ... & Martello, F. (2022). Ant diversity studies in Brazil: an overview of the myrmecological research in a megadiverse country. *Insectes Sociaux*, 69: 105-121. <https://doi.org/10.1007/s00040-022-00848-6>
- Schultheiss, P., Nooten, S.S., Wang, R., Wong, M.K.L., Brassard, F. & Guénard, B. (2022). The abundance, biomass, and distribution of ants on Earth. *Proceedings of the National Academy of Sciences USA*, 119: 2201550119. <https://doi.org/10.1073/pnas.2201550119>
- Silva, R.R., Martello, F., Feitosa, R.M., Silva, O.G.M., do Prado, L.P., Brandão, C.R.F., de Albuquerque, E.Z., Morini, M.S.C., Delabie, J.H.C., dos Santos Monteiro, E.C., Emanuel Oliveira Alves, A., Wild, A.L., Christianini, A.V., Arnhold, A., Casadei Ferreira, A., Oliveira, A.M., Santos, A.D., Galbán, A., de Oliveira, A.A., Subtil, A.G.M., Dias, A.M., de Carvalho Campos, A.E., Waldschmidt, A.M., Freitas, A.V.L., Avalos, A.N., Meyer, A.L.S., Sánchez-Restrepo, A.F., Suarez, A.V., Souza, A.S., Queiroz, A.C.M., Mayhé-Nunes, A.J., da Cruz Reis, A., Lopes, B.C., Guénard, B., Trad, B.M., Caitano, B., Yagound, B., Pereira-Silva, B., Fisher, B.L., Tavares, B.L.P., Moraes, B.B., Filgueiras, B.K.C., Guarda, C., Ribas, C.R., Cereto, C.E., Esbérard, C.E.L., Schaefer, C.E.G.R., Paris, C.I., Bueno, C., Lasmar, C.J., da Costa-Milanez, C.B., Lutinski, C.J., Ortiz-Sepulveda, C.M., Wazema, C.T., Mariano, C.S.F., Barrera, C.A., Klunk, C.L., Santana, D.O., Larrea, D., Rother, D.C., Souza-Campana, D.R., Kayano, D.Y., Alves, D.L., Assis, D.S., Anjos, D., França, E.C.B., Santos, E.F., Silva, E.A., Santos, É.V., Koch, E.B., Siqueira, E.L.S., Almeida, É.A., Araujo, E.S., Villarreal, E., Becker, E., de Oliveira Canedo-Júnior, E., Santos-Neto, E.A., Economo, E.P., Araújo-Oliveira, É.S., Cuzzo, F., Magalhães, F.S., Neves, F.M., Rosumek, F.B., Dorneles, F.E., Noll, F.B., Arruda, F.V., Esteves, F.A., Ramos, F.N., Garcia, F.R.M., de Castro, F.S., Serna, F., Marcineiro, F.R., Neves, F.S., do Nascimento, G.B., de Figueiredo Jacintho, G., Camacho, G.P., Ribeiro, G.T., Lourenço, G.M., Soares, G.R., Castilho, G.A., Alves, G.P., Zurita, G.A., Machado Santos, G.H., Onody, H.C., Oliveira, H.S., Vasconcelos, H.L., Paulino-Neto, H.F., Brant, H., Rismo Coelho, I., de Melo Teles e Gomes, I.J., Leal, I.R., Dos Santos, I.A., Santos, I.C.S., Fernandes, I.O., Nascimento, I.C., Queiroz, J.M., Lattke, J.E., Majer, J., Schoederer, J.H., Dantas, J.O., Andrade-Silva, J., Díaz Guastavino, J.M., Silveira dos Santos, J., Filloy, J., Chaul, J.C.M., Lutinski, J.A., Carvalho, K.S., Ramos, K.S., Sampaio, K.L.S., Ribeiro, L.A.M., Sousa-Souto, L., Paolucci, L.N., Elizalde, L., Podgaiski, L.R., Chifflet, L., Carvalho-Leite, L.J., Calcaterra, L.A., Macedo-Reis, L.E., Magnago, L.F.S.,

- Madureira, M.S., Silva, M.M., Pie, M.R., Uehara-Prado, M., Pizo, M.A., Pesquero, M.A., Carneiro, M.A.F., Busato, M.A., de Almeida, M.F.B., Belloq, M.I., Tibcherani, M., Casimiro, M.S., Ronque, M.U.V., da Costa, M.M.S., Angotti, M.A., de Oliveira, M.V., Leponce, M., Imata, M.M.G., de Oliveira Martins, M.F., Antunes Ulysséa, M., do Espírito Santo, N.B., Ladino López, N.M., Balbino, N.S., da Silva, N.S., Safar, N.V.H., de Andrade, P.L., Camargo, P.H.S.A., Oliveira, P.S., Dodonov, P., Luna, P., Ward, P.S., Hanisch, P.E., Silva, P.S., Divieso, R., Carvalho, R.L., Campos, R.B.F., Antoniazzi, R., Vicente, R.E., Giovenardi, R., Campos, R.I., Solar, R.R.C., Fujihara, R.T., de Jesus Santos, R., Fagundes, R., Guerrero, R.J., Probst, R.S., de Jesus, R.S., Silvestre, R., López-Muñoz, R.A., de Souza Ferreira-Châline, R., Almeida, R.P.S., de Mello Pinto, S., Santoandré, S., Althoff, S.L., Ribeiro, S.P., Jory, T., Fernandes, T.T., de Oliveira Andrade, T., Pereira, T.P.L., Gonçalves-Souza, T., da Silva, T.S.R., Silva, V.N.G., Lopez, V.M., Tonetti, V.R., Nacagava, V.A.F., Oliveira, V.M., Dáttilo, W., DaRocha, W., Franco, W., Dröse, W., Antonialli, W. & Ribeiro, M.C. (2022). ATLANTIC ANTS: a data set of ants in Atlantic Forests of South America. *Ecology*, 103: e03580. <https://doi.org/10.1002/ecy.3580>
- Souza, J.L.P. & Araújo, J.S. (2020). Evaluation of sampling techniques and influence of environmental variables on ants in forest fragments in an oil extraction area in the Amazon. *Sociobiology*, 67: 364-375. <https://doi.org/10.13102/sociobiology.v67i3.5148>
- Souza, J.L.P., Baccaro, F.B., Landeiro, V.L., Franklin, E. & Magnusson, W.E. (2012). Trade-offs between complementarity and redundancy in the use of different sampling techniques for ground-dwelling ant assemblages. *Applied Soil Ecology*, 56: 63-73. <https://doi.org/10.1016/j.apsoil.2012.01.004>
- Stringer, L.D., Stephens, A.E., Suckling, D.M. & Charles, J.G. (2009). Ant dominance in urban areas. *Urban Ecosystems*, 12: 503-514. <https://doi.org/10.1007/s11252-009-0100-4>
- Vicente RE, Prado LP, Izzo TJ (2016) Amazon rainforest ant-fauna of parque estadual do Cristalino: understory and ground-dwelling ants. *Sociobiology*, 63: 894-908. <https://doi.org/10.13102/sociobiology.v63i3.1043>
- Vicente, R.E., Ferreira-Silva, D. & Guerreiro de Lima, M. (2019). New records of three Neotropical arboreal ant species of *Camponotus*, subgenus *Dendromyrmex* (Hymenoptera: Formicidae) for the southern amazon, including biological information. *Acta Amazonica*, 49: 36-40. <https://doi.org/10.1590/1809-4392201801951>
- Wheeler, W.M. (1936). Ecological relations of ponerine and other ants to termites. *Proceedings of the American Academy of Arts and Sciences*, 71: 159-243. <https://doi.org/10.2307/20023221>

