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Ants (Hymenoptera, Formicidae) of APA Pandeiros: A Perspective from a Decade of Research in an Environmental Protection Area in the Cerrado-Caatinga Transition

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Abstract

Habitat transformation and species loss bring enormous environmental damage, whereas establishing protected areas promotes more sustainable use of environmental resources through biodiversity conservation. In this study, we aimed to point out gaps in ant knowledge and provide a species checklist that contributes to biodiversity conservation in the transition areas between Cerrado and Caatinga biomes, constantly threatened by land use changes. This checklist integrates data from previous studies developed at "Área de Proteção Ambiental do Rio Pandeiros" (APA Pandeiros), Minas Gerais, Brazil, involving ant diversity and their contribution to ecological processes accessed and described in the studies. We showed and discussed how authors managed and provided information regarding methodologies and habitats sampled. We listed 143 ant species formally named. *Pheidole*, *Camponotus* and *Cephalotes* were the most speciose genera, with more than ten species each. Among ants involved in ecological processes, 40 are linked to diaspore removal (part of seed dispersal) and 30 to carcass interaction (part of the decomposition process). Unbaited pitfall traps, epigeic stratum and Cerrado *sensu stricto*, were the top sampling method, stratum, and habitats among ant studies. We presented proposals for the best management and integration of data from surveys in APA Pandeiros (e.g., sharing the results of the studies with the APA managers, creating a database, and the local community). These surveys are fundamental for understanding biodiversity and ecological processes and provide valuable information to conservation biology. Therefore, neglecting the importance of the Cerrado-Caatinga transition can lead to irreparable setbacks for scientific knowledge and biodiversity.

Introduction

Habitat transformation and the consequent increase in species extinction rates bring enormous damage to biodiversity knowledge (Tedesco et al., 2014). Furthermore, recent studies show that species loss exceeds early estimates (Barlow et al., 2016). On the other hand, public policies such as creating protected areas are adopted to minimize biodiversity losses and conserve the ecosystems (Assad et al., 2017; Venter et al., 2017).

In Brazil, most protected areas occur in the Amazon biome (~70%) (Vieira et al., 2019). Therefore, there is a need to increase protection in non-forest environments, neglected in protection policies in recent years. Two of these neglected non-forest biomes, Cerrado and Caatinga, have less than 10% of protected areas each (Vieira et al., 2019) and are increasingly threatened by changes in land use (e.g., conversion of habitats for production of agricultural commodities) (Overbeck et al., 2015).

The Cerrado is one of the world's biodiversity hotspots, as it has many endemic species and high anthropogenic pressure (Myers et al., 2000). The Cerrado biome, also known as Brazilian Savanna, has a rich myrmecofauna (Vasconcelos et al., 2018) due to its great diversity of habitats, edaphic and climatic conditions (Oliveira & Marquis, 2002). In the Cerrado, ants forage and/or nest in different strata and have an intimate relationship with many plant species, so we find a great diversity of these insects, whether in the ground or vegetation.

The Caatinga, an arid environment and the only uniquely Brazilian biome, is a center of plant species diversity (Overbeck et al., 2015). However, the ant fauna in the Caatinga is not as diverse as in Cerrado (Leal et al., 2018). Endemic ant species are rarely found in Caatinga, which helps to characterize this group as an impoverished Formicidae fauna of Cerrado (Leal et al., 2017). Since knowledge about the diversity of ants in the Caatinga is incipient, it is expected that the same occurs with ant-plant interactions, which are present in this biome (Câmara et al., 2018; Leal et al., 2018; Oliveira et al., 2019).

Cerrado and Caatinga are rich in terrestrial invertebrates, but there is a discrepancy in knowledge about terrestrial invertebrate species in these biomes. If, on the one hand, studies in the Cerrado are growing increasingly (Borges et al., 2015), on the other hand, we know very little about the Caatinga (Lewinsohn et al., 2005; Ganem et al., 2017), a pattern that repeats itself if we consider only ants (Divieso et al., 2020). Thus, more studies on non-forest biomes are essential for discovering and describing new species, their interactions and ecological functions in Brazil, a center of neotropical ant diversity (Fernández et al., 2021; Feitosa et al., 2022; Schmidt et al., 2022).

The Rio Pandeiros Environmental Protection Area (Área de Proteção Ambiental do Rio Pandeiros – APA Pandeiros) is the largest protected area in Minas Gerais state and one of the protected areas that cover the transition of the Cerrado-Caatinga biomes with vegetation types of both biomes. "APA" is one of the categories of conservation units (UCs) existing in Brazil (IUCN – International Union for Conservation of Nature – Category V). As a sustainable use conservation unit, the APA Pandeiros presents fewer restrictions, allowing human occupation, scientific research, and sustainable use of natural resources (Brasil, 2000). Located north of Minas Gerais state, this area covers the entire Pandeiros river basin, an important tributary of the São Francisco River, and is present in the municipalities of Bonito de Minas, Januária and Cônego Marinho (Nunes et al., 2009; IEF-MG, 2022).

Queiroz-Dantas et al. (2011) published the first study on ant diversity regarding APA Pandeiros. It showed ant richness differences across habitats and strata. Ant diversity varies across habitats, vegetation types, strata, and disturbances (Philpott et al., 2010; Queiroz et al., 2020). Since then, different research groups have performed studies with distinct aims and methodologies evaluating ant diversity and their contribution to ecological processes in the Pandeiros region. Almost ten years later, Santiago et al. (2020) reported ants removing diaspores in APA Pandeiros. Ants act by influencing plant distribution and environment structure dispersing plant seeds that facilitate their establishment. These insects also play essential roles in nutrient cycling via decomposition through environments by removing organic matter or altering the microbial community (Del-Toro et al., 2012). Furthermore, ants participate in several other vital processes for ecosystem functioning (e.g., nutrient cycling, pollination, bioturbation, and biological control) (Elizalde et al., 2020). However, despite many studies in this region, we still did not have a study that compiled information about the species in this conservation unit.

In this study, we aimed to integrate previous studies involving ants at APA Pandeiros to formulate a species checklist and discuss their novelties and inconsistencies. This list demonstrates a compilation of original and published data from studies that tried to understand ant assemblages and their contribution to ecological processes. These studies described and accessed the ecological processes: diaspore removal (part of seed dispersal) and carcass interaction (part of the decomposition process). In addition, we point out which are the most common habitats, methods, and strata in samplings. Finally, we identify, fill, and point out gaps in ant knowledge that contribute to biodiversity conservation in the transition areas between Cerrado and Caatinga biomes.

Material and methods

The Ants of APA Pandeiros

The "Área de Proteção Ambiental do Rio Pandeiros" (APA Pandeiros), northern Minas Gerais State, Brazil (Fig 1) is a conservation unit with 396,060.407 hectares (IEF-MG, 2022) and is in the transition between Cerrado and Caatinga biomes (Rizzini, 1997). This ecotonal region is semiarid, with a mean temperature ranging from 21 to 24ºC and two well-defined seasons: a dry winter, from April to September, and rainy summer, from October to March. The area is under many environmental pressures involving anthropogenic activities, such as vegetation loss, fire, monocultures (*Eucalyptus* spp.), pasture, and charcoal production (Nunes et al., 2009).

We compiled original and published data from studies focused on understanding ant assemblages and their contribution to processes such as diaspore removal and carcass interaction (e.g., Neves et al., 2013; Santiago et al., 2020; Rabelo et al., 2021). Once we aimed to provide a broad inventory of the ant fauna by compiling records from the datasets, we detailed the projects implemented at APA Pandeiros since 2008, regarding references, sampling methods used, habitats, and location. Ant diversity samplings were performed with pitfall traps (baited or not) (Table 1). Diaspore removal was evaluated using artificial diaspores with beads and attractive paste (made with sugars, protein and fat), and the interaction with the carcass was collected through the installation of the decaying carcass (chicken feet). Details on species identification were extracted from studies or interviews with researchers. All specimens collected during research are deposited at Centro de Coleções, Biodiversidade e Patrimônio Genético (ICN-UFLA), Coleção Zoológica da Universidade Federal de Uberlândia (UFU), Coleção Entomológica Padre Jesus Santiago Moure da Universidade Federal do Paraná (DZUP-UFPR), and Coleção de Formicidae do Centro de Pesquisas do Cacau (UESC-CEPLAC).

All occurrences in the literature and original data were compiled and classified in a table (with data on the study area, habitat, collection method, and sampled stratum). We estimated the number of redundant species by counting the minimum and the maximum number of species that could occur if we had the identification of all morphospecies from the databases. For example, if we had found three *Camponotus* sp.1 in three different databases, we considered these works showed a minimum of one species not formally named and a maximum of three *Camponotus* sp.1 species. However, suppose we found two *Camponotus* sp.1 in two databases and just one *Camponotus rufipes* (Fabricius, 1775) in the other. In this case, we considered a minimum of zero new species (among these morphospecies, once the morphospecies could be *C. rufipes*) and a maximum of two. We adopted this method because we do not have the compatibility of morphospecies among the studies.

Table 1. References, species and morphospecies richness, sampling methods, strata, habitats and geographic coordinates related to datasets (Ds). A and B are parts of the same datasets published or considered separately: (D1) PCT-Hidro "Dinâmicas de organismos associados aos ambientes de matas ciliares, cerrado e floresta estacional decidual, no médio São Francisco, Norte de Minas Gerais". (CNPq grant ED. 35/2006, no. 555978/2006-0); (D2) "Rede de Pesquisa Biota do Cerrado – Isoptera e Hymenoptera" (CNPq grant 457407/2012-3) and (FAPDF, Projeto PRONEX 563/2009); (D3, D4, D5) "Desenvolvimento de ferramenta para priorização de descomissionamento de Pequenas Centrais Hidrelétricas (PHC) no estado de Minas Gerais e estudo de caso para a PCH Pandeiros" (FAPEMIG APQ-03593-12). CSS = Cerrado *sensu stricto*,TDF = Tropical Dry Forest, RIF = Riparian Forest, ANT = Anthropogenic habitats.

Data	References	Species and Morphospecies Richness	Sampling Method	Strata	Habitats	Coordinates
D1	Queiroz-Dantas et al., 2011; Neves et al., 2013	73; 113	Baited pitfalls; Baited pitfalls, Beating	Hypogeic, Epigeic, Arboreal; Hypogeic, Epigeic, Arboreal, Canopy	CSS, TDF, RIF	15°30'26.2" S, 44°45'21.3" W
D2	Vasconcelos et al., 2018 (Pandeiros)	102	Baited and unbaited pitfalls	Epigeic, Arboreal	CSS	15º29'54" S, 44º42'29" W
D3	Rabelo et al., 2021	11	Hand collecting (diaspores removal)	Epigeic	CSS	15º26'00" S, 44º49'19" W
D4	Santiago, unpublished data; Santiago et al., 2020	174; 37	Unbaited pitfalls, Hand collecting (diaspores removal); Hand collecting (diaspores removal)	Epigeic	CSS, TDF, ANT; CSS	15º29'18.3" S, 44º45'30.5" W 15°30'24.5" S, 44°45'30.5" W 15°30'47.5" S, 44°45'12.6" W; 15º29'18.3" S, 44º45'30.5" W
D5	Santiago, unpublished data	251	Unbaited pitfalls, Hand collecting (diaspores removal and carcass interaction)	Epigeic	CSS	15°28'2.1" S, 44°49'53.2" W 15°41'25.1" S, 44°34'18.8" W

Results

Ant samplings at APA Pandeiros are concentrated to the south, in or surrounding the State Wildlife Refuge of Pandeiros River (REVS do Rio Pandeiros) (Fig 1). We obtained a list with 470 ant species records from 66 genera and eight subfamilies. This list can present ~120 redundant records based on the number of morphospecies due to differences in specimen identification in the projects. In this way, we estimate that the sampled richness was of at least 350 species. In total, 143 species (from 470: 30.4%; from 350: 40.9%) were formally named (Table 2). Myrmicinae was the most speciose subfamily, with 51% identified species, followed by Formicinae (15.4%) and Pseudomyrmecinae (7%).

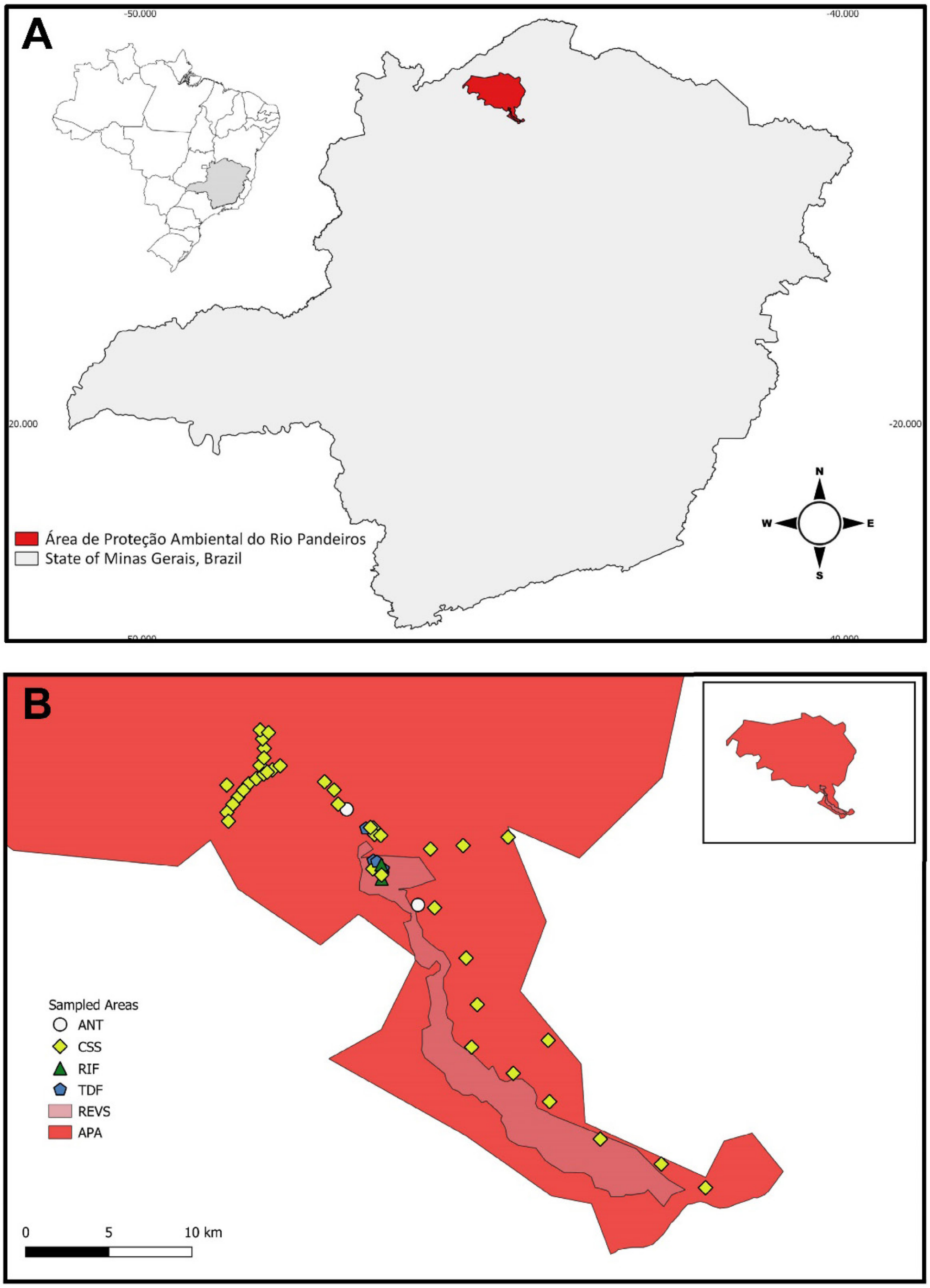

Fig 1. Map of Minas Gerais state (gray), in Brazil, with Área de Proteção Ambiental do Rio Pandeiros – APA Pandeiros (red) (A). Map of APA Pandeiros in (red) and REVS do Rio Pandeiros (pink), Riparian Forest (RIF, represented by green triangles), Anthropogenic habitats (ANT, represented by white dots), Tropical Dry Forest (TDF, represented by blue pentagons), and Cerrado *sensu stricto* (CSS, represented by yellow diamonds) sampled areas (B).

The most speciose of the 51 genera were *Pheidole* (22), *Camponotus* (17), and *Cephalotes* (11). On the other hand, the highest richness among the morphospecies without confirmed identification is from the subfamilies: Myrmicinae (46.6%), Formicinae (9.8%), and Dolichoderinae (7.2%) (Table 3). Among genera, *Pheidole* (24.7%), *Camponotus* (6.6%), and *Solenopsis* (4.9%) dominated the group of morphospecies that need a description or confirmation of identification.

Ectatomma edentatum Roger, 1863 was sampled in all datasets, areas, strata, with all sampling methods and performing both processes (diaspore removal and carcass interaction). In total, ten species belonging to three genera (*Camponotus*, *Pheidole* and *Strumigenys*) and two subfamilies (Formicinae and Myrmicinae) were recorded for the first time in Minas Gerais (see Table 2). Among these, one species was also a new record for Brazil (*P. gigaflavens* Wilson, 2003) and another species was recorded for the first time for South America (*P. caribbaea* Wheeler, 1911).

We have two different ant profiles among the ants that performed diaspore removal and interacted with the carcass.

From 40 ant species that interacted with diaspores, *Pheidole* (35%), *Camponotus* (15%), and *Ectatomma* (12.5%) dominate. Among the species, 87.5% interacted positively by removing the diaspores (e.g., *E. permagnum* Forel, 1908 and *Odontomachus bauri* Emery, 1892), 45% partially consumed the diaspores (e.g., *Forelius brasiliensis* (Forel, 1908) and *Linepithema cerradense* Wild, 2007), and 32.5% interacted from both ways (e.g., *C. blandus* (Smith, F. 1858) and *E. edentatum* Roger, 1863). Regarding 30 ant species interacting with the carcass, *Camponotus* and *Pheidole* genera represented 50% of the total. As examples of ants captured interacting with the carcass, we have *Nomamyrmex esenbeckii* (Westwood, 1842) and *Sericomyrmex* sp.1.

When we considered just species formally named, among sampling methods, unbaited pitfall traps captured more species and a higher number of exclusive species, followed by baited pitfall traps, hand collection, and beating (that did not present exclusive species) (Fig 2A). Pitfall and hand collection seem to be the best complementary sampling methods (Fig 3A). The highest richness is in the epigeic, followed by arboreal, canopies and the hypogeic stratum, respectively (Fig 2B). Canopy does not present a specific fauna and the hypogeic stratum presents only one exclusive species (Fig 3B). The Cerrado *sensu stricto* (CSS) is, by far, the vegetation type with the highest number of identified species, followed by Tropical Dry Forest (TDF), Anthropogenic habitats (ANT), and the Riparian Forest (RIF) (Fig 2C). The RIF does not present a specific fauna, sharing almost the total species richness with TDF and CSS (Fig 3C).

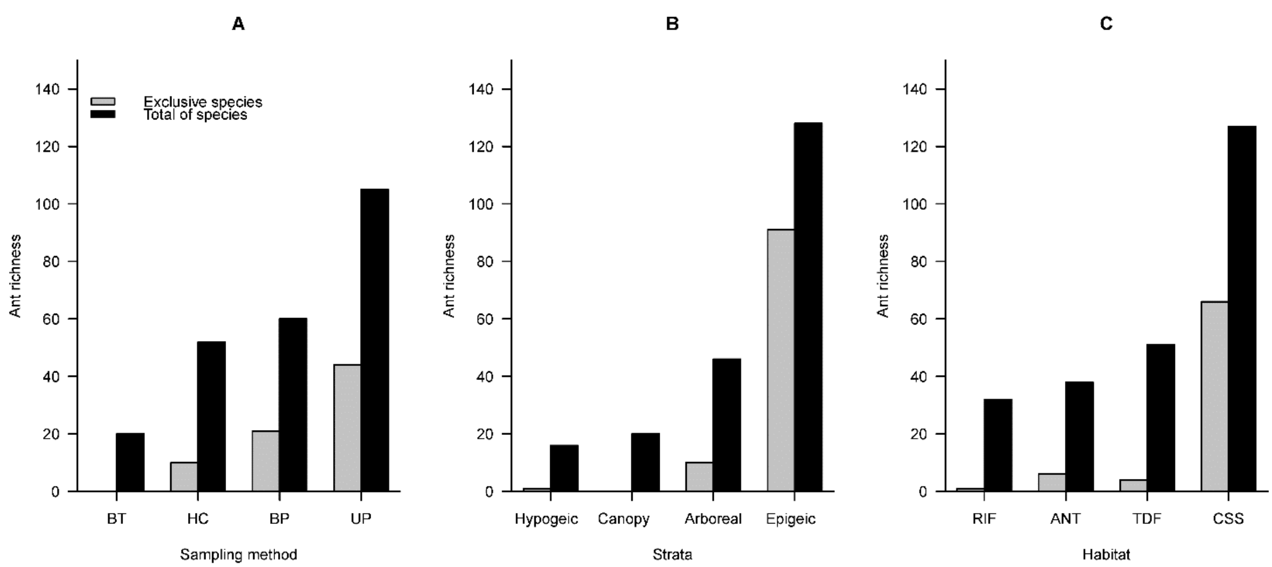

Fig 2. Graphs representing the number of exclusive (grey) and total (black) species according to: (A) sampling methods, (B) strata, and (C) habitats. BT = Beating, HC = Hand collection, BP = Baited pitfall traps, UP = Unbaited pitfall traps, RIF = Riparian Forest, ANT = Anthropogenic habitats, TDF = Tropical Dry Forest, CSS = Cerrado *sensu stricto*.

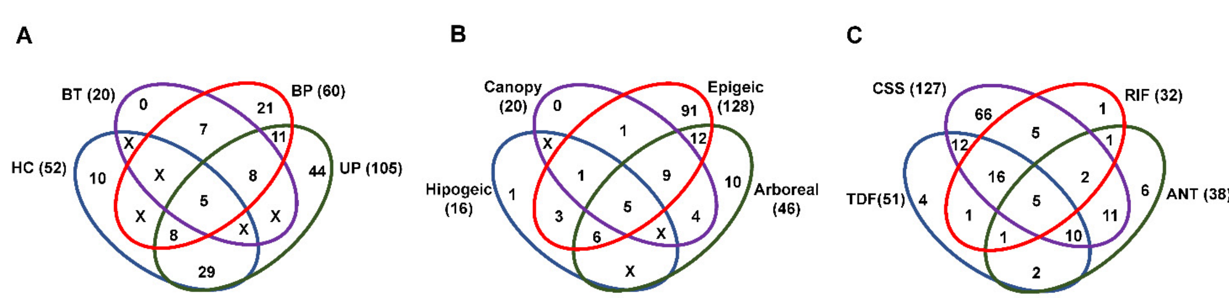

Fig 3. Diagrams representing the number of shared and exclusive species according to: (A) sampling methods, (B) strata and (C) habitats. Different colors represent different methods, strata, and habitats. BT = Beating, HC = Hand collection, BP = Baited pitfall traps, UP = Unbaited pitfall traps, RIF = Riparian Forest, ANT = Anthropogenic habitats, TDF = Tropical Dry Forest, CSS = Cerrado *sensu stricto*. X represents that is no occurrence of ants in the intersection.

Discussion

We obtained a list of 470 species and morphospecies of ants by compiling species records from published and unpublished sources that used different sampling methods in different habitats and strata. Our checklist provides the basis for talking about state of the art and the challenges and opportunities related to a decade of studies at APA Pandeiros that will contribute to biodiversity conservation in the transition areas between Cerrado and Caatinga biomes.

Protected areas are essential to limit the loss of biodiversity, as they prevent the increase in deforestation and maintain high levels of biodiversity and endemism (Oliveira et al., 2017). Although inventories in protected areas are considered a priority for understanding and preserving biodiversity, recently published works have drawn attention to the scarcity of records of ants in protected areas (e.g., Prado et al., 2019; Divieso et al., 2020). Our survey points to an expressive ant richness in this protected area, at the transition between Cerrado and Caatinga biomes, compared to other surveys (Ulysséa & Brandão, 2011; Camacho & Vasconcelos, 2015; Costa et al., 2015; Leal et al., 2017). APA Pandeiros was created in 1995 (IEF-MG, 2022), and the diversity of Formicidae at the site only started to be investigated over a decade later. Regardless of whether research on ant diversity was carried out before the publication of the "REVS do Rio Pandeiros" management plan (IEF-MG, 2019), there is just one mention of ant studies in the document. This neglect contrasts with ants' ecological and cultural importance, which play vital roles in different environments (Del-Toro et al., 2012), arousing curiosity and getting people's attention (Queiroz et al., 2021).

Profile of ant species and morphospecies diversity

The richness distribution between genera and subfamilies in APA Pandeiros follows the proportion expected for these groups of ants in Brazil, with *Camponotus*, *Pheidole* and *Solenopsis* belonging to the subfamilies Formicinae and Myrmicinae, as the most recurrent (Baccaro et al., 2015). Despite efforts to identify challenging genera, these three still dominate the list of morphospecies in our checklist. Sixty years ago, Kempf (1961) already drew attention to the difficulty of identifying part of these genera, indicating the complexity of these groups and the need to advance in their taxonomy. The study of these morphospecies will contribute to understanding their biodiversity and role in the environment, increasing the number of new occurrences, and may lead to the discovery of new species. Another 41 genera had species not identified at a specific level. Although Minas Gerais is one of the best-sampled states concerning ants (Schmidt et al., 2022; Silva et al., 2022), further efforts and investments are needed to identify and describe possible new species (Camacho & Vasconcelos, 2015).

The new distribution records revealed in APA Pandeiros belong to *Camponotus*, *Pheidole* and *Strumigenys*. These genera are highly diverse and taxonomically challenging, with many described (over 800 species) and undescribed species (Baccaro et al., 2015). In this sense, our checklist helps to fill gaps in species distribution. We found both widely distributed species in South America (*P. exigua*) and surprising records (*P. caribbaea*), which, until then, was only known from a few specimens from Jamaica (Janicki et al., 2016).

In addition, we highlight the species *E. edentatum*, from the subfamily Ectatomminae, also widely distributed in Brazil (see Baccaro et al., 2015; Delabie et al., 2015), as the most common species in studies carried out at APA Pandeiros. This species has reasonably deep nests in the ground, with trash disposal that favors better seed germination (Delabie et al., 2007). In the Cerrado, *E. edentatum* is also frequently found consuming nectar or honeydew provided by homopterans, acting in plant defense (Marques et al., 2015). Furthermore, this species may play a fundamental role in biological control (Delabie et al., 2007).

Profile of ants that contribute to ecological functions

The diaspore removal, part of the secondary seed dispersal by ants, was carried out in APA Pandeiros mainly by species of the most common genera, more prominently in Poneromorphic species, such as *E. edentatum*, *E. permagnum* and *Odontomachus bauri*. Poneromorphs play a crucial role in seed dispersal in the Cerrado and Caatinga (Christianini, 2015). These ants, considered high-quality dispersers, remove many seeds and disperse them over greater distances (Magalhães et al., 2018), in contrast to species of the genus *Pheidole*, considered low-quality dispersers (Leal et al., 2014), who mainly clean the seeds, which can sometimes reduce fungal infections and favor germination and survival. Dolichoderinae from open habitats in the Cerrado and Caatinga, such as *Forelius brasiliensis* and *Linepithema cerradense* (Wild, 2007; Leal et al., 2017), present in APA Pandeiros, can also be considered poor quality dispersers. Such species have generalist habits and remove particles from diaspores without carrying them (Padilha, 2013). Therefore, due to the large proportion of ants that remove and clean diaspores (70%), we saw that the contribution of these ants to the restoration of degraded areas by dispersing seeds could be high, especially in Pandeiros that presented many abandoned sites that recovered to Cerrado in the last years (Guimarães-Silva, 2019).

Despite the contribution of ants to decomposition (Del-Toro et al., 2012), studies on this process are still unusual. In this study, we saw that most of the species that contributed to the process were *Camponotus* and *Pheidole*. The ants participating in decomposition are mostly generalists (Tabor et al., 2005). However, *Nomamyrmex esenbeckii* and *Sericomyrmex* sp.1 were found exclusively interacting with the carcass. *Nomamyrmex* often follows and attacks other ant species (Baccaro et al., 2015). In experiments, this ant may have been collected occasionally. *Sericomyrmex* genus is a fungus-growing ant whose biology is not well known (Baccaro et al., 2015). The fact that this species is removing putrefying organic matter indicates that the sources for the fungus may be broader than previously documented. Therefore, these records reinforce the need to know the species' biology that acts in each process.

Methodologies, strata and habitats sampled focusing on ants in APA Pandeiros

The differences found in species richness, especially between sampling methods and studies, are directly related to the sampling effort (e.g., exposure time, number of samples, habitats and microhabitats sampled) and the capture approach (e.g., micro-habitat to be sampled). It is natural that the studies that used manual collections to evaluate processes presented lower richness than the capture of ants with pitfall traps. Still, we found more exclusive species captured through unbaited pitfall traps. Since ground pitfalls capture larger numbers of ants per sampling point (Agosti & Alonso, 2000; Wang et al., 2001) it is not surprising that this technique sampled the highest proportion of species. However, in this study, we saw that adding baits helps to capture more ants in other strata, such as the arboreal (10 arboreal ants exclusively sampled with baited pitfalls). It is also possible that pitfall trapping is the most efficient technique for capturing insects in more open environments with fewer litter cover. For instance, the vegetation types of non-forest environments such as the Cerrado and Caatinga. Finally, we found that the beating adds a small number of species, but we emphasize that the methods used are, in a way, complementary and the use of one or more methods depends on the need and objectives of the study.

The greatest ant richness was found in the Cerrado *sensu stricto* and in the epigeic stratum, the best-sampled vegetation type and stratum present in all studies. In Neves et al. (2013), the Cerrado *sensu stricto* showed similar richness compared to other vegetation types, but the epigeic stratum had the highest ant richness, composed mainly by species of the genera *Camponotus* and *Pheidole* (Neves et al., 2013; Schmidt et al., 2013). However, we emphasize that the Caatinga of northern Minas Gerais is still a poorly studied area (Lessa et al., 2019), and ants' studies in Tropical Dry Forests of the region (e.g., Marques & Schöereder, 2013) can bring valuable new information. As seen in the map (Fig 1B), the areas sampled and mentioned above are concentrated to the south of the APA. Probably, researchers focused their work on these areas for logistical reasons. Thus, it is necessary to point out that sampling ants in other APA Pandeiros regions and habitats can present us with many other novelties concerning ant diversity.

Recommendations and conclusions

In this study, we provided a list of 143 ant species. With this list, we can reinforce the importance of Poneromorph ants to the seed dispersal process that helps seedling establishment and growth and, consequently, the increment in plant cover (Christianini, 2015). Still, we need to know how low-quality diaspore dispersers can contribute to ecological restoration in APA Pandeiros. We also found that little is known about the ecology and biology of ants involved in the decomposition process. Furthermore, the collection of the highest number of species in the Cerrado *sensu stricto*, epigeic stratum, and unbaited pitfall traps is due to the number of samples and studies with these characteristics.

Based on the information compiled here, we propose in the short term: 1) sharing studies products and creating a database to strengthen the dialogue among academia, APA managers and the local community, at the most appropriate time, highlighting positive aspects of ants (Queiroz et al., 2021). 2) Use the information presented here to suggest priority areas for conservation in the region (places with high species diversity, endemic species, endangered species and species that are essential to ecological processes). 3) The publication and permanent updating of The APA Pandeiros Ant Species Database in repositories, at least from projects of the same groups. Some actions have been incorporated and improved on recent projects in APA Pandeiros (e.g., activities with children's books and presentations in local primary schools). In the long term, we also recommend that future studies with ants at APA Pandeiros implement standardized approaches in other areas of the APA for further excellent knowledge of diversity in the conservation unit. Preferably, at the north of "REVS do Rio Pandeiros".

Insects' surveys, especially ants, in protected areas are fundamental for understanding biodiversity and ecological functions. This type of survey can contribute to the management and monitoring of areas by using ants as bioindicators of environmental quality and ecosystem services. However, the decrease in funding for studies in Brazil, provided mainly by public agencies (McManus & Neves, 2021) in little-known regions, such as the Cerrado-Caatinga transition areas, can lead to irreparable setbacks for scientific knowledge and its biodiversity (Overbeck et al., 2018; Feitosa et al., 2022). If not, we will observe the advance of new agricultural frontiers, mining, dam and reservoir projects in these regions with rapid habitat transformation and consequent species loss, many before they are formally described.

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Table 2. Taxa recorded for APA Pandeiros. Species indicated with an asterisk (*) represent new records for the state of Minas Gerais, two asterisks (**) represent new records for Brazil, and three asterisks (***) represent new records for South of America. The numbering provided after the species name represent different datasets: (1) Queiroz-Dantas et al., 2011 and Neves et al., 2013; (2) Vasconcelos et al., 2018; (3) Rabelo et al., 2021; (4) Santiago, unpublished data from Santiago 2015 and Santiago et al., 2020; (5) Santiago, unpublished data from Santiago 2019. Non-numbered species represent data included in this work. CSS = Cerrado *sensu stricto*, RIF = Riparian Forest, ANT = Anthropogenic habitats, TDF = Tropical Dry Forest.

Subfamilies	Genus/Species	Habitats
Amblyoponinae	***Fulakora***	
	Fulakora armigera (Mayr, 1887)[2]	CSS
	Prionopelta	
	Prionopelta punctulata Mayr, 1866[5]	CSS
Dolichoderinae	***Azteca***	
	Azteca instabilis (Smith, 1862)[1]	CSS, RIF
	Dolichoderus	
	Dolichoderus bispinosus (Olivier, 1792)[1,4]	ANT, RIF
	Dolichoderus diversus Emery, 1894[1,2]	CSS, RIF, TDF
	Dolichoderus lamellosus (Mayr, 1870)[2]	CSS
	Dorymyrmex	
	Dorymyrmex brunneus Forel, 1908[2,3,4,5]	ANT, CSS, TDF
	Dorymyrmex goeldii Forel, 1904[2]	CSS
	Forelius	
	Forelius brasiliensis (Forel, 1908)3	CSS
	Gracilidris	
	Gracilidris pombero Wild & Cuezzo, 2006[1,2,4,5]	ANT, CSS, RIF
	Linepithema	
	Linepithema cerradense Wild, 2007[2,3]	CSS
Dorylinae	***Acanthostichus***	
	Acanthostichus serratulus (Smith, 1858)[1]	TDF
	Labidus	
	Labidus coecus (Latreille, 1802)[1,2,4,5]	ANT, CSS, RIF
	Labidus mars (Forel, 1912)[1]	CSS
	Labidus praedator (Smith, 1858)[1,4,5]	CSS, TDF
	Neivamyrmex	
	Neivamyrmex minensis (Borgmeier, 1928)[4,5]	CSS, TDF
	Neivamyrmex pseudops (Forel, 1909)[2,4,5]	ANT, CSS
	Nomamyrmex	
	Nomamyrmex esenbeckii (Westwood, 1842)[5]	CSS
Ectatomminae	***Acanthoponera***	
	Acanthoponera goeldii Forel, 1912[5]	CSS
	Acanthoponera mucronata (Roger, 1860)[1]	CSS
	Ectatomma	
	Ectatomma brunneum Smith, 1858[3,4,5]	ANT, CSS
	Ectatomma edentatum Roger, 1863[1,2,3,4]	ANT, CSS, RIF, TDF
	Ectatomma muticum Mayr, 1870[1,2]	CSS, RIF, TDF
	Ectatomma opaciventre (Roger, 1861)[1,2,3,4,5]	CSS
	Ectatomma permagnum Forel, 1908[2,4,5]	ANT, CSS
	Ectatomma planidens Borgmeier, 1939[3,4,5]	ANT, CSS
	Ectatomma tuberculatum (Olivier, 1792)[1,2,4,5]	CSS
	Gnamptogenys	
	Gnamptogenys sulcata (Smith, 1858)[5]	CSS
	Holcoponera	
	Holcoponera striatula (Mayr, 1884)	CSS

Table 2. Taxa recorded for APA Pandeiros. (Continuation)

Subfamilies	Genus/Species	Habitats
	Acropyga	
	Acropyga fuhrmanni (Forel, 1914)[2]	CSS
	Brachymyrmex	
	Brachymyrmex heeri Forel, 1874[1]	CSS, RIF, TDF
	Brachymyrmex patagonicus Mayr, 1868[1,2]	CSS, RIF, TDF
	Camponotus	
	Camponotus ager (Smith, 1858)[4]	CSS
	Camponotus arboreus (Smith, 1858)[1,2,4,5]	CSS, RIF, TDF
	Camponotus atriceps (Smith, 1858)[1,2,4,5]	CSS, TDF
	Camponotus blandus (Smith, 1858)[2,3,4,5]	ANT, CSS, TDF
	Camponotus bonariensis Mayr, 1868[2]	CSS
	Camponotus cingulatus Mayr, 1862[1]	CSS, RIF, TDF
	Camponotus crassus Mayr, 1862[3,4,5]	CSS
Formicinae	*Camponotus fastigatus* Roger, 1863[1,2,4,5]	ANT, CSS, TDF
	Camponotus leydigi Forel, 1886[4,5]	ANT, CSS
	Camponotus melanoticus Emery, 1894[1,2,4,5]	ANT, CSS, RIF, TDF
	Camponotus mus Roger, 1863[4,5*]	CSS, TDF
	Camponotus novogranadensis Mayr, 1870[2]	CSS
	Camponotus renggeri Emery, 1894[1,2,4,5]	ANT, CSS, RIF, TDF
	Camponotus rufipes (Fabricius, 1775)[1]	CSS, RIF, TDF
	Camponotus senex (Smith, 1858)[1,2]	CSS, RIF, TDF
	Camponotus substitutus Emery, 1894[2]	CSS
	Camponotus vittatus Forel, 1904[3]	CSS
	Myrmelachista	
	Myrmelachista nodigera Mayr, 1887[2]	CSS
	Paratrechina	
	Paratrechina longicornis (Latreille, 1802)[4]	ANT
	Atta	
	Atta laevigata (Smith, 1858)[1,5]	CSS, RIF
	Atta sexdens (Linnaeus, 1758)[1,4,5]	ANT, CSS, TDF
	Blepharidatta	
	Blepharidatta conops Kempf, 1967[1,2,3,4,5]	ANT, CSS, RIF, TDF
	Cardiocondyla	
	Cardiocondyla emeryi Forel, 1881[4]	ANT
	Carebara	
	Carebara brevipilosa Fernández, 2004[4]	CSS
	Carebara urichi (Wheeler, 1922)[1]	CSS, RIF
	Cephalotes	
Myrmicinae	*Cephalotes atratus* (Linnaeus, 1758)[1,5]	CSS, RIF, TDF
	Cephalotes betoi De Andrade & Baroni Urbani, 1992[2]	CSS
	Cephalotes clypeatus (Fabricius, 1804)[2,5]	CSS
	Cephalotes grandinosus (Smith, 1860)[1]	CSS, TDF
	Cephalotes maculatus (Smith, 1876)[1]	TDF
	Cephalotes minutus (Fabricius, 1804)[1,2,5]	CSS, TDF
	Cephalotes notatus (Mayr, 1866)[1]	CSS, RIF, TDF
	Cephalotes pallidoides De Andrade, 1999[2]	CSS
	Cephalotes pavonii (Latreille, 1809)[1]	CSS, TDF
	Cephalotes persimilis De Andrade, 1999[2,5]	CSS
	Cephalotes pusillus (Klug, 1824)[1,2,4,5]	CSS, RIF, TDF
	Crematogaster	

Table 2. Taxa recorded for APA Pandeiros. (Continuation)

Subfamilies	Genus/Species	Habitats
Myrmicinae	*Crematogaster abstinens* Forel, 1899[1,5]	CSS, RIF
	Crematogaster chodati Forel, 1921[5]	CSS
	Crematogaster crinosa Mayr, 1862[1]	CSS, RIF, TDF
	Crematogaster erecta Mayr, 1866[1]	CSS, RIF, TDF
	Crematogaster obscurata Emery, 1895[4,5]	CSS, TDF
	Crematogaster rochai Forel, 1903[5]	CSS
	Crematogaster stollii Forel, 1885[3]	CSS
	Cyatta	
	Cyatta abscondita Sosa-Calvo et al., 2013[4]	CSS
	Cyphomyrmex	
	Cyphomyrmex transversus Emery, 1894[2]	CSS
	Hylomyrma	
	Hylomyrma reitteri (Mayr, 1887)[4,5]	CSS
	Kalathomyrmex	
	Kalathomyrmex emeryi (Forel, 1907)[4,5]	ANT, CSS
	Megalomyrmex	
	Megalomyrmex silvestrii Wheeler, 1909[4]	ANT
	Monomorium	
	Monomorium pharaonis (Linnaeus, 1758)[4]	ANT
	Mycetarotes	
	Mycetarotes parallelus (Emery, 1906)[4,5]	ANT, CSS, TDF
	Mycetomoellerius	
	Mycetomoellerius dichrous (Kempf, 1967)[5]	CSS
	Mycetomoellerius urichii (Forel, 1893)[1]	RIF
	Mycetophylax	
	Mycetophylax lectus (Forel, 1911)[2]	CSS
	Mycocepurus	
	Mycocepurus goeldii (Forel, 1893)[2,4,5]	ANT, CSS
	Mycocepurus smithii (Forel, 1893)[2,4,5]	ANT, CSS
	Nesomyrmex	
	Nesomyrmex costatus (Emery, 1896)[1]	CSS
	Nesomyrmex asper (Mayr, 1887)[1]	CSS, RIF, TDF
	Ochetomyrmex	
	Ochetomyrmex semipolitus Mayr, 1878[2]	CSS
	Paratrachymyrmex	
	Paratrachymyrmex bugnioni (Forel, 1912)[2]	CSS
	Pheidole	
	Pheidole aberrans Mayr, 1868[4,5]	ANT, CSS
	Pheidole biconstricta Mayr, 1870[4,5 *]	CSS
	Pheidole capillata Emery, 1906[3]	CSS
	Pheidole caribbaea Wheeler, 1911[4,5***]	ANT, CSS
	Pheidole cyrtostela Wilson, 2003[2]	CSS
	Pheidole exigua Mayr, 1884[4,5*]	ANT, CSS, TDF
	Pheidole fracticeps Wilson, 2003[2,4,5]	ANT, CSS, TDF
	Pheidole gigaflavens Wilson, 2003[4**]	ANT
	Pheidole jelskii Mayr, 1884[4,5]	CSS
	Pheidole microps Wilson, 2003[5*]	CSS
	Pheidole obscurithorax Naves, 1985[4,5]	ANT, CSS, TDF
	Pheidole oxyops Forel, 1908[2,5]	CSS
	Pheidole radoszkowskii Mayr, 1884[2]	CSS

Table 2. Taxa recorded for APA Pandeiros. (Continuation)

Subfamilies	Genus/Species	Habitats
	Pheidole rochai Forel, 1912[5*]	CSS
	Pheidole scapulata Santschi, 1923[4,5]	CSS
	Pheidole schwarzmaieri Borgmeier, 1939[2]	CSS
	Pheidole subarmata Mayr, 1884[5]	CSS
	Pheidole susannae Forel, 1886[4]	ANT, TDF
	Pheidole triconstricta Forel, 1886[2,4,5]	ANT, CSS, TDF
	Pheidole valens Wilson, 2003[4]	TDF
	Pheidole vallifica Forel, 1901[5]*	CSS
	Pheidole zelata Wilson, 2003[4]**	ANT, CSS
	Pogonomyrmex	
	Pogonomyrmex naegelii Emery, 1878[1,5]	CSS, RIF
	Solenopsis	
Myrmicinae	*Solenopsis globularia* (Smith, 1858)[5]	CSS
	Solenopsis invicta Buren, 1972[4]	ANT, TDF
	Solenopsis substituta Santschi, 1925[2,4,5]	CSS
	Solenopsis tridens Forel, 1911[3,4]	ANT, CSS, TDF
	Strumigenys	
	Strumigenys borgmeieri Brown, 1954[5*]	CSS
	Strumigenys grytava (Bolton, 2000)[2]	CSS
	Strumigenys infidelis Santschi, 1919[4,5]	CSS
	Tetramorium	
	Tetramorium simillimum (Smith, 1851)[4]	ANT
	Wasmannia	
	Wasmannia auropunctata (Roger, 1863)[2,4,5]	CSS, TDF
	Wasmannia lutzi Forel, 1908[2]	CSS
	Anochetus	
	Anochetus inermis André, 1889[2]	CSS
	Centromyrmex	
	Centromyrmex brachycola (Roger, 1861)[2]	CSS
	Neoponera	
	Neoponera laevigata (Smith, 1858)[5]	CSS
Ponerinae	*Neoponera villosa* (Fabricius, 1804)[1,2,4]	CSS, TDF
	Odontomachus	
	Odontomachus bauri Emery, 1892[2,4,5]	CSS, TDF
	Odontomachus brunneus (Patton, 1894)[1]	CSS, TDF
	Odontomachus chelifer (Latreille, 1802)[4]	CSS
	Odontomachus haematodus (Linnaeus, 1758)[4]	CSS
	Thaumatomyrmex	
	Thaumatomyrmex mutilatus Mayr, 1887[1,4]	ANT, RIF, TDF
	Pseudomyrmex	
	Pseudomyrmex curacaensis (Forel, 1912)[2]	CSS
	Pseudomyrmex elongatus (Mayr, 1870)[1,2]	CSS, RIF, TDF
	Pseudomyrmex gracilis (Fabricius, 1804)[1,2,4,5]	ANT, CSS, RIF, TDF
	Pseudomyrmex oculatus (Smith, 1855)[1]	RIF, TDF
Pseudomyrmecinae	*Pseudomyrmex schuppi* (Forel, 1901)[4]	TDF
	Pseudomyrmex tenuis (Fabricius, 1804)[1,4,5]	CSS, RIF, TDF
	Pseudomyrmex tenuissimus (Emery, 1906)[2]	CSS
	Pseudomyrmex termitarius (Smith, 1855)[4,5]	CSS
	Pseudomyrmex unicolor (Smith, 1855)[2,4]	CSS
	Pseudomyrmex urbanus (Smith, 1877)[2]	CSS

Table 3. Morphospecies recorded for APA Pandeiros regarding publications or databases. The morphospecies follows the alphabetical order. The number in parentheses refers to the richness recorded. As the species recorded in the literature were not examined, the genus identified as "*Trachymyrmex*" was updated to *Mycetomoellerius*/*Paratrachymyrmex*. The morphospecies are not standardized among the datasets (Ds).

	Number of morphospecies/Dataset				
Genus	**D1**	**D2**	**D3**	**D4**	**D5**
Acromyrmex				2	1
Anochetus					1
Apterostigma		1		1	
Atta					3
Azteca		1		1	
Brachymyrmex		3	1	4	6
Camponotus	5	1	1	11	21
Cardiocondyla	1				
Carebara				1	
Cephalotes					1
Crematogaster	1	5		4	8
Cyphomyrmex				1	2
Dolichoderus				1	
Dorymyrmex	1	2		5	9
Eciton				1	1
Ectatomma			1	2	4
Eurhopalothrix					1
Forelius	3	2	1	5	5
Gnamptogenis					3
Hypoponera				1	1
Labidus	1				
Linepithema	1			2	2
Megalomyrmex		1			1
Mycetophylax				1	2
Mycetosoritis					1
Mycocepurus	1				
Myrmicinae (Subfamily)				1	
Myrmicocrypta	1			2	2
Neivamyrmex	2	3			3
Nesomyrmex	1				1
Nylanderia	2		1	1	1
Ochetomyrmex				1	1
Odontomachus				1	
Oxyepoecus				1	5
Pheidole	23	13	1	34	64
Pseudomyrmex	2			4	2
Rogeria					2
Sericomyrmex	1				1
Solenopsis	7	5		9	11
Strumigenys	2	1		3	1
Tapinoma	1	1			3
Mycetomoellerius/Paratrachymyrmex	6	1		5	5
Wasmannia	3			3	6
Xenomyrmex		1			
Morphospecies richness	**65**	**41**	**6**	**108**	**181**

Authors' Contribution

ACMQ, RAC conceived and designed the research and wrote the first draft; ACMQ and LPP organized the data; GSS, MAR helped with non-published data, all authors contributed writing and editing the manuscript.

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