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ARTICLE

# Species list of ground-dwelling ants (Hymenoptera: Formicidae) in the Nhecolândia, Pantanal, Mato Grosso do Sul, Brazil

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**Abstract.** This study provides a list of the ground-dwelling ant species in Nhecolândia, Pantanal, Mato Grosso Sul, Brazil. The Pantanal is the largest tropical wetland in the world and is currently under strong anthropic pressure. Ground-dwelling ants were collected in three sites: (1) a forest regeneration area; (2) a pasture area; and (3) an area of secondary native vegetation. In each site, 120 samples were collected using pitfall traps in the dry and rainy seasons of 2016. Additional samplings were performed with Winkler extractors (30 leaf-litter samples) and manually, also in dry and rainy seasons of 2016. In total, we collected 172 species, which, summed with the additional records from literature, raise the number of ant species recorded in Nhecolândia to 184 in 42 genera and nine subfamilies. Eleven species were recorded for the first time in the state of Mato Grosso do Sul. Also, the survey adds two new species records to Brazil. Besides contributing to the inventory of the ant species present in the Pantanal biome, the present study provides an important resource for future conservation plans for this threatened ecoregion.

**Keywords.** Ant sampling; Conservation; Diversity; Epigaeic ants.

## INTRODUCTION

The Pantanal is the largest tropical wetland in the world, distributed across three countries: Brazil, Bolivia, and Paraguay. The largest portion of the biome is located in Brazil, with approximately 150,000 km$^2$ (Uehara-Prado, 2005; Junk *et al.*, 2006; Mioto *et al.*, 2012). The biome is recognized as a natural heritage by the Brazilian constitution, and a natural heritage of humanity by the United Nations Educational, Scientific and Cultural Organization (UNESCO) (Boin *et al.*, 2019; Correa *et al.*, 2019). Despite its remarkable biodiversity, the Pantanal is restricted to a relatively small area compared to other Brazilian biomes, being only bigger than the Pampa biome (Correa *et al.*, 2019; MMA, 2020). Until recently it was considered the most preserved Brazilian biome (with approximately 83% of the natural area preserved until 2018) (MMA, 2020), but this is no longer the case after the expansion of agricultural frontiers (Grasel *et al.*, 2019), and the 2020 arson that devastated about 30% of it (Arréllaga *et al.*, 2020; Einhorn *et al.*, 2020; INPE, 2020a).

The high species diversity of the Pantanal results from its morphogeological and phytophysiognomic diversity (Junk *et al.*, 2006, 2013; Alho *et al.*, 2019; Louzada *et al.*, 2020). In fact, some researchers have proposed that the Pantanal is not a biome, but a mosaic of phytophysiognomies (Demétrio *et al.*, 2017; Boin *et al.*, 2019) that differ according to their degree of similarity between the Cerrado and the Chaco in the South, and the Cerrado and the Amazon in the North (Junk *et al.*, 2006), forming different wetlands. The Brazilian Pantanal is a sedimentary basin surrounded by plateaus, forming a set of terrestrial and aquatic ecosystems (Boin *et al.*, 2019). It is divided into subregions that have distinct physiomorphological (flood, relief, soil, and vegetation) and ecological characteristics (Silva & Abdon, 1998; McGlue *et al.*, 2017). Mioto *et al.* (2012) identified 18 subregions, Nhecolândia being the largest, accounting for 14% of the Pantanal area.

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Located in the state of Mato Grosso do Sul (Brazil), Nhecolândia is characterized by the coexistence of thousands of lakes called baías (fresh water) and salinas (waters of alkaline composition), in addition to the cordilheiras (sand banks with at least two meters, covered by cerradão – a type of forested Brazilian savanna) (Rodela & Queiroz-Neto, 2007; Mioto *et al.,* 2012). The uniqueness of this location is due to the fact that salinas and baías are the main formations (Oliveira *et al.,* 2018). This region is socially and economically important because it is one of the largest cattle pastures in the Pantanal (Rodela & Queiroz-Neto, 2007). Besides that, Nhecolândia has one of the highest wild vertebrate densities in the Pantanal (Alho, 2008; Alho & Sabino, 2011), especially of threatened species (Alho *et al.,* 2019), and a high floral heterogeneity (Oliveira *et al.,* 2018). A large number of studies have assessed the vertebrate and floral diversity in Nhecolândia (Alho, 2008; Alho & Sabino, 2011; Junk *et al.,* 2013; Alho *et al.,* 2019), but invertebrate inventories for the region are scarce (Lewinsohn *et al.,* 2005; Junk *et al.,* 2006; Demétrio *et al.,* 2017).

Invertebrates constitute the greatest part of the tropical forest biomass corresponding to approximately 75% of the terrestrial biomass (Fittkau & Klinge, 1973; Bar-On *et al.,* 2018). Due their high density, shorter life cycle (in relation to vertebrates), and high frequency of occurrence in samplings, terrestrial invertebrates can be used as bioindicators, and can contribute to the understanding and establishment of environmental conservation measures (Lewinsohn *et al.,* 2005). Ants are the most abundant component of the invertebrate biomass (Fittkau & Klinge, 1973; Demétrio *et al.,* 2017). They are conspicuous organisms and live in almost all environments (Folgarait, 1998), from the arboreal strata to the underground (Lucky *et al.,* 2013; Jacquemin *et al.,* 2016).

Despite the fact that the Pantanal is a hotspot and ants are relatively easy to sample (Myers *et al.,* 2000), there have been few studies on the ants of this biome when compared to other biomes (*see* Oliveira *et al.,* 1987; Adis *et al.,* 2001; Batirolla *et al.,* 2005; Orr *et al.,* 2003 Uehara-Prado, 2005; Corrêa *et al.,* 2006; Ribas & Schoreder, 2007; Lange *et al.,* 2008; Pereira *et al.,* 2013; Soares *et al.,* 2013; Neves *et al.,* 2014; Cuissi *et al.,* 2015; Meurer *et al.,* 2015; Aranda *et al.,* 2016; Yamazaki *et al.,* 2016; Demétrio *et al.,* 2017; Dambros *et al.,* 2018), and most of them deal with the vertical flow of ants following the hydrological cycle. In addition, if we rank the Brazilian biomes according to the loss of natural cover between 2000 to 2016, the Caatinga is ranked first place followed by Pantanal (Divieso *et al.,* 2020). Thus, that should be the priority for scientific studies including ant sampling.

The aim of this study is to provide a list of species for the ground-dwelling ants in Nhecolândia, Pantanal, Mato Grosso Sul, Brazil.

## MATERIAL AND METHODS

### Sampled areas

The sampled areas were part of the Biomas Project, which was carried out between 2014 and 2019 in partnership with Confederação da Agricultura e Pecuária do Brasil (CNA), and Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA). The study areas are located in the Nhecolândia subregion, in the Taquari megafan (between the Taquari and Negro rivers) (Oliveira *et al.,* 2018). The differences in salinity between *salinas* and *baías,* and within *salinas,* are the result of their different levels of interconnectivity. *Salinas* do not connect and are surrounded by *cordilheiras* (areas with a predominance of xeromorphic vegetation over sandy strands, old river dikes), whereas *baías* may connect, forming *vazantes* (runoff channels formed during the rainy season) (McGlue *et al.,* 2017; Oliveira *et al.,* 2018; Boin *et al.,* 2019). Due to their saline composition, the lakes can also be distinguished by color (Oliveira *et al.,* 2018). According to Oliveira *et al.* (2018), the climate in Nhecolândia is more semi-arid than tropical, with annual average temperature of 24°C and accumulated rainfall of 1,100 mm. The concentrated rains occur between October and March, with irregular distribution in the East-West direction (higher volumes in the west). The temperature varies greatly and may oscillate from 1°C to 40°C in the same day (during the Winter, from June to August), due the influence of cold air masses originated in the Andean region (Oliveira *et al.,* 2018).

The following sites were selected for this study: (A1) an area undergoing forest regeneration (18°58′45″S and 56°38′33″W), where a cultivated pasture (*Brachiaria* spp.) was reforested with arboreal species, such as *Sterculia apetala* (Jacq.) H. Karst., *Dipteryx alata* Vog., *Hymenaea stigonocarpa* Mart. ex Hayne and *Handroanthus impetiginosus* (Mart. ex DC) in 2015 by the Biomas Project; (A2) a degraded area used as pasture (covered by *Brachiaria* spp.) (19°15′00″S and 57°03′25″W); and (A3) an area with secondary native vegetation (cerradão) (18°57′53″S and 56°37′33″W), without human intervention for at least 25 years, located at the Private Reserve of Natural Heritage Fazenda Nhumirim (18°59′17″S and 56°37′08″W), which was created in 1990, owned by EMBRAPA Pantanal.

Additional qualitative samplings were obtained in areas of primary native vegetation, present in the cordilheiras (close to the areas systematically sampled, especially in Fazenda Nhumirim), whose floristic composition is quite heterogeneous, with reference to the species *Attalea phalerata* Mart. ex Spreng., *Diospyros lasiocalyx* (Mart.) B. Walln. and *Annona dioica* A. St.-Hil. (Freitas *et al.,* 2011).

### Sampling methods

We carried out two expeditions: one in the dry season (January) and one in the rainy season (July) of 2016. The methodology followed the ALL protocol for ant sampling proposed by Agosti & Alonso (2000), with modifications. In each area, we allocated three transects of 200 m, spaced by 10 m, forming a grid. Along each transect, we installed 20 epigaeic pitfall traps spaced by 10 m, totaling 60 pitfalls per area (per expedition) that remained in the field for 48h. Pitfall traps consisted of 200 ml plastic cups, half filled with water, detergent, and salt (NaCl), buried at the ground level. Additional qualitative sampling was carried out manually (on soil and vegetation) and through Winkler extractors, both without a specific sampling design. We collected 30 Winkler samples (15 per season), for which only the leaf-litter was sieved, excluding the soil surface (for details about Winkler extractor see Fisher, 1999).

The sampled material was processed at the Entomology Laboratory at EMBRAPA Florestas (Colombo, PR) and at the Laboratório de Sistemática e Biologia de Formigas at Universidade Federal do Paraná (UFPR). The ants were mounted and identified at the genus level using the identification key in Baccaro *et al.* (2015). For species classification, specific literature was used (Gonçalves, 1961; Andrade & Baroni-Urbani, 1999; Longino & Fernández, 2007; Cuezzo *et al.,* 2015), and specialists (Alexandre C. Ferreira, Natalia M. Ladino, Thiago S.R. da Silva and John E. Latke) were consulted. The material was deposited at the Padre Jesus Santiago Moure Entomological Collection (DZUP) and the duplicates were stored in the Entomology Laboratory of EMBRAPA Florestas.

To confirm species occurrences in the Nhecolândia, we used AntMaps (Janicki *et al.,* 2016; Guénard *et al.,* 2017). The following combination of words: "ants", "Pantanal", "floodplains", "Nhecolândia", and "Brazilian wetlands", was searched in Google Scholar, Scielo, and Web of Science databases for data on ant species recorded in the Pantanal available on literature. We gathered 17 papers: Oliveira *et al.* (1987), Adis *et al.* (2001), Batirolla *et al.* (2005), Orr *et al.* (2003), Uehara-Prado (2005), Corrêa *et al.* (2006), Ribas & Schoreder (2007), Lange *et al.* (2008), Pereira *et al.* (2013), Soares *et al.* (2013) Neves *et al.* (2014), Cuissi *et al.* (2015), Meurer *et al.* (2015), Yamazaki *et al.* (2016), Aranda *et al.* (2016), Demétrio *et al.* (2017), and Dambros *et al.* (2018). The species associated with these bibliographies, for the Nhecolândia subregion, were listed and identified as "literature data" (see Tables 1 and 2: L1 and L2). For the sake of taxonomic precision, species identified as near ("*nr.*" and "*aff.*") nominal taxa in the literature were here considered morphospecies, but are treated as species for comparison purposes, even that not formally described. The taxonomic classification of the taxa names obtained from the literature was updated according to the most recent proposal (Bolton, 2021).

We used the richness estimators Jackknife 1, and Bootstrap, with the pitfall traps data, to evaluate if the species sampled are nearest to the expected with this

**Table 1.** Coordinates from the sampled areas in this study (A1, A2, A3, and Faz. Nhumirim), and the literature referred to samplings in Pantanal. (*) samplings performed by Biomas Project in Nhecolândia; (§) others studies in Nhecolândia.

| Papers | Longitude GMS | Latitude GMS | Longitude GD | Latitude GD |
|---|---|---|---|---|
| (A1) Biomas * | 56°38′33″W | 18°58′45″S | -56.6425 | -18.97916667 |
| (A2) Biomas * | 57°03′25″W | 19°15′00″S | -57.05694444 | -19.25 |
| (A3) Biomas * | 56°37′33.65″W | 18°57′53.37″S | -56.62583333 | -18.96472222 |
| (Faz. Nhumirim) Biomas qualitative * | 56°37′08″W | 18°59′17″S | -56.61888889 | -18.98805556 |
| (L1) Uehara-Prado (2005)§ | 56°14′W | 19°34′S | -56.23333333 | -19.56666667 |
| (L2) Corrêa *et al.* (2006)§ | 56°14′W | 19°34′S | -56.23333333 | -19.56666667 |
| Adis *et al.* (2001) | 56°22′12″W | 16°15′12″S | -56.37 | -16.25333333 |
| Aranda *et al.* (2016) | 57°36′17″W | 19°11′05″S | -57.60472222 | -19.18472222 |
| Batirolla *et al.* (2005) | 56°36′24″W | 16°15′24″S | -56.60717273 | -16.25709732 |
| Batirolla *et al.* (2005) | 57°56′23″W | 17°54′32″S | -57.94024147 | -17.9093228 |
| Cuissi *et al.* (2015) | 55°11′W | 20°59′S | -55.18333333 | -20.98333333 |
| Dambros *et al.* (2018) | 56°32′W | 16°18′S | -56.53333333 | -16.3 |
| Dambros *et al.* (2018) | 56°24′W | 16°30′S | -56.4 | -16.5 |
| Demétrio *et al.* (2017) | 57°29′18″W | 18°06′44″S | -57.48833333 | -18.11222222 |
| Demétrio *et al.* (2017) | 57°01′08″W | 19°34′35″S | -57.01888889 | -19.57638889 |
| Demétrio *et al.* (2017) | 57°49′30″W | 21°15′20″S | -57.825 | -21.25555556 |
| Demétrio *et al.* (2017) | 57°36′04″W | 19°12′10″S | -57.60111111 | -19.20277778 |
| Lange *et al.* (2008) | 57°01′06″W | 19°28′4″S | -57.01833333 | -19.46777778 |
| Meurer *et al.* (2015) | 58°08′25″W | 16°28′49″S | -58.14027778 | -16.48027778 |
| Neves *et al.* (2014) | 57°01′37.6″W | 19°38′56.4″S | -57.02762972 | -19.64944299 |
| Neves *et al.* (2014) | 57°02′32.40″W | 19°22′20.28″S | -57.04285116 | -19.37274191 |
| Oliveira *et al.* (1987) | 56°59′18.4″W | 17°16′15.6″S | -56.98384455 | -17.26710056 |
| Orr *et al.* (2003) | 57°01′W | 19°34′S | -57.01666667 | -19.56666667 |
| Pereira *et al.* (2013) | 57°52′53″W | 21°40′19″S | -57.88138889 | -21.67194444 |
| Pereira *et al.* (2013) | 57°53′10.00″W | 21°41′40.86″S | -57.88611111 | -21.69468333 |
| Pereira *et al.* (2013) | 57°52′51.81″W | 21° 41′10.39″S | -57.88105833 | -21.68621945 |
| Pereira *et al.* (2013) | 57°53′30.6″W | 21°40′27.0″S | -57.89183333 | -21.67416667 |
| Pereira *et al.* (2013) | 57°54′58.7″W | 21°45′56.0″S | -57.91630556 | -21.76555556 |
| Ribas & Schoreder (2007) | 57°45′00″W | 19°34′34″S | -57.0125 | -19.57611111 |
| Ribas & Schoreder (2007) | 57°10′00″W | 19°34′57″S | -57.01666667 | -19.5825 |
| Soares *et al.* (2013) | 56°30′22.8″W | 20°10′30.4″S | -56.50633333 | -20.17511111 |
| Yamazaki *et al.* (2016) | 56°24′W | 16°26′S | -56.40050515 | -16.43376523 |

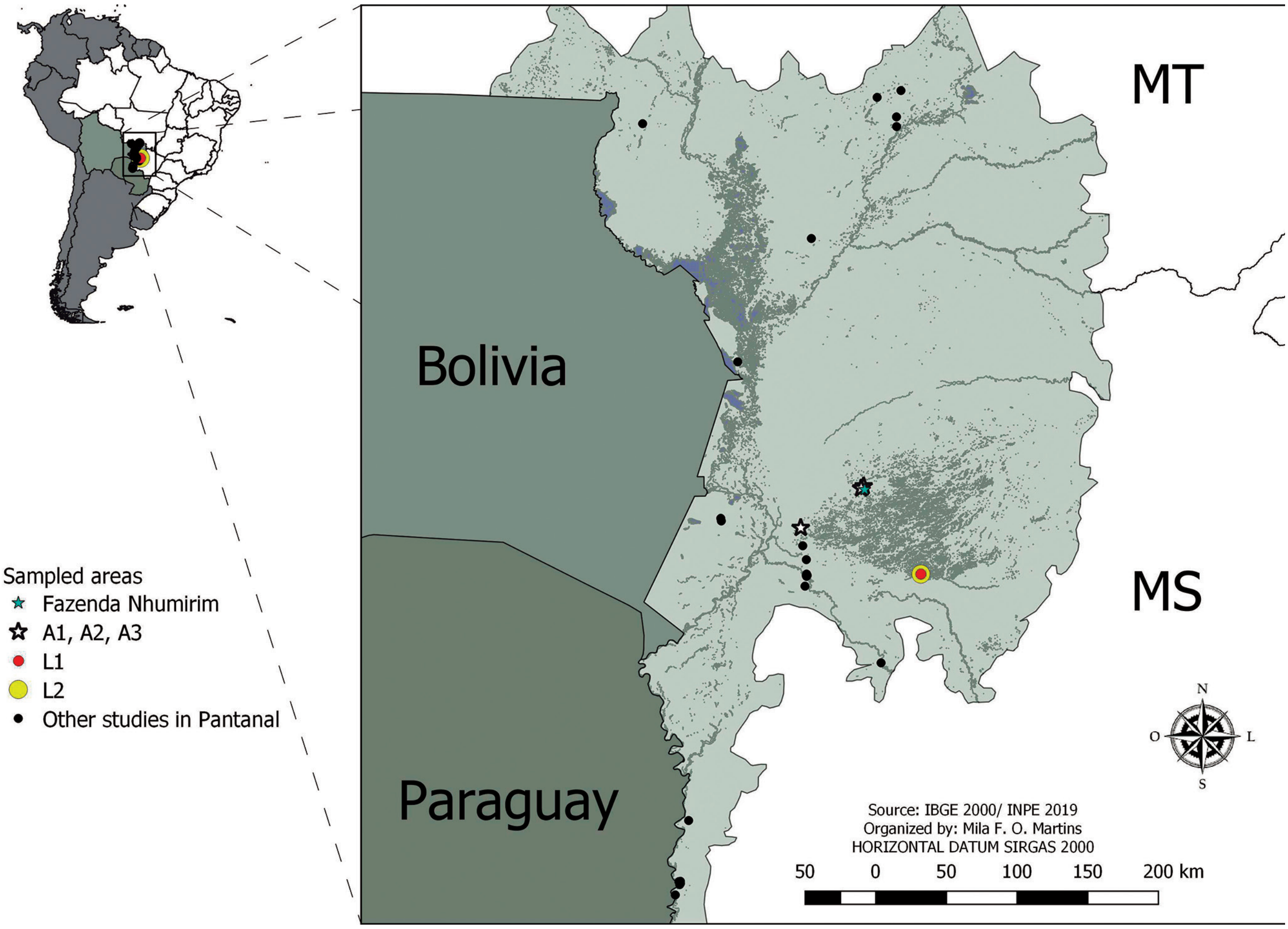


**Figure 1: Sampled areas and hydrography of the Brazilian Pantanal.** The black dots correspond to previous ant samplings in this biome (other studies). The stars represent our study areas (Fazenda Nhumirim, A1, A2 and A3), and the red and yellow dots represent L1 (Uehara-Prado, 2005) and L2 (Corrêa *et al.,* 2006), respectively, which are ant diversity studies for the Nhecolândia subregion.

sampling effort (Hortal *et al.,* 2006). A map (Fig. 1) was made to indicate the distribution of sampling areas in Pantanal gathering the coordinates of the sampled areas of this study (A1, A2, A3, Faz. Nhumirim) and the literature compiled here (L1, L2, Other studies) (Table 1). All the coordinates referring in the literature were included in the map after conversion from GMS-SAD69 to GD-SIRGAS2000 using the calculator provided by Instituto Nacional de Pesquisas Espaciais (INPE, 2020b). The map was generated using the software QGis 3.0.3, and shapefiles provided by the Instituto Brasileiro de Geografia e Estatística (IBGE) and Instituto Nacional de Pesquisas Espaciais (INPE) (Assis *et al.,* 2019).

Ant collecting was authorized by the Brazilian Biodiversity Information and Authorization System – SISBIO (license number 55313-1) and the access to the genetic heritage was registered in the National Management System of the Genetic Heritage – SisGen (register number ACDFB38).

## RESULTS

Considering the samplings from this study and the literature information, we registered 184 species in 42 genera and nine subfamilies for the Nhecolândia subregion of Pantanal (Table 2). Specifically for the samplings carried out in this study, we collected 172 species belonging to 42 genera and nine subfamilies. Of these species, 81 were formally named (corresponding to 47.1% of the total recorded), while the remaining unnamed species were here treated as morphospecies. Myrmicinae was the most species-rich subfamily (86 species), followed by Formicinae (32) and Dolichoderinae (19), which accounted for 50%, 18.6% and 11% of the total species, respectively. *Pheidole* Westwood, 1839 was the most species-rich genus, with 28 species (16.2%), followed by *Brachymyrmex* Mayr, 1868, and *Solenopsis* Westwood, 1840 with 16 species (9.3%, each) and *Camponotus* Mayr, 1861 with 12 (7%). The most frequent species were *Pheidole* sp. 1, *Dorymyrmex pyramicus* (Roger, 1863), *Solenopsis invicta* Buren, 1972 and *Forelius* sp. 1. A total of 66, 45, and 85 species were sampled in areas 1, 2, and 3, respectively. This is less than the number estimated by Jackknife 1 (76%, 73%, and 68.5%) and bootstrap (86%, 88% and 84%) (Table 3).

Regarding the registers from the literature, only two papers added species to the local list: (L1) Uehara-Prado (2005) with three species – *Dorymyrmex* aff. *goeldii, Solenopsis globularia* (Smith, 1858), and *Solenopsis*

**Table 2.** Species list in the Nhecolândia, subregion of the Pantanal, Mato Grosso do Sul, Brazil. (Qual.) qualitative: manual and Winkler samplings; (A1) forest regeneration area; (A2) pasture area; and (A3) secondary native vegetation. Literature data: (L1) Uehara-Prado, 2005; and (L2) Corrêa *et al.,* 2006.

| | Species | Qual. | A1 | A2 | A3 | L1 | L2 |
|---|---|---|---|---|---|---|---|
| | **Amblyoponinae** | | | | | | |
| 1 | *Prionopelta antillana* Forel, 1909 | X | | | X | | |
| | **Dolichoderinae** | | | | | | |
| 2 | *Azteca* sp. 1 | X | | X | X | | |
| 3 | *Azteca* sp. 2 | | | | X | | |
| 4 | *Azteca* sp. 3 | | | | X | | |
| 5 | *Azteca* sp. 4 | X | | | | | |
| 6 | *Dolichoderus diversus* Emery, 1894 | X | | | | | |
| 7 | *Dorymyrmex brunneus* Forel, 1908 | X | X | X | | X | |
| 8 | *Dorymyrmex* aff. *goeldii* | | | | | X | |
| 9 | *Dorymyrmex paranensis* Santschi, 1922 | | X | X | | | |
| 10 | *Dorymyrmex pyramicus* (Roger, 1863) | X | X | X | | | |
| 11 | *Dorymyrmex* sp. 1 | | X | X | | | |
| 12 | *Dorymyrmex* sp. 2 | | X | X | | | |
| 13 | *Dorymyrmex* sp. 3 | | X | X | | | |
| 14 | *Dorymyrmex* sp. 4 | | X | X | | | |
| 15 | *Dorymyrmex* sp. 5 | X | | | | | |
| 16 | *Dorymyrmex* sp. 6 | X | | | | | |
| 17 | *Forelius brasiliensis* (Forel, 1908) | X | X | X | | | |
| 18 | *Forelius* sp. 1 | | X | X | | | |
| 19 | *Forelius* sp. 2 | X | X | X | X | | |
| 20 | *Forelius* sp. 3 | | X | X | | | |
| 21 | *Gracilidris pombero* Wild & Cuezzo, 2006 | | X | X | | | |
| | **Dorylinae** | | | | | | |
| 22 | *Eciton burchelii* Westwood (1842) | | | | | | X |
| 23 | *Eciton dulcium* Forel, 1912 | | | | X | | |
| 24 | *Labidus coecus* (Latreille, 1802) | | | | X | | |
| 25 | *Labidus mars* (Forel, 1912) | | X | | | | X |
| 26 | *Labidus praedator* (Smith, 1858) | | | | | | X |
| 27 | *Neivamyrmex* sp. 1 | | X | | | | |
| 28 | *Neivamyrmex* sp. 2 | | X | | X | | |
| 29 | *Neivamyrmex* sp. 3 | | X | | | | |
| 30 | *Neivamyrmex* sp. 4 | | X | | X | | |
| 31 | *Nomamyrmex hartigii* (Westwood, 1842) | X | | | | | |
| | **Ectatomminae** | | | | | | |
| 32 | *Ectatomma brunneum* Smith, 1858 | | X | X | | X | X |
| 33 | *Ectatomma edentatum* Roger, 1863 | | X | | X | | X |
| 34 | *Ectatomma lugens* Emery, 1894 | | | | X | | X |
| 35 | *Ectatomma opaciventre* (Roger, 1861) | | X | X | X | | X |
| 36 | *Ectatomma permagnum* Forel, 1908 | X | | | X | | X |
| 37 | *Ectatomma planidens* Borgmeier, 1939 | X | X | X | X | | X |
| 38 | *Ectatomma tuberculatum* (Olivier, 1792) | | | | X | | X |
| 39 | *Gnamptogenys striatula* Mayr, 1884 | X | | | X | | |
| | **Formicinae** | | | | | | |
| 40 | *Brachymyrmex pilipes* Mayr, 1887 | | X | | X | | |
| 41 | *Brachymyrmex* sp. 1 | | | X | | | |
| 42 | *Brachymyrmex* sp. 2 | X | X | X | X | | |
| 43 | *Brachymyrmex* sp. 3 | | X | X | X | | |
| 44 | *Brachymyrmex* sp. 4 | | X | | | | |
| 45 | *Brachymyrmex* sp. 5 | | X | | X | | |
| 46 | *Brachymyrmex* sp. 6 | | X | | | | |
| 47 | *Brachymyrmex* sp. 7 | | | X | | | |
| 48 | *Brachymyrmex* sp. 8 | | X | | | | |
| 49 | *Brachymyrmex* sp. 9 | | X | X | | | |
| 50 | *Brachymyrmex* sp. 10 | | X | | | | |
| 51 | *Brachymyrmex* sp. 11 | | | | X | | |
| 52 | *Brachymyrmex* sp. 12 | | | | X | | |
| 53 | *Brachymyrmex* sp. 13 | X | | | | | |
| 54 | *Brachymyrmex* sp. 14 | X | | | | | |
| 55 | *Brachymyrmex* sp. 15 | X | | | | | |
| 56 | *Camponotus arboreus* (Smith, 1858) | | | | X | | |
| 57 | *Camponotus balzani* Emery, 1894 | X | | | | | |
| 58 | *Camponotus brasiliensis* Mayr, 1862 | X | X | X | X | | |
| 59 | *Camponotus crassus* Mayr, 1862 | X | | X | X | | |
| 60 | *Camponotus* aff. *crassus* | | | | | | X |
| 61 | *Camponotus leydigi* Forel, 1886 | | | | X | | |
| 62 | *Camponotus novogranadensis* Mayr, 1870 | X | X | X | X | | |
| 63 | *Camponotus* nr. *novogranadensis* | | | | X | | |
| 64 | *Camponotus pallescens* Mayr, 1887 | | | | | | X |
| 65 | *Camponotus personatus* Emery, 1894 | | X | X | | | |
| 66 | *Camponotus renggeri* Emery, 1894 | X | X | | X | | X |
| 67 | *Camponotus seiriceiventris* (Guérin-Méneville, 1838) | | | | | | X |
| 68 | *Camponotus silvicola* Forel, 1902 | | | | X | | |
| 69 | *Camponotus substitutus* Forel, 1899 | | X | | X | | |
| 70 | *Camponotus* sp. 1 | | | X | X | | |
| 71 | *Nylanderia fulva* (Mayr, 1862) | X | X | | | | |
| 72 | *Nylanderia* sp. 1 | | X | | X | | |
| 73 | *Nylanderia* sp. 2 | X | X | X | X | | |
| 74 | *Nylanderia* sp. 3 | | | X | X | | |
| | **Myrmicinae** | | | | | | |
| 75 | *Acromyrmex fracticornis* (Forel, 1909) | X | X | | | | |
| 76 | *Acromyrmex subterraneus* (Forel, 1893) | | | | X | | |
| 77 | *Acromyrmex* sp. 1 | X | | | | | |
| 78 | *Apterostigma* gr. *auriculatum* | X | | | X | | |
| 79 | *Atta laevigata* (Smith, 1858) | X | | X | X | | |
| 80 | *Atta sexdens* (Linnaeus, 1758) | | | | | | X |
| 81 | *Atta* sp. 1 | | | | X | | |
| 82 | *Blepharidatta conops* Kempf, 1967 | X | | | X | | |
| 83 | *Carebara* sp. 1 | | | | X | | |
| 84 | *Cephalotes atratus* (Linnaeus, 1758) | X | | X | X | | |
| 85 | *Cephalotes grandinosus* (Smith, 1860) | | | X | | | |
| 86 | *Cephalotes incertus* (Emery, 1906) | X | | | | | |
| 87 | *Cephalotes pallidus* De Andrade, 1999 | | | | X | | |
| 88 | *Cephalotes persimilis* De Andrade, 1999 | X | | | | | |
| 89 | *Cephalotes pusillus* (Klug, 1824) | X | | | | | |
| 90 | *Cephalotes* quadratus (Mayr, 1868) | X | | | | | |
| 91 | *Crematogaster abstinens* Forel, 1899 | X | X | X | X | | |
| 92 | *Crematogaster ampla* Forel, 1912 | | | X | X | | |
| 93 | *Crematogaster evallans* (Forel, 1907) | | | | X | | |
| 94 | *Crematogaster obscurata* Emery, 1895 | | X | | | | |
| 95 | *Crematogaster victima* Smith, 1858 | X | | | | | |
| 96 | *Crematogaster* sp. 1 | X | | | | | |
| 97 | *Cyatta abscondita* Sosa-Calvo *et al.,* 2013 | | | | X | | |
| 98 | *Cyphomyrmex* nr. *minutus* | X | X | X | X | | |
| 99 | *Mycetophylax olitor* (Forel, 1893) | X | X | X | X | | |
| 100 | *Mycetophylax* nr. *bruchi* | | X | | | | |
| 101 | *Mycocepurus goeldii* (Forel, 1893) | | X | | | | |
| 102 | *Mycocepurus smithii* (Forel, 1893) | | X | X | | | |
| 103 | *Myrmicocrypta* sp. 1 | | X | | | | |
| 104 | *Myrmicocrypta* sp. 2 | X | | | | | |
| 105 | *Oxyepoecus* nr. *kempfi* | | | | X | | |
| 106 | *Oxyepoecus vezenyii* (Forel, 1907) | | | | X | | |
| 107 | *Pheidole cyrtostela* Wilson, 2003 | | X | | X | | |
| 108 | *Pheidole exigua* Mayr, 1884 | X | | | | | |
| 109 | *Pheidole fracticeps* Wilson, 2003 | | | | X | | |
| 110 | *Pheidole microps* Wilson, 2003 | | | | X | | |

| Species | Qual. | A1 | A2 | A3 | L1 | L2 |
|---|---|---|---|---|---|---|
| 111 *Pheidole obscurifrons* Santschi, 1925 | X | | | | | |
| 112 *Pheidole obscurithorax* Naves, 1985 | | | | X | | |
| 113 *Pheidole oxyops* Forel, 1908 | X | X | | X | | |
| 114 *Pheidole triconstricta* Forel, 1886 | X | | | | | |
| 115 *Pheidole vallifica* Forel, 1901 | X | X | X | X | | |
| 116 *Pheidole* sp. 1 | X | X | X | X | | |
| 117 *Pheidole* sp. 2 | X | | | | | |
| 118 *Pheidole* sp. 3 | X | | | | | |
| 119 *Pheidole* sp. 4 | | | | X | | |
| 120 *Pheidole* sp. 5 | X | | | | | |
| 121 *Pheidole* sp. 6 | | | | X | | |
| 122 *Pheidole* sp. 7 | X | | | | | |
| 123 *Pheidole* sp. 8 | X | | | | | |
| 124 *Pheidole* sp. 9 | | | | X | | |
| 125 *Pheidole* sp. 10 | | | | X | | |
| 126 *Pheidole* sp. 11 | X | | | | | |
| 127 *Pheidole* sp. 12 | X | | | | | |
| 128 *Pheidole* sp. 13 | | | X | | | |
| 129 *Pheidole* sp. 14 | X | X | X | X | | |
| 130 *Pheidole* sp. 15 | X | | | | | |
| 131 *Pheidole* sp. 16 | | | | X | | |
| 132 *Pheidole* sp. 17 | | | | X | | |
| 133 *Pheidole* sp. 18 | | | X | | | |
| 134 *Pheidole* sp. 19 | | X | | | | |
| 135 *Rogeria curvipubens* Emery, 1894 | X | | | X | | |
| 136 *Solenopsis geminata* (Fabricius, 1804) | X | | | | | |
| 137 *Solenopsis globularia* (Smith, 1858) | | | | | X | |
| 138 *Solenopsis invicta* Buren, 1972 | X | X | X | | | |
| 139 *Solenopsis substituta* Santschi, 1925 | | | | X | | |
| 140 *Solenopsis wagneri* Santschi, 1916 | | | | | X | |
| 141 *Solenopsis* sp. 1 | X | | | | | |
| 142 *Solenopsis* sp. 2 | | X | X | | | |
| 143 *Solenopsis* sp. 3 | X | X | X | X | | |
| 144 *Solenopsis* sp. 4 | | X | | X | | |
| 145 *Solenopsis* sp. 5 | | X | | X | | |
| 146 *Solenopsis* sp. 6 | | X | | | | |
| 147 *Solenopsis* sp. 7 | | X | | X | | |
| 148 *Solenopsis* sp. 8 | | | | X | | |
| 149 *Solenopsis* sp. 9 | X | | | | | |
| 150 *Solenopsis* sp. 10 | | | | X | | |
| 151 *Solenopsis* sp. 11 | X | | | | | |
| 152 *Solenopsis* sp. 12 | | | | X | | |
| 153 *Solenopsis* sp. 13 | | X | | X | | |
| 154 *Strumigenys eggersi* Emery, 1890 | X | | | | | |
| 155 *Strumigenys elongata* Roger, 1863 | X | | | | | |
| 156 *Strumigenys lilloana* (Brown, 1950) | X | | | | | |
| 157 *Strumigenys* nr. *gytha* | X | | | | | |
| 158 *Strumigenys* nr. *louisianae* | X | | | | | |
| 159 *Mycetomoellerius kempfi* (Fowler, 1982) | | X | | | | |
| 160 *Mycetomoellerius* sp. 1 | X | | | | | |
| 161 *Tranopelta gilva* Mayr, 1866 | | | | X | | |
| 162 *Wasmannia auropunctata* (Roger, 1863) | X | X | | X | | X |
| 163 *Wasmannia rochai* Forel, 1912 | X | | | | | |
| **Ponerinae** | | | | | | |
| 164 *Anochetus bispinosus* (Smith, 1858) | | X | | | | |
| 165 *Hypoponera* sp. 1 | X | | | | | |
| 166 *Hypoponera* sp. 2 | X | | | | | |
| 167 *Hypoponera* sp. 3 | X | | | | | |
| 168 *Hypoponera* sp. 4 | | | | X | | |
| 169 *Neoponera inversa* (Smith, 1858) | X | | | X | | |
| 170 *Neoponera obscuricornis* (Emery, 1890) | | | | | | X |
| 171 *Neoponera unidentata* (Mayr, 1862) | | | | | | X |
| 172 *Neoponera villosa* (Fabricius, 1804) | | | | | | X |
| 173 *Odontomachus haematodus* (Linnaeus, 1758) | X | | | X | | |
| 174 *Pachycondyla harpax* (Fabricius, 1804) | X | | | X | | |
| **Proceratiinae** | | | | | | |
| 175 *Discothyrea sexarticulata* Borgmeier, 1954 | X | | | | | |
| **Pseudomyrmecinae** | | | | | | |
| 176 *Pseudomyrmex gracilis* (Fabricius, 1804) | | X | | X | | |
| 177 *Pseudomyrmex tenuis* (Fabricius, 1804) | | | | X | | |
| 178 *Pseudomyrmex termitarius* (Smith, 1855) | | X | | | | X |
| 179 *Pseudomyrmex unicolor* (Smith, 1855) | X | | | | | |
| 180 *Pseudomyrmex* sp. 1 | X | | | | | |
| 181 *Pseudomyrmex* sp. 2 | X | | | | | |
| 182 *Pseudomyrmex* sp. 3 | | | X | | | |
| 183 *Pseudomyrmex* sp. 4 | | | | X | | |
| 184 *Pseudomyrmex* sp. 5 | | | | X | | |
| **Total** | 81 | 66 | 45 | 85 | 5 | 19 |

*wagneri* Santschi, 1916; and (L2) Corrêa *et al.* (2006) with nine species – *Eciton burchelii* Westwood (1842), *Labidus praedator* (Smith, 1858), *Camponotus* aff. *crassus, Camponotus pallescens* Mayr, 1887, *Camponotus seiriceiventris* (Guérin-Méneville, 1838), *Atta sexdens* (Linnaeus, 1758), *Neoponera obscuricornis* (Emery, 1890), *Neoponera unidentata* (Mayr, 1862), and *Neoponera villosa* (Fabricius, 1804). *Ectatomma brunneum* Smith, 1858 was listed on both studies.

From the total species recorded in our samplings, 91 were collected only in epigaeic pitfall traps (quantitative sampling), 46 were sampled only through qualitative collections (Winkler extractor, and manual sampling) in areas of primary vegetation – cordilheiras, and 35 were sampled in both quantitative and qualitative efforts. From qualitative samplings, three species were reported for the first time for the state of Mato Grosso do Sul: *Cephalotes quadratus* (Mayr, 1868), *Pheidole exigua* Mayr, 1884, and *Strumigenys lilloana* (Brown, 1950). Also, in the areas where ants were sampled with systematized epigaeic pitfall traps, eight species were recorded for the first time for the state: *Anochetus bispinosus* (Smith, 1858), *Crematogaster ampla* Forel, 1912, *Crematogaster obscurata* Emery, 1895, *Cyatta abscondita* Sosa-Calvo *et al.,* 2013, *Pheidole cyrtostela* Wilson, 2003, *Pheidole fracticeps* Wilson, 2003, *Pheidole microps* Wilson, 2003, and *Pheidole vallifica* Forel, 1901. In addition, the survey adds two new ant species records to Brazil: *Camponotus silvicola* Forel, 1902, and *Pheidole obscurifrons* Santschi, 1925; and the southernmost record of *Rogeria curvipubens* Emery, 1894 in Brazil.

**Table 3.** Species richness observed ($R_{OBS}$), estimated by Jackknife 1 ($R_{JACK1}$), and Bootstrap ($R_{BOOT}$). Areas: (A1) forest regeneration area; (A2) pasture area, and (A3) control area (secondary native vegetation).

| Area | $R_{OBS}$ | $R_{JACK1}$ | $R_{BOOT}$ |
|---|---|---|---|
| **A1** | 66 | 87 | 76 |
| **A2** | 45 | 61 | 51 |
| **A3** | 85 | 124 | 101 |

## DISCUSSION

We recorded a total of 184 ant species in the Nhecolândia ecoregion. From those species recorded in this study (172), 53% were collected using only epigaeic pitfalls, 26.7% using only qualitative sampling (Winkler extractor, and manual sampling), and 20.3% using both methods. The emphasis on the sampling method used in this work is important because there is a great number of studies focusing on the arboreal ants of the Pantanal biome (exclusively arboreal ants: Oliveira *et al.,* 1987; Adis *et al.,* 2001; Batirolla *et al.,* 2005; Ribas & Schoereder, 2007; Soares *et al.,* 2013; Aranda *et al.,* 2016; Yamazaki *et al.,* 2016; and combined methods which includes arboreal ants: Cuissi *et al.,* 2015; Demétrio *et al.,* 2017; Dambros *et al.,* 2018). It could be explained by the fact that vertical migrations are considered the main survival strategy for arthropods that inhabit floodplains (Adis *et al.,* 2001). However, Adis & Junk (2002) listed other two strategies for floodplain organisms: temporary flight to the uplands, and horizontal migration following the higher waterline. Only the latter is applicable to ants, at least in a major part of the year.

Studies on the ground-dwelling ants of the Pantanal are important because this fauna has been partially neglected in favor of arboreal ants. When studying the ground-dwelling fauna, it is important to outline the association between the sampling method and the ground-dwelling community. For example, a previous study found 205 species in four distinct subregions of the Pantanal Biome (Miranda, Abobral, Nabileque, and Tuiuiu) using at least seven sampling methods (Demétrio *et al.,* 2017), while the total species number in studies, in subregions other than Nhecolândia, that sampled only the vegetation or the canopy varies from 20 to 75, approximately (*see* Oliveira *et al.,* 1987; Batirolla *et al.,* 2005; Ribas & Schoereder, 2007; Pereira *et al.,* 2013; Soares *et al.,* 2013; Yamazaki *et al.,* 2016). A few more species of ants were found by Dambros *et al.* (2018), who used fogging to obtain arboreal species and recorded 105 ant species in the Poconé subregion.

Beyond the differences between the species richness present in canopy and soil, sampling ground-dwelling ants allow us to access a completely distinct ant community (Yanoviak & Kaspari, 2000). When we compare the species listed in most of the studies carried out in the region and the species sampled here, the differences between the compositions are evident. Once the arboreal species are mainly represented by the genera *Crematogaster* Lundi, 1831, *Cephalotes* Latreille, 1802, *Pseudomyrmex* Lundi, 1831, and *Camponotus* Mayr, 1861 (Ribas & Schoereder, 2007; Yamazaki *et al.,* 2016; Dambros *et al.,* 2018), our samplings registered a higher diversity of other, ground-related, genera as *Pheidole, Solenopsis,* and fungus-farming ants.

The richness recorded in the present study, considering just the species sampled in pitfalls, is consistent with the results of another work carried out in capões, also in the Nhecolândia subregion, which registered 71 species sampled with epigaeic pitfall traps (Corrêa *et al.,* 2006). However, the species richness here is highest than that found by Uehara-Prado (2005) in distinct pasture areas (12 morphospecies), as expected for such ecologically simplified environment. The richness of ground-dwelling ants found in these inventories, indicate the importance of sampling this community to understand the ant diversity of the Pantanal as a whole. Beyond the epigaeic species, investigated in the present research, we also need to improve our knowledge about the hypogaeic species. The only study that investigated the subterranean strata in the Brazilian Pantanal found eight morphospecies (Lange *et al.,* 2008). This number may seem low if compared with the ant species on the soil surface, but the subterranean ants correspond to approximately 15% of a total species in an extensively sampled area (Martins *et al.,* 2020).

The eleven species recorded for the first time in the state of Mato Grosso do Sul had already been found in the neighboring states or in Cerrado areas (*see* Camacho & Vasconcelos, 2015; Oliveira *et al.,* 2016; Franco & Feitosa, 2018; Vicente *et al.,* 2018). This can be explained by the fact that, even though the predominant phytophysiognomy of the cordilheira is the cerradão, other phytophysiognomies occur in the area, for example the more typical Cerrado formation. Therefore, species that had been previously registered in localities where the typical Cerrado occurs were also expected to occur in our sampling site. Of the first record of two ant species to Brazil, *C. silvicola* also occurs in Bolivia, and *P. obscurifrons* also occurs in Argentina. The locality of *C. silvicola* in the neighboring country is approximately 460 kilometers from our site. Likewise, our record of *P. obscurifrons* is 1,047 km to the north.

Even though ants seem to be resilient to natural burning regimes in studies carried out in Australian or African savannas (Philpott *et al.,* 2010), this may not be the case of the Pantanal (Vasconcelos *et al.,* 2017). In the Brazilian Cerrado, Maravalhas & Vasconcelos (2014) found considerable differences among ant assemblages sampled in areas with distinct fire frequencies, indicating considerable variation in species composition. Since the phytophysiognomy of the Pantanal is similar to the Cerrado, ants from the Pantanal may have a similar behavior to the ants in the *cerradão.* Future studies are necessary to test this hypothesis, since the entire Pantanal has lost around 30% of its natural coverage in 2020 (INPE, 2020a) due to arson. Also, flooded forests can be the most impacted by wildfires, in tropical Brazilian savannas, with significative losses on the seed banks and biomass (Flores *et al.,* 2020). Besides fires, the ants (and other terrestrial invertebrates) live under the pressure of environmental modifications caused by livestock. About 93% of the Brazilian Pantanal corresponds to private areas (Tomas *et al.,* 2019). These facts are extremely worrying, because the main regional activity there is livestock, especially in the Nhecolândia subregion (Rodela & Queiroz-Neto, 2007).

Divieso *et al.* (2020) have called attention to the importance of sampling ants in ecoregions that are conservation priority areas on a more refined scale. Even though they did not outline the Pantanal subregions as ecoregions, the Pantanal subregions can be characterized as ecoregions according to the characteristics of their soil composition (Silva & Abdon, 1998), phytophysiognomies (Mioto *et al.,* 2012), and hydrological regime and climate (Rodela & Queiroz-Neto, 2007). The large number of ant species assembled here for a unique subregion of the Pantanal, and the fact that 84 morphospecies of this study have no scientific name and are potential new species, highlight the importance of conducting more researches in Pantanal. Our study contributes to the inventory of species present in the Nhecolândia, Pantanal, and is an important ant sampling resource for the future choices for sampling areas, and future conservation plans in this biome.

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## AUTHORS' CONTRIBUTIONS

MFOM and MAN elaborated the project, wrote the manuscript, participated in the sampling expeditions, and identified the ant species. RMF, MRP, and WRF helped with the project elaboration, support the discussions, and corrected the manuscript. Also, RMF identified the species, and WRF participated in the sampling expeditions.

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