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Original Article

Ant diversity (Hymenoptera: Formicidae) in Turvo State Park, municipality of Derrubadas, state of Rio Grande do Sul, Brazil

Diversidade de formigas (Hymenoptera: Formicidae) no Parque Estadual do Turvo, Derrubadas, Rio Grande do Sul, Brasil

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Abstract

The knowledge of ant assemblages that occurs in Conservation Units in the Atlantic Forest domain is a priority, considering the number of endemic species and the impacts that this biome has been suffering. The aim of this study was to evaluate ant assemblages in the Turvo State Park, which is the largest conservation unit in the State of Rio Grande do Sul and presents an important role on biodiversity protection. Two samplings were conducted in 2019, one in the summer (January) and the other in the spring (November and December), at five sites 2 km apart, with pitfall traps (soil and canopy), sardine baits, glucose, beating net, sweeping net and manual collection. We sampled 121 species in the summer and 120 in the spring, totaling 163 ant species. A total of 78 species (47.8%) occurred in both sampling seasons. The richest genera in the study were *Camponotus* (S = 30), *Pheidole* (S = 23) and *Linepithema* (S = 11). Seventeen species were recorded for the first time for Rio Grande do Sul state. The results indicate that this is one of the most species-rich assemblages of ants ever surveyed in a conservation unit in southern Brazil. The study highlights the importance of Conservation Units as protected environments against habitat loss for ant biodiversity. The results of this study contribute to myrmecofauna knowledge and serve as a basis for environmental impact studies, management plans and conservation of Atlantic Forest remnants.

Keywords: bioindicators, Atlantic Forest, myrmecofauna, conservation units.

Resumo

O conhecimento das assembleias de formigas que ocorrem em Unidades de Conservação no domínio Mata Atlântica é prioritário, considerando-se o número de espécies endêmicas e os impactos que este bioma vem sofrendo. O objetivo desse trabalho foi caracterizar a assembleia de formigas que ocorre no Parque Estadual do Turvo, a maior unidade de conservação do Rio Grande do Sul que se destaca pelo seu papel na proteção da biodiversidade da Mata Atlântica austral. Foram realizadas duas amostragens no ano de 2019, uma no verão (janeiro) e a outra na primavera (novembro e dezembro), em cinco pontos distantes 2 km entre si, com armadilhas *pitfall* (solo e dossel), iscas de sardinha, iscas de glicose, guarda-chuva entomológico, rede de varredura e coleta manual. A riqueza amostrada no verão foi de 121 e na primavera de 120, totalizando 163 espécies. Ao todo, 78 espécies (47,8%) ocorreram concomitantemente nas duas amostragens. Os gêneros mais ricos foram *Camponotus* (S=30), *Pheidole* (S=23) e *Linepithema* (S=11). Dezessete espécies foram registradas pela primeira vez para o estado do Rio Grande do Sul. Os resultados se constituem em uma das mais ricas assembleias de formigas já inventariadas em uma unidade de conservação na região sul do Brasil. O estudo destaca a importância das Unidades de Conservação como ambientes protegidos contra a perda de habitat para a biodiversidade de formigas. Os resultados deste estudo contribuem para o conhecimento da mirmecofauna e servem como base para estudos de impacto ambiental, planos de manejo e conservação de remanescentes da Mata Atlântica.

Palavras-chave: bioindicadores, Mata Atlântica, mirmecofauna, unidades de conservação.

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1. Introduction

The Brazilian biodiversity is one of the biggest in the world, given the presence of biomes such as the Atlantic Forest which concentrates high biodiversity and endemism. Land-use changes is one of the main threats to biological diversity conservation and results in habitat loss (Goulart and Callisto, 2003). The natural environments conversion into agro-ecosystems or urban areas results in fragmentation and loss of habitats and biodiversity. Whether by limiting gene flow or loss of habitats, biodiversity, especially endemic species of animals and plants are threatened (Kulevicz et al., 2020). The knowledge of the remaining biodiversity in Biome Conservation Units such as in the fragmented Atlantic Forest becomes crucial for the creation and implementation of management and conservation plans.

The multiple ecological roles of ants indicate their importance as predators, seed dispersers, fungus cultivators, pollinators (in some cases) or promoting or inhibiting herbivory (Hölldobler and Wilson, 1990). The presence of ants provides interspecific interactions and indicates biodiversity (Silvestre et al., 2003). Thus, the knowledge of the ant fauna becomes important for the conservation of the environments where they live, providing subsidies for management and conservation plans.

Knowing the ant fauna is essential for the development of management and conservation plans, serving as a comparison for other ant assemblages sampled in environmental disturbances conditions as well as for understanding the role of this Conservation Unit in maintaining biodiversity. Ants' activities are regulated by environmental factors such as temperature (Hölldobler and Wilson, 1990), so samples taken in seasons with higher temperatures such as summer and spring can contribute to a more complete richness and abundance inventory of these insects.

The ant assemblage can be affected by environmental changes and, thus, indicate the degree of degradation or the stage of restoration of an environment, increasing or decreasing in terms of richness, abundance and composition (Lutinski et al., 2016). Ants are recognized for their bioindicator potential and wide distribution in terrestrial ecosystems. Ants can indicate the conservation status of an environment (Bharti et al., 2016). These insects present large geographical distribution, ecological specializations (Hölldobler and Wilson, 1990), richness and relatively well-established taxonomy (Bolton, 2020). The inclusion of ants in environmental impact studies (EIA) and environmental impact reports (RIMA) has already occurred in Brazilian states, such as Paraná (Lutinski et al., 2016). Ants have also been used to describe the structural complexity of ecosystems, environmental disturbances (Bharti et al., 2016) and changes in habitat structure, microclimate and availability of resources (Philpott et al., 2010).

One way to assess the environmental impact is to monitor the species richness, abundance and composition that inhabit therein (Ilha et al., 2017). Ants are widely distributed and abundant in terrestrial ecosystems (Hölldobler and Wilson, 1990). Although scientific knowledge about the ant fauna in southern Brazil is well known (Ulysséa et al., 2011; Diehl et al., 2014; Dröse et al., 2017; Lutinski et al., 2017; Dröse et al., 2019), there are still unsampled areas. In the northwest region of Rio Grande do Sul, ants have already been sampled in rural and forested environments (Cantarelli et al., 2015; Rizzotto et al., 2019) as well as in urban environments (Roani et al., 2019). The Turvo State Park is one of the largest Conservation Units in the southern region of Brazil and the ant fauna that occurs in this environment remains unknown.

The aim of this study was to describe ant assemblages occurring in the deciduous seasonal forest of Turvo State Park, Rio Grande do Sul, Brazil, through different sampling methods in two sampling seasons.

2. Material and Methods

2.1. Study area

The research was conducted with authorization of the Secretariat of Environment and Infrastructure of the State of Rio Grande do Sul under number 619/2019 and SISBIO license 50736-1. The study was carried out at Turvo State Park (27° 8' 44" S; 53° 53' 10" W), located in the municipality of Derrubadas, State of Rio Grande do Sul, Brazil. This Park covers a total area of 174.9 km^2. Its western and southern surroundings are occupied by agricultural practices, while, to the east and north, it´s limited by Missiones (Argentina) province and Santa Catarina state, bordered by the Uruguay River (Porto Alegre, 2005).

Initially created as a State Forest Reserve in 1947, it became a State Park in 1954. Its area includes the largest fragment of deciduous seasonal forest in the State, and the Yucumã Fall, in the Uruguay River, with 1,800 meters long (Cassenote et al., 2019). The average annual temperature in the municipality is located is 19.1 °C and the average rainfall is 1,800 mm per year (Alvares et al., 2013). Turvo State Park is a remnant of subtropical forest in the northwest region of the State of Rio Grande do Sul (Cassenote et al., 2019).

2.2. Sampling

We sampled ants in 2019, in two seasons' events, one in January (summer) and another in November (spring), with the same sampling effort. There was a small spatial variation from one sample to another, in the installation of traps and baits, within each point, although the same trails were used.

We used pitfall traps on the soil and canopy, sardine baits, glucose baits, beating net, sweeping net and manual collection. We selected five sites for sampling: Site 1 was the the edge (entrance to the Park) and was located approximately 500 meters from the administrative headquarters. Sites 2 and 3 were defined in the central region of the park, while sites 4 and 5 were set closer to the boundary with the Uruguay River, in which site 4 was placed in the riparian forest strip (Figure 1).

At each of five sites (transects perpendicular to the road that crosses the Park), 20 pitfalls (10 soil and 10 canopy) and 20 baits (10 sardine and 10 glucose) were installed. Pitfalls and baits were distributed evenly, 20 meters apart.

Figure 1. Distribution of sampled sites for the ant assemblages in the Turvo State Park, Rio Grande do Sul, Brazil, 2019. Source: Google Earth (2020).

Each pitfall consisted of a plastic cup with a capacity of 500 mL (10 cm in diameter and 12 cm in height), buried at ground level. In each trap it was added 150 mL of water with a drop of detergent to break the surface tension of the water. The canopy traps (pitfall) consisted of plastic cups with a capacity of 500 mL (10 cm in diameter and 12 cm in height), a drop of detergent and 1 g sardines, which were tied in trees with a diameter at breast height (DBH) of at least 30 cm. The sardine (~1 g) and glucose (~1 mL) baits were placed on 20 × 30 cm paper rectangles on the ground. Pitfalls remained in the environment for 72 hours and bait for one hour (Fernández, 2003; Baccaro et al., 2015).

The beating net consists of a rectangle of 1m^2, supported by a X-shaped wooden batten, tied at the four corners. At each site, the beating net was used under 10 unidentified bushes, chosen at random, which were shaken ten times each. The sweeping net was used over the vegetation present in trails and clearings, with an effort of 30 minutes at each site. The manual sample was conducted using tweezers and vials containing alcohol (70%), where the sampled specimens were stored. Altogether, a one-hour manual sampling effort was employed at each site and this sample was carried out on tree trunks (up to 1.5 meters in height), soil and stones.

The sampled specimens were placed in vials containing 70% alcohol and transported to the Entomology Laboratory of the Universidade Comunitária da Região de Chapecó (Unochapecó) for sorting and identification. The genera identification was performed using the keys proposed by Fernández (2003) and Baccaro et al. (2015). The classification was based on Bolton (2020). Ants were identified using the literature by Gonçalves (1961), Lattke (1995), Fernandez (2003), Longino (2003) and Wild (2007).

2.3. Data analysis

The richness was defined as the number of ant species occurring in each sample. Abundance was defined based on the relative frequency (number of occurrences of a given species in each trap or bait) and not based on the number of individuals (Romero and Jaffe, 1989). To compare the assemblages of ants sampled in the two seasons, it was used a rarefaction analysis based on the species occurrences in each sampling unit.

Estimates of richness were obtained using Chao 1 estimator. Principal Component Analysis (PCA) was used to evaluate the association of species with the methods and the seasons (summer and spring). Altogether, 109 species were excluded from the PCA analysis because they had less than five records in the samples. The PCA analysis is biased by the inclusion of species with low abundance (Stolar and Nielsen, 2015). These analyses were performed in the statistical software Past (Hammer et al., 2001).

3. Results

We identified 163 species of ants, belonging to 37 genera and eight subfamilies. The subfamilies with the highest richness were Myrmicinae (S = 71), followed by Formicinae (S = 42), Ponerinae (S = 16) and Dolichoderinae (S = 14). The richest genera were *Camponotus* (S = 30), *Pheidole* (S = 23) and *Linepithema* (S = 1). A total of 17 species are new records for the state of Rio Grande do Sul and four species are exotic (Table 1).

A total of 78 species occurred in both sampling seasons, 43 exclusively in summer and 42 exclusively in spring. In summer, there were 541 occurrences, 121 species and the most abundant being *Pheidole lignicola* Mayr, 1887 (n=53),

Table 1. Ant species richness and abundance (occurrences) in two seasons (summer and spring) at Turvo State Park, State of Rio Grande do Sul, Brazil, 2019.

Taxa	Summer		Spring		Sampling method
	n	%	n	%	
Subfamly Dolichoderinae					
Dorymyrmex brunneus Forel, 1908	2	0.37			Sb; Gb
Dorymyrmex pyramicus (Roger, 1863)			1	0.14	Sb
Linepithema angulatum (Emery, 1894)	1	0.18	2	0.28	Sb; Bn
Linepithema gallardoi (Brèthes, 1914)	1	0.18	2	0.28	Ps; Mc
Linepithema humile (Mayr, 1868)	2	0.37	18	2.55	Ps; Pc; Sb; Gb; Bn; Sn; Mc
Linepithema iniquum (Mayr, 1870)	1	0.18	3	0.42	Pc; Mc
Linepithema micans (Forel, 1908)	1	0.18	2	0.28	Pc; Sb; Mc
Linepithema sp. 1	1	0.18	10	1.41	Ps; Sb; Gb
Linepithema sp. 2	1	0.18	3	0.42	Pc; Sb
Linepithema sp. 3	1	0.18	1	0.14	Sb; Sn
Linepithema sp. 4			2	0.28	Os
Linepithema sp. 5			3	0.42	Sb; Gb
Linepithema sp. 6			2	0.28	Pc
Tapinoma melanocephalum (Fabricius, 1793) #	1	0.18			Ps
Subfamily Dorylinae					
Labidus coecus (Latreille, 1802)	2	0.37	2	0.28	Os
Labidus praedator (F. Smith, 1858)	12	2.22	6	0.85	Ps; Sb; Bn; Sn
Neivamyrmex punctaticeps (Emery, 1894)	1	0.18			Mc
Neocerapachys splendens Borgmeier, 1957	1	0.18			Ps
Nomamyrmex hartigii (Westwood, 1842) *			1	0.14	Pc
Subfamily Ectatomminae					
Gnamptogenys striatula Mayr, 1884	22	4.07	14	1.98	Ps; Sb; Gb
Gnamptogenys striolata (Borgmeier, 1957) *	1	0.18			Sb
Gnamptogenys sp. 1	2	0.37			Ps; Gb
Gnamptogenys sp. 2	1	0.18	2	0.28	Ps
Ectatomma edentatum Roger, 1863	1	0.18			Os
Subfamily Formicinae					
Tribe Camponotini					
Camponotus atriceps (Smith, 1858)	4	0.74	21	2.97	Ps; Pc; Sb; Bn; Sn; Mc
Camponotus blandus (Smith, 1858)	1	0.18			Bn
Camponotus cameranoi Emery, 1894	2	0.37	3	0.42	Ps; Bn; Sn; Mc
Camponotus cingulatus Mayr, 1862	3	0.55	4	0.57	Ps; Pc; Bn
Camponotus crassus Mayr, 1862	8	1.48	3	0.42	Pc; Sb; Gb; Bn; Sn; Mc
Camponotus fastigatus Roger, 1863	1	0.18			Os
Camponotus lespesii Forel, 1886 *	4	0.74	22	3.11	Ps; Pc; Gb; Bn; Sn; Mc
Camponotus melanoticus Emery, 1894	1	0.18	1	0.14	Pc; Bn
Camponotus mus Roger, 1863	5	0.92	3	0.42	Pc; Sb; Bn; Mc
Camponotus novogranadensis Mayr, 1870	1	0.18	1	0.14	Bn
Camponotus punctulatus Mayr, 1868			4	0.57	Pc; Mc
Camponotus rufipes (Fabricius, 1775)	8	1.48	45	6.36	Ps; Pc; Sb; Gb; Bn; Sn; Mc

n: abundance; Bn: Beating net; Gb: Glucose bait; Mc: Manual collection; Pc: Pitfall (canopy); Ps: Pitfall (ground); Sb: Sardine bait; Sn: Sweeping net. *New record to Rio Grande do Sul state, Brazil; #Exotic specie.

Table 1. Continued...

Taxa	Summer		Spring		Sampling method
	n	%	n	%	
Camponotus sericeiventris (Guérin-Méneville, 1848)	1	0.18	3	0.42	Ps; Pc; Mc
Camponotus sexguttatus (Fabricius, 1793)	1	0.18	1	0.14	Ps; Mc
Camponotus sp. 1	2	0.37	3	0.42	Ps; Pc; Mc
Camponotus sp. 2	1	0.18	1	0.14	Bn; Sn
Camponotus sp. 3	1	0.18	1	0.14	Pc; Bn
Camponotus sp. 4	1	0.18			Ps
Camponotus sp. 5			5	0.71	Ps; Pc
Camponotus sp. 6			6	0.85	Pc
Camponotus sp. 7			1	0.14	Pc
Camponotus sp. 8			1	0.14	Bn
Camponotus sp. 9			3	0.42	Pc
Camponotus sp. 10			2	0.28	Bn; Mc
Camponotus sp. 11			3	0.42	Sb; Mc
Camponotus sp. 12			1	0.14	Pc
Camponotus sp. 13			4	0.57	Ps; Pc
Camponotus sp. 14			4	0.57	Bn; Sn
Camponotus sp. 15			1	0.14	Mc
Camponotus sp. 16			1	0.14	Pc
Tribe Myrmelachistini					
Brachymyrmex coactus Mayr, 1887	1	0.18	3	0.42	Ps; Sb; Gb
Brachymyrmex cordemoyi Forel, 1895	3	0.55	1	0.14	Sb; Sn; Mc
Brachymyrmex pilipes Mayr, 1887 *	4	0.74	3	0.42	Pc; Sb; Gb; Bn; Mc
Brachymyrmex sp. 1	3	0.55			Sn; Mc
Brachymyrmex sp. 2	1	0.18			Mc
Myrmelachista catharinae Mayr, 1887			2	0.28	Pc
Myrmelachista kloetersi Forel, 1903 *	3	0.55	3	0.42	Ps; Pc; Sn; Mc
Myrmelachista nodigera Mayr, 1887 *			4	0.57	Ps; Pc
Myrmelachista sp.			1	0.14	Ps
Tribe Lasiini					
Nylanderia fulva (Mayr, 1862)	3	0.55	9	1.27	Ps; Sb; Gb; Bn; Mc
Nylanderia sp. 1	3	0.55	3	0.42	Ps; Sb; Gb
Paratrechina longicornis (Latreille, 1802) #	1	0.18	1	0.14	Ps; Gb
Subfamily Heteroponerinae	0				
Heteroponera dolo (Roger, 1860)	1	0.18			Ps
Heteroponera flava Kempf, 1962	3	0.55	1	0.14	Ps; Sb; Gb
Heteroponera inermis (Emery, 1894)	2	0.37			Ps
Heteroponera microps Borgmeier, 1957 *	1	0.18			Sb
Subfamily Myrmicinae					
Tribe Attini					
Acromyrmex ambiguus (Emery, 1888)	3	0.55	11	1.56	Ps; Gb; Sn; Mc
Acromyrmex aspersus (F. Smith, 1858)	3	0.55	3	0.42	Sb; Gb; Sn; Mc

n: abundance; Bn: Beating net; Gb: Glucose bait; Mc: Manual collection; Pc: Pitfall (canopy); Ps: Pitfall (ground); Sb: Sardine bait; Sn: Sweeping net. *New record to Rio Grande do Sul state, Brazil; #Exotic specie.

Table 1. Continued...

Taxa	Summer		Spring		Sampling method
	n	%	n	%	
Acromyrmex disciger (Mayr, 1887)	1	0.18	2	0.28	Gb; Mc
Acromyrmex lundii (Guérin-Méneville, 1848)			4	0.57	Ps; Gb; Mc
Acromyrmex niger (F. Smith, 1858)	2	0.37	1	0.14	Gb; Mc
Acromyrmex subterraneus (Forel, 1893)	4	0.74	7	0.99	Ps; Pc; Gb; Bn; Sn; Mc
Acromyrmex sp. 1	2	0.37			Ps
Acromyrmex sp. 2	1	0.18			Ps
Acromyrmex sp. 3			1	0.14	Mc
Apterostigma mayri Forel, 1893 *	3	0.55			Ps
Apterostigma pilosum Mayr, 1865	2	0.37	1	0.14	Ps
Apterostigma wasmannii Forel, 1891	2	0.37			Ps
Apterostigma sp.	7	1.29			Sb; Gb
Atta sexdens (Linnaeus, 1758)	1	0.18	3	0.42	Ps; Mc
Basiceros convexiceps (Mayr, 1887) *	0	0.00	1	0.14	Bn
Cephalotes angustus (Mayr, 1862)	2	0.37			Bn; Mc
Cephalotes pusillus (Klug, 1824)	2	0.37			Bn; Mc
Cyphomyrmex rimosus (Spinola, 1851)			1	0.14	Ps
Mycetophylax plaumanni (Kempf, 1962)	1	0.18	1	0.14	Ps
Mycetophylax strigatus (Mayr, 1887)	1	0.18			Ps
Mycocepurus goeldii (Forel, 1893)	1	0.18			Ps
Mycocepurus sp.	1	0.18			Ps
Octostruma rugifera (Mayr, 1887)	2	0.37			Ps
Octostruma sp.	1	0.18			Ps
Pheidole aberrans Mayr, 1868	10	1.85	18	2.55	Ps; Pc; Sb; Gb
Pheidole brevicona (Mayr, 1887) *	2	0.37	7	0.99	Ps; Sb; Gb
Pheidole dyctiota Kempf, 1972	6	1.11	25	3.54	Ps; Pc; Sb; Gb; Mc
Pheidole laevifrons Mayr, 1887	9	1.66	4	0.57	Ps; Sb;Gb
Pheidole lignicola Mayr, 1887	53	9.80	68	9.62	Ps; Pc; Sb; Gb; Bn
Pheidole pubiventris Mayr, 1887	9	1.66	8	1.13	Ps; Pc; Sb; Gb; Bn
Pheidole punctatissima Mayr, 1870 *#	5	0.92	8	1.13	Sb; Gb; Bn; Mc
Pheidole risii Forel, 1892	26	4.81	19	2.69	Ps; Pc; Sb; Gb; Bn; Sn; Mc
Pheidole sp. 1	5	0.92	16	2.26	Ps; Pc; Sb; Gb; Sn
Pheidole sp. 2	4	0.74	3	0.42	Ps; Sb; Gb
Pheidole sp. 3	4	0.74	4	0.57	Ps; Gb
Pheidole sp. 4	4	0.74	4	0.57	Ps; Sb; Gb; Mc
Pheidole sp. 5	4	0.74			Ps; Mc
Pheidole sp. 6	4	0.74	2	0.28	Ps; Pc; Sb; Gb
Pheidole sp. 7	4	0.74	4	0.57	Ps; Sb; Gb
Pheidole sp. 8	2	0.37	1	0.14	Gb
Pheidole sp. 9	1	0.18	3	0.42	Sb; Gb
Pheidole sp. 10			6	0.85	Ps; Pc; Sb
Pheidole sp. 11			1	0.14	Ps

n: abundance; Bn: Beating net; Gb: Glucose bait; Mc: Manual collection; Pc: Pitfall (canopy); Ps: Pitfall (ground); Sb: Sardine bait; Sn: Sweeping net. *New record to Rio Grande do Sul state, Brazil; #Exotic specie.

Table 1. Continued...

Taxa	Summer		Spring		Sampling method
	n	%	n	%	
Pheidole sp. 12			2	0.28	Sn; Mc
Pheidole sp. 13			1	0.14	Ps
Pheidole sp. 14			1	0.14	Gb
Pheidole sp. 15			3	0.42	Bn; Sn
Procryptocerus adlerzi (Mayr, 1887) *	3	0.55	1	0.14	Ps; Pc; Sn; Mc
Procryptocerus convergens (Mayr, 1887)	1	0.18			Bn
Strumigenys sp. 1	1	0.18			Ps
Strumigenys sp. 2	1	0.18			Ps
Tribe Crematogastrini					
Crematogaster acuta (Fabricius, 1804)	1	0.18			Ps
Crematogaster bingo Forel, 1908	4	0.74	5	0.71	Ps; Pc; Sb; Bn; Sn; Mc
Crematogaster corticicola (Mayr, 1887)	6	1.11	2	0.28	Ps; Sb; Bn; Sn; Mc
Crematogaster magnifica Santschi, 1926 *	3	0.55	21	2.97	Pc; Gb; Bn; Sn; Mc
Crematogaster sp. 1	7	1.29	1	0.14	Ps; Gb; Bn; Mc
Crematogaster sp. 2	4	0.74			Bn; Mc
Crematogaster sp. 3			2	0.28	Ps; Pc
Crematogaster sp. 4			1	0.14	Bn
Tribe Pogonomyrmecini					
Pogonomyrmex naegelii Forel, 1878	1	0.18			Ps
Patagonomyrmex angustus Mayr, 1870 *			3	0.42	Ps
Tribe Solenopsidini					
Monomorium floricola (Jerdon, 1851) #	2	0.37			Ps; Sn
Solenopsis helena Emery, 1895	3	0.55			Ps; Sb
Solenopsis invicta Buren, 1972	2	0.37			Gb; Mc
Solenopsis saevissima (F. Smith, 1855)	2	0.37			Sn; Mc
Solenopsis stricta Emery, 1896	4	0.74	5	0.71	Pc; Sb; Gb
Solenopsis sp. 1	4	0.74	5	0.71	Ps; Pc; Gb; Bn; Sn; Mc
Solenopsis sp. 2	7	1.29			Sb; Gb
Solenopsis sp. 3			18	2.55	Ps; Pc
Solenopsis sp. 4			13	1.84	Ps; Pc; Sb; Gb
Solenopsis sp. 5			2	0.28	Sb
Subfamily Ponerinae					
Tribe Ponerini					
Dinoponera australis Emery, 1901	45	8.32	47	6.65	Ps; Pc Sb; Gb; Bn; Mc
Hypoponera distinguenda (Emery, 1890) *	7	1.29	1	0.14	Ps
Hypoponera opaciceps (Mayr, 1887)			1	0.14	Mc
Hypoponera trigona (Mayr, 1887)	2	0.37			Ps
Hypoponera sp. 1	2	0.37	1	0.14	Ps; Bn
Hypoponera sp. 2			1	0.14	Ps
Odontomachus chelifer (Latreille, 1802)	19	3.51	19	2.69	Ps; Pc; Sb; Gb; Bn; Mc
Odontomachus affinis G.-Méneville, 1844 *	6	1.11	1	0.14	Ps; Pc; Bn; Mc

n: abundance; Bn: Beating net; Gb: Glucose bait; Mc: Manual collection; Pc: Pitfall (canopy); Ps: Pitfall (ground); Sb: Sardine bait; Sn: Sweeping net. *New record to Rio Grande do Sul state, Brazil; #Exotic specie.

Table 1. Continued...

Taxa	Summer		Spring		Sampling method
	n	%	n	%	
Neoponera crenata (Roger, 1858)	8	1.48	5	0.71	Ps; Pc; Bn; Mc
Neoponera villosa (Fabricius, 1804) *	2	0.37	2	0.28	Ps; Sb; Mc
Pachycondyla harpax (Fabricius, 1804)	1	0.18	5	0.71	Ps; Sb; Mc
Pachycondyla striata F. Smith, 1858	50	9.24	30	4.24	Ps; Sb; Gb; Mc
Pachycondyla sp. 1	1	0.18			Ps
Pachycondyla sp. 2	1	0.18	2	0.28	Ps; Pc; Bn
Pachycondyla sp. 3			1	0.14	Bn
Pachycondyla sp. 4			4	0.57	Ps; Bn; Sn; Mc
Subfamily Pseudomyrmecinae					
Tribe Pseudomyrmecini					
Pseudomyrmex gracilis (Fabricius, 1804)	12	2.22	7	0.99	Pc; Bn; Sn; Mc
Pseudomyrmex flavidulus (F. Smith, 1858)	2	0.37	1	0.14	Bn; Mc
Pseudomyrmex phyllophilus (F. Smith, 1858)	1	0.18	1	0.14	Bn
Pseudomyrmex sp. 1	2	0.37			Bn
Pseudomyrmex sp. 2	1	0.18			Bn
Pseudomyrmex sp. 3			2	0.28	Pc; Bn
Richness	**121**		**120**		
Abundance (occurences)	**541**		**707**		

n: abundance; Bn: Beating net; Gb: Glucose bait; Mc: Manual collection; Pc: Pitfall (canopy); Ps: Pitfall (ground); Sb: Sardine bait; Sn: Sweeping net. *New record to Rio Grande do Sul state, Brazil; #Exotic specie.

Pachycondyla striata F. Smith, 1858 (n=50), *Dinoponera australis* Emery, 1901 (n=45), *Pheidole risii* Forel, 1892 (n=22) and *Gnamptogenys striatula* Mayr, 1884 (n=22). In the spring, we register 707 occurrences, 120 species and the most abundant being *Pheidole lignicola* Mayr, 1887 (n=68), *Dinoponera australis* Emery, 1901 (n=47), *Camponotus rufipes* (Fabricius, 1775) (n=45), *Pachycondyla striata* F. Smith, 1858 (n=30) and *Pheidole dyctiota* Kempf, 1972 (n=25) (Table 1).

There was no difference regarding the richness of assemblages sampled in the two seasons, summer and spring (rarefaction: CI <5%). The total observed richness (S = 163) corresponded to 86.01% of the expected richness according to the Chao 1 estimator (189.5).

Regarding the sampling methods, the greatest richness was obtained with the use of soil traps (pitfall) (S = 96), followed by manual collection (S = 60), sardine baits (S = 53), beating net (S = 51) and glucose baits (S = 49). With the exception of the sweeping net in which all species were also sampled by other methods, all methods showed the occurrence of exclusive species, with the highest number in the soil pitfall traps (S = 35). The highest abundance was also observed in soil pitfalls (n = 417), followed by sardine baits (n = 227), canopy pitfalls (n = 181) and glucose baits (n = 176) (Table 2).

Altogether, 64.1% of variation in occurrences recorded in the seasons (summer and spring) was explained by component 1 and 35.9% by component 2 of the PCA. The species *D. australis*, *G. striatula*, *L. praedator*, *O. chelifer*, *P. striata*, *P. lignicola*, *P. pubiventris*, *P. risii* and *P. gracilis* were associated with the sample carried out in the summer. With the spring sample, the species associated were *C. atriceps*, *C. lespesii*, *C. rufipes*, *C. magnifica*, *P. dyctiota* and *Pheidole* sp. 1 (Figure 2).

A total of 61.1% variation of occurrences, according to the methods, was explained by components 1 and 2 of the PCA. There was similarity in the occurrences in the soil pitfall and sardine and glucose baits with *D. australis*, *G. striatula*, *L. praedator, O. chelifer*, *P. striata*, *P. aberrans*, *P. dyctiota*, *P. lignicola*, *P. pubiventris*, *P. risii* and *Pheidole* sp. 1 (Figure 3). The other methods were similar to each other. The ants associated with these methods were *A. subterraneus*, *C. atriceps*, *C. lespesii*, *C. rufipes*, *C. magnifica* and *L. humile*. The other species analyzed in the PCA occurred independently of the sampling methods (Figure 3).

4. Discussion

The composition and richness of ant assemblages sampled in this study reflects the accumulated knowledge about the myrmecofauna occurring in southern Brazil (Ulysséa et al., 2011; Diehl et al., 2014; Dröse et al., 2017). The most species-rich subfamilies in samples from the Turvo State Park, Myrmicinae, Formicinae, Ponerinae and Dolichoderinae, corroborates Lutinski et al. (2018). The richness of the subfamily Mymicinae predominate in ant samples of the States of Santa Catarina, Paraná, and

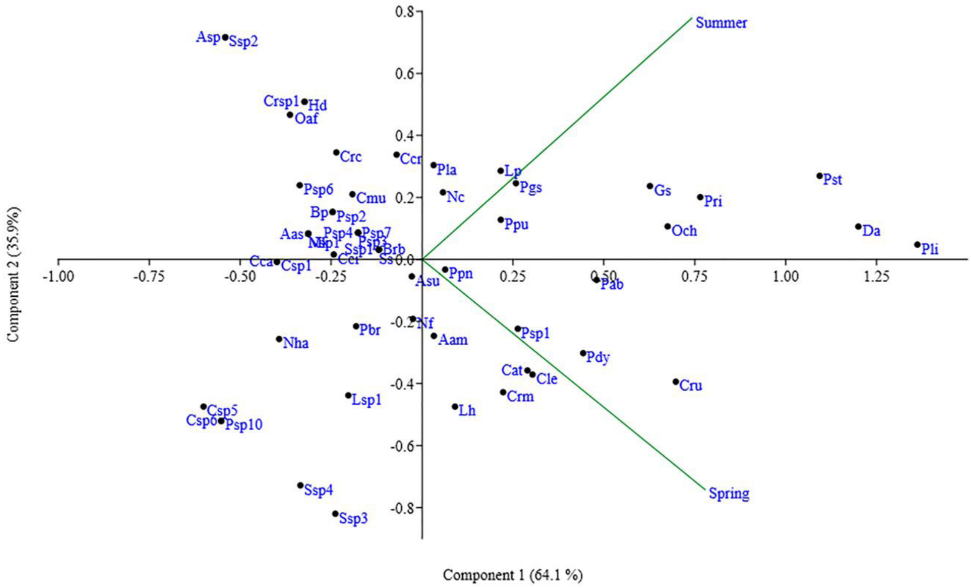

Figure 2. Association by Principal Component Analysis (PCA) of ant species and two samples seasons (summer and spring) in the Turvo State Park, Rio Grande do Sul, Brazil, 2019. Aam: *Acromyrmex ambiguus*; Aas: *Acromyrmex aspersus*; Asp: *Apterostigma* sp.; Asu: *Acromyrmex subterraneus*; Bp: *Brachymyrmex pilipes*; Brb: *Crematogaster bingo*; Cat: *Camponotus atriceps*; Cca: *Camponotus cameranoi*; Cci: *Camponotus cingulatus*; Ccr: *Camponotus crassus*; Cle: *Camponotus lespesii*; Cmu: *Camponotus mus*; Crc: *Crematogaster corticícola*; Crm: *Crematogaster magnifica*; Crsp1: *Crematogaster* sp. 1; Cru: *Camponotus rufipes*; Csp1: *Camponotus* sp. 1; Csp5: *Camponotus* sp. 5; Csp6: *Camponotus* sp. 6; Da: *Dinoponera australis*; Gs: *Gnamptogenys striatula*; Hd: *Hypoponera distinguenda*; Lh: *Linepithema humile*; Lp: *Labidus praedator*; Lsp1: *Linepithema* sp. 1; Mk: *Myrmelachista kloetersi*; Nc: *Neoponera crenata*; Nf: *Nylanderia fulva*; Nha: *Pachycondyla harpax*; Nsp1: *Nylanderia* sp. 1; Oaf: *Odontomachus affinis*; Och: *Odontomachus chelifer*; Pab: *Pheidole aberrans*; Pbr: *Pheidole brevicona*; Pdy: *Pheidole dyctiota*; Pgs: *Pseudomyrmex gracilis*; Pla: *Pheidole laevifrons*; Pli: *Pheidole lignicola*; Ppn: *Pheidole punctatissima*; Ppu: *Pheidole pubiventris*; Pri: *Pheidole risii*; Psp1: *Pheidole* sp. 1; Psp10: *Pheidole* sp. 10; Psp2: *Pheidole* sp. 2; Psp3: *Pheidole* sp. 3; Psp4: *Pheidole* sp. 4; Psp6: *Pheidole* sp. 6; Psp7: *Pheidole* sp. 7; Pst: *Pachycondyla striata*; Ss: *Solenopsis stricta*; Ssp1: *Solenopsis* sp. 1; Ssp2: *Solenopsis* sp. 2; Ssp3: *Solenopsis* sp. 3; Ssp4: *Solenopsis* sp. 4.

Table 2. Richness and abundance for the ant assemblage sampled in two seasons (summer and spring) in Turvo State Park, State of Rio Grande do Sul, Brazil, 2019, according to the methods used.

	Richness (S)	%	Exclusive richness	%	Occurences
Sampling method					
Beating net	51	31.3	13	8.0	103
Glucose bait	49	30.1	2	1.2	176
Manual collection	60	36.8	5	3.1	101
Pitfall (canopy)	52	31.9	8	4.9	181
Pitfall (ground)	96	58.9	35	21.5	417
Sardine bait	53	32.5	5	3.1	227
Sweeping net	29	17.8	0	0.0	43

Rio Grande do Sul (Ulysséa et al., 2011; Diehl et al., 2014; Lutinski et al., 2016; Dröse et al., 2017; Rizzotto et al., 2019). Myrmecine ants perform a variety of ecosystem functions, occupy different niches, colonize different strata from the subsoil, litter to the top of the canopy, and some species establish relationships with fungi, plants and even other ants (Fernández, 2003; Baccaro et al., 2015). The highest richness in samples of the genera *Pheidole* (S=23), *Acromyrmex* (S=9), *Crematogaster* (S=8) and *Solenopsis* (S=8) also corroborates the literature about this subfamily (Ulysséa et al., 2011; Rizzotto et al., 2019). While *Acromyrmex* ants (leafcutters) feed on fungi grown on fresh leaves, *Crematogaster*, *Pheidole* and *Solenopsis* are characterized as generalists (Baccaro et al., 2015).

The subfamily Formicinae is the second most species-rich among Formicidae in the Neotropical region (Martins et al., 2020). This subfamily has abundant genera, easily sampled, most of them have arboreal habits, while others inhabit the

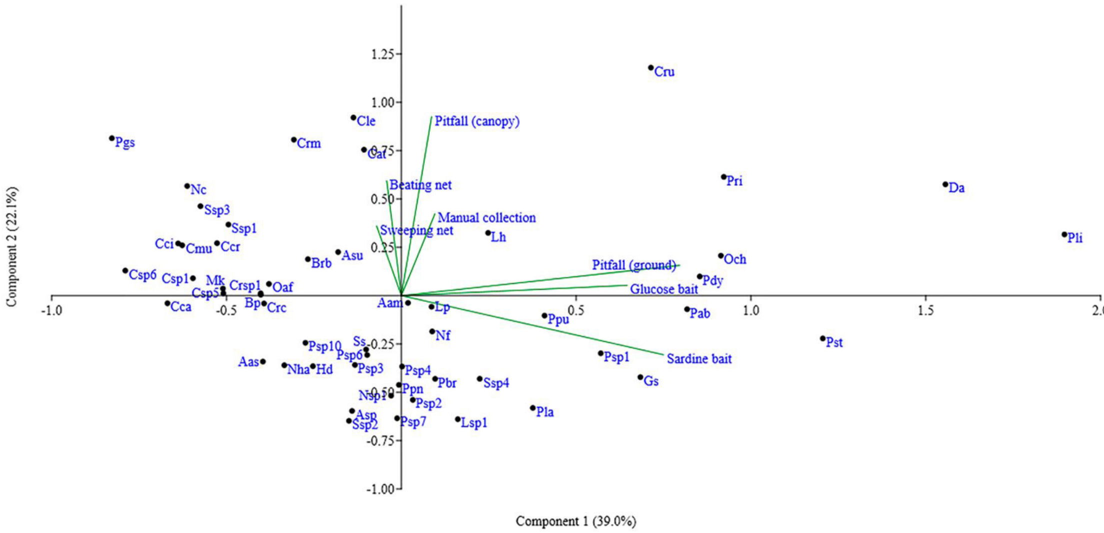

Figure 3. Association by Principal Component Analysis (PCA) of ant species with sampling methods in two seasons (summer and spring) in the Turvo State Park, Rio Grande do Sul, Brazil, 2019. Legend: see Figure 2.

soil or litter (Baccaro et al., 2015). The genus *Camponotus*, richest in the samples (S = 30) is constant in the records of the southern Atlantic Forest (Cantarelli et al., 2015). This genus includes generalist ants, although they can establish close relationships with other insects, such as aphids (Hemiptera, Aphididae) (Silvestre et al., 2003) that can also be found in urban environments (Lutinski et al., 2017). The genera *Brachymyrmex* (S = 5) and *Myrmelachysta* (S = 4) were also important in the samples, ants associated with litter and vegetation, respectively (Silvestre et al., 2003).

The subfamily Ponerinae stands out for its richness and abundance in samples already taken in Conservation Units and forest fragments in southern Brazil (Lutinski et al., 2018). The genera *Pachycondyla* (S = 6) and *Hypoponera* (S = 5) richness is similar to that obtained in other studies performed in the same region (Cantarelli et al., 2015; Rizzotto et al., 2019). Ants of these genera are specialized predators and found in soil and litter, where they prey on small arthropods. Among the Ponerinae ants sampled, it's worth mentioning the abundance of *D. australis*, the record of two species of *Neoponera,* and two species of *Odontomachus*, large ants, conserved environments dependent, where they find their prey (Silvestre et al., 2003).

Dolichoderinae ants are constantly recorded in samples taken in the Atlantic Forest Biome (Franco and Feitosa, 2018). In general, they usually have relationships with some plants, from which they extract sugary liquids from floral nectaries for food, with emphasis in this study on the richness of *Linepithema* (S = 11). Ants of this genus are generalists and support fragmentation and anthropized environments (Lutinski et al., 2017). The subfamily Dorylinae gathers ants known as legionary or army ants (Ulysséa et al., 2011). These ants have an important ecological role as predators of other invertebrates and even small vertebrates, therefore, depending on conserved environments for their maintenance (Baccaro et al., 2015).

The richness was similar in the two sample seasons. However, the composition varied, as observed in the occurrences of exclusive species, increasing the richness in the second sampling (spring) by 34.7% compared to the first sampling (summer). Ant samples in the south of Brazil are influenced by seasonality (Rizzotto et al., 2019) and therefore, samplings in different seasons of the year are recommended, in addition to a diversified sampling protocol to include the different niches in the sampling unit. Estimates such as Chao 1 help in the analysis of sampling fill (Lemes and Köhler, 2017), however, the difference of less than 15% between the sampled and the estimated richness indicates that the sampling effort was adequate. The distribution of ant species in the two samples was homogeneous, although species exclusivity was found in each sampled site. It´s highlighted that the balance in larger forest fragments like the Conservation Units contributes positively to the diversification of ant fauna in these environments.

Silva et al. (2018) sought to identify the soil macrofauna in a forest fragment in Rio Grande do Sul, and recorded a greater number of Formicidae occurences; and in November, there was a greater abundance of these insects compared to other months. Oliveira et al. (2009) also obtained a greater abundance of ants in November, however in restinga formations. The greater abundance in the second sampling (spring), in relation to the first, corroborate the studies mentioned.

The time of exposure in the environment and the stratum that each sampling method allow the collection of different ant guilds (Silvestre et al., 2003). Therefore, each method used has the potential to inform about specific niches occupied by ants and about ecological aspects of them. In this sense, 35.6% (S = 58) of the sampled ant fauna occurred exclusively in the soil and litter (soil pitfall, sardine and glucose baits) and 24.5% (S = 40), exclusively in the vegetation (sweeping net, beating net and canopy pitfall)

(Figure 3). The use of different ant sampling methods, in addition to maximizing the sampled richness (Salata et al., 2020), can provide environmental information about the community structure and the state of environment conservation (Souza and Araujo, 2020).

The relevance of the Turvo State Park for the conservation of the Atlantic Forest's biodiversity is corroborated by the results of this study. The sampled richness is one of the largest ever recorded in a single Conservation Units in southern Brazil. The 163 species sampled in the Park is equal to the richness sampled by Franco and Feitosa (2018) at Guartelá State Park (PEG) in the state of Paraná and greater than the 72 species sampled in vineyards, in the state of Rio Grande do Sul (Rosado et al., 2012). The 17 species recorded for the first time for the state of Rio Grande do Sul represent more than 10% of the ant fauna sampled in the Turvo State Park, indicating that the knowledge about these insects still needs further studies. Despite the ecological and biological aspects of the ant fauna are already known by scientific community, studies on richness, abundance and composition of these insects in a Conservation Units with the characteristics and importance such as that of the Turvo State Park are fundamental, since they reflect the regional biodiversity.

In conclusion, it's evident the importance of the Park as a refuge for the biodiversity of ants and the organisms associated with them. In addition to the scientific knowledge of the occurrence and distribution of species in the Park, the results serve as a basis for environmental impact studies in southern Brazil, as well as management plans and conservation of Atlantic Forest remnants. The sampled richness, the methods used and the seasons (summer and spring) in which the study was carried out may serve as a methodological reference and as a comparison for studies with these insects in the region.

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