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ZOOLOGY

Semideciduous seasonal forest opiliofauna (Arachnida, Opiliones), State of Paraná, Brazil

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ABSTRACT. Harvestmen are arachnids that play an important role in organic matter breakdown. However, there are many ecosystems in Brazil, including Conservation Units, which lack information about these organisms or are sub-sampled. Even in areas of Atlantic forest, a biome that hosts the greatest diversity and endemic rates of these arthropods in the world. In this perspective, the purpose of this study was to survey the harvestmen fauna in areas of Semideciduous Seasonal Forest in the Ilha Grande National Park, Paraná, southern Brazil, from February to November 2019, totaling 15 days and 60 hours, on six islands in the Paraná River. A total of 170 specimens was collected, distributed in five genera, comprising two species and three morphotypes. The low species richness may reflect the isolation of populations imposed by the island effect, however the study expanded the geographic distribution of *Parapachyloides uncinatus* and *Discocyrtus invalidus*, for which until then there was no record of occurrence in the Paraná State.

Keywords: richness; biogeography; Atlantic rainforest; conservation units; harvestmen.

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Introduction

Harvestmen comprise an Order of the Class Arachnida, known in Brazil as bodum, aranha-alho or aranha-bode, due to odorous secretions used as defense mechanisms (Machado, Pinto-da-Rocha, & Giribet, 2007). Opiliones include approximately 6,500 described species, distributed in 50 families and 1,500 genera, divided into four suborders: Cyphophthalmi, Dyspnoi, Eupnoi and Laniatores (Machado et al., 2007). They are harmless animals and, in general, little is known since most species have nocturnal habits and cryptic coloring, which is essential for protection against predators (Bragagnolo & Pinto-da-Rocha, 2003; Machado et al., 2007).

Many species of harvestmen require high levels of humidity to survive, so they are directly influenced by microclimate conditions, which restricts these animals to humid and shaded habitats (Machado et al., 2007; Santos, 2007; Ferreira, Pinheiro, Ázara, Clemente, & Souza, 2020). They can live buried in the soil, under litter, under stones and bark, in moss patches, bromeliads, or even in caves (Machado et al., 2007). They are omnivores and can feed on other invertebrates, plants and decomposing animals, thus facilitating nutrient cycling and playing an important role in organic matter breakdown (Moore, Hunt, & Elliott, 1991; Resende, Pinto-da-Rocha, & Bragagnolo, 2012; Giribet & Sharma, 2015).

They are, therefore, strongly affected by quality and number of habitats, since when compared with other arthropod groups, they are relatively uniform in several relevant biological aspects, such as nocturnal predation and dependence on microclimate conditions (Machado et al., 2007; Ferreira, Pinheiro, & Souza, 2019). As a result, many species have restricted distribution and a high endemism degree, which makes them models for biogeographic and ecological studies (Pinto-da-Rocha, Silva, & Bragagnolo, 2005; DaSilva, Pinto-da-Rocha, & DeSouza, 2015), with particularly high endemism in the Atlantic Forest (Pinto-da-Rocha et al., 2005).

The Atlantic Forest biome stands out for being the forest formation most affected by fragmentation due to logging, agricultural expansion, livestock and forestry (Salemi et al., 2012; Gotardo, Pinheiro, Kaufmann, Piazza, & Torres, 2019). Besides being the predominant biome in the Paraná State, the Atlantic Forest is extremely important because of its high diversity of animal and plant species (Gotardo et al., 2019). The different phytophysiognomies of this biome constitute, for example, the habitat of innumerable harvestmen species, harboring the greatest diversity of these organisms worldwide (Pinto-da-Rocha et al., 2005).

Gonyleptidae is an abundant family of Brazilian harvestmen and it is very important in the Atlantic Forest since there are eight subfamilies restricted to this biome (DaSilva, Pinto-da-Rocha, & DeSouza, 2011).

The Semideciduous Seasonal Forest, one of the Atlantic Forest biome phytophysiognomies, occurs in the West, Northwest and North of the Paraná State. The forest cover of the State corresponded, at the beginning of the last century, to 83.41% of its territory (Souza & Monteiro, 2005). Nowadays, it is estimated that less than 5% original total area of Paraná remains occupied by the seasonal semideciduous forest, whose distribution is completely modified by the advance of areas with secondary vegetation, due to different human activities, with emphasis on intensive agriculture and livestock (Mikich & Silva, 2001). This justifies carrying out survey and distribution studies of little-known species, such as harvestmen, in tropical forests (Mathieu et al., 2005).

The opiliofauna of this biome, together with those of the other Brazilian biomes, add up to about 1,008 species (Kury, 2002). However, despite this diversity in the country, many ecosystems, Conservation Units and even states are sub-sampled (Ferreira et al., 2020). For example, there are few records on the biodiversity of harvestmen for the Paraná State (Pinto-da-Rocha, 1993; Kury, 2003; Mestre & Pinto-da-Rocha, 2004; Acosta, Kury, & Juárez, 2007). Therefore, the goal of this study was to survey the diversity of Opiliones (Arachnida) at the Ilha Grande National Park, Paraná State, and to expand the information about this taxon for the state.

Material and methods

This study, authorized by the *Instituto Chico Mendes de Conservação da Biodiversidade* under license Sisbio 65047-1, was conducted in the Ilha Grande National Park, an integral protection Conservation Unit created in 1997, and located on the Paraná River, between Paraná and Mato Grosso do Sul States, close to Paraguay border.

The park consists of approximately 180 islands, in addition to sandbanks, natural lagoons and freshwater swamps, totalizing 76,033 hectares (*Ministério do Meio Ambiente* [MMA] & *Instituto Chico Mendes de Conservação da Biodiversidade* [ICMBio], 2008). In addition, it protects two types of environment belonging to the Atlantic Forest Biome: Semideciduous Seasonal Forest (on the margins of the larger islands and inside the smaller islands on higher grounds and less subjected to flooding) and pioneer formations with fluvial-lacustrine influence (vegetation formed by grasses and shrubs that occupy continually flooded areas of islands and adjacent plains).

Collections were carried out on six islands (Figure 1), selected by transport logistics. However, richness, frequency and abundance were not assessed per island, but by the total area sampled. The sampled area represents around 0.11% Conservation Unit area, calculated by the Google Earth Pro software®, through which polygons were created around the sampled islands, following as reference the images from 2020 Maxar Technologies, available in the software for that region.

According to Leli, Stevaux, and Assine (2020), the upper Paraná River presents two different groups of island formation: central bar islands (formed by sediments deposited at higher points of the channel bed) and islands by floodplain excision (formed by the intersection of a channel along the island connecting two points of the main channel, due to flow and flooding processes). Thus, among the environments studied, islands 1 and 2 (unnamed) are central bar islands, with pioneer vegetation formations of grasses and shrubs. The Grande, Izabel, Rodrigues and Saraiva islands are formed by floodplain excision, with plant formations in ecological succession processes.

However, it is important to highlight that during the 70s and 90s, these islands underwent different types of occupations. This resulted in degradation of most forest formations, giving way to pastures and agricultural production. In 1997, from conservationist movements in the region, the Ilha Grande National Park was created, which resulted in the vacancy of the islands and the regeneration of degraded areas from the 2000s (Motta, 2001). Thus, it is essential to consider that the sampled islands are in the process of recovery.

The sampling effort comprised three collection campaigns, lasting five days each and fieldwork of six people, in the periods: February 6, 2019 to February 10, 2019 (Summer); April 27, 2019 to May 1, 2019 (Fall); and November 15, 2019 to November 19, 2019 (Spring); totaling about 15 days and 60 hours. Sampling was not carried out in the Winter because of a large forest fire in the park during this season.

Harvestmen specimens were sampled through active search, captured manually with the help of tweezers, and then sacrificed in 70% alcohol. The search took place in hollow trunks, under fallen branches, in abandoned human constructions, or in search of those who were foraging on tree trunks and in the forest litter. Collections were performed at night between 6 and 9 pm, the time of greatest foraging activity for these arachnids (Bragagnolo & Pinto-da-Rocha, 2003). The collected specimens were sent for identification and screening in the zoology laboratory of the IFSULDEMINAS and they were deposited in the Arachnids and Myriapods collection of the Arachnology Laboratory of the *Museu Nacional do Rio de Janeiro* (UFRJ), under the care of PhD. Ludson Àzara.

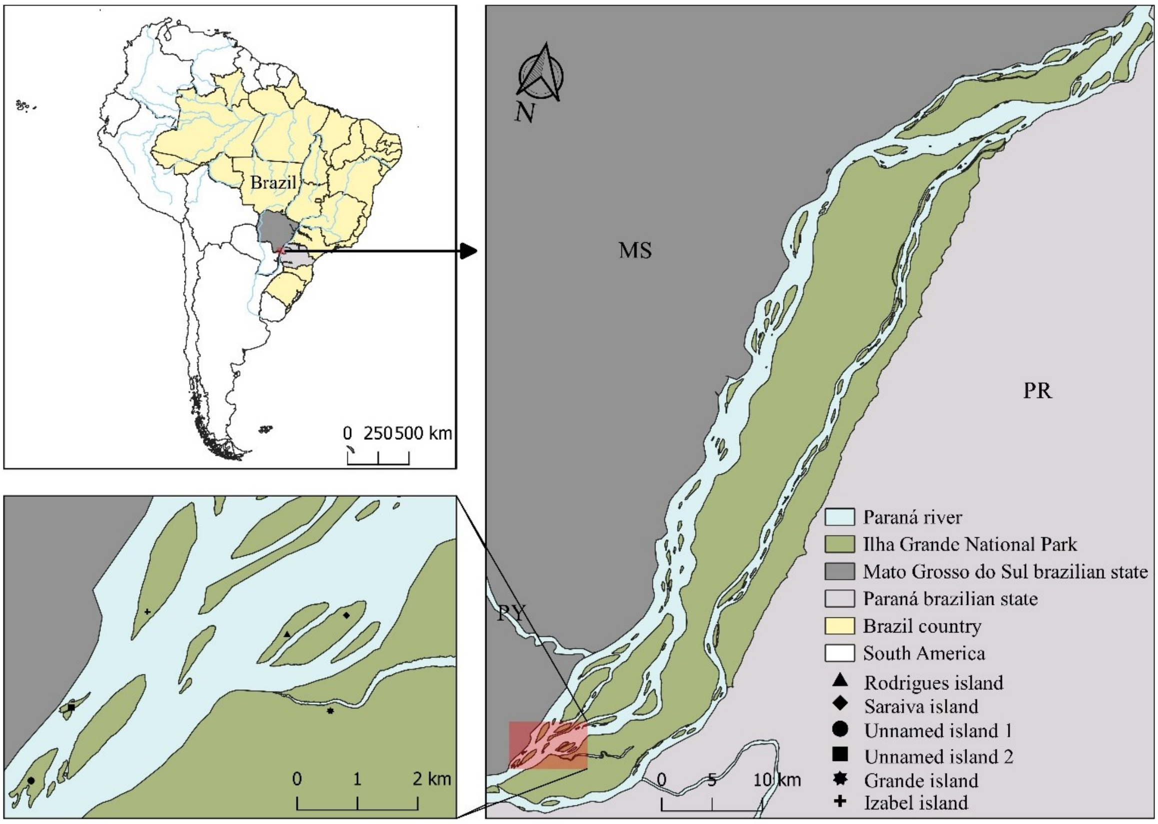

Figure 1. Location map of the study area showing sampling sites. Source: Bertinoti et al. (2020).

Species richness of the sampled area was estimated using *Chao 1*, as it is based on the abundance of rare species (Shtilerman, Thompson, Stone, Bode, & Burgman, 2014) and *Jackknife 2*, which allows a richness to be estimated, even with low sampling (Shtilerman et al., 2014). In addition, the *Mao Tau* method was used (Colwell, Mao, & Chang, 2004), being that for this index the number of species was calculated according to the number of nights sampled.

The frequency of species was also measured using the Constancy Index (CI), being the species classified as Common (CI ≥ 50%), Relatively Common (25 ≤ CI < 50%) and Rare (CI < 25%) (Pires & Fabián, 2013). Richness estimates were calculated using the PAST 3.24 software (Hammer, Harper, & Ryan, 2001) and the graphics were produced in R (R Core Team, 2018).

Results and discussion

A total of 170 specimens were collected, distributed into five genera, comprising two species and three morphotypes (Table 1 and Figure 2). In the present study, two taxa were considered rare (Table 1), and the *Chao 1* index estimated 6 ± 0.83 species for the sampled area, the *Jackknife 2* index estimated 8.21 ± 1.81 species, and for Mao Tau index, the richness was estimated at 7 ± 1.53 species (Figure 3).

The most abundant species in this study were *Parapachyloides uncinatus* (Sørensen, 1879; Figure 4A and B) and *Discocyrtus invalidus* (Piza, 1938), which together accounted for about 82% of the collected material. *Parapachyloides uncinatus* already had occurrence records for the states of Goiás, São Paulo, Mato Grosso do Sul (Kury, 2003), Ceará (Azevedo et al., 2016), Tocantins (Kury, Chagas-Jr, Giuponni, & González, 2010), cave areas in the Minas Gerais State (Ázara, Bernardi, & Ferreira, 2016), and occupying different biomes, such as Atlantic Forest and Caatinga (DeSouza, DaSilva, Carvalho, & Oliveira, 2014). With the sampling carried out in this study, the distribution of this species expanded, since there was no record for the state of Paraná. Even so, the knowledge about the distribution of this species can be expanded in later studies, since new synonyms have been proposed by Pinto-da-Rocha, Benedetti, Vasconcelos, and Hara (2012).

Discocyrtus invalidus, in general, has a wide distribution (Kury, 2003; Ázara & Ferreira, 2018), commonly found in disturbed areas, which may indicate synanthropy (Ferreira et al., 2020), but they are also found in forest fragments with varying conservation degrees (Costa, Ázara, Clemente, & Souza, 2020). However, until then in Brazil, it had occurrence records only for the state of São Paulo (Kury, 2003) and Minas Gerais (Ferreira et al., 2020); its distribution was extended by the present study.

Table 1. List of species, number of specimens and sex of harvestmen collected in the Ilha Grande National Park, Paraná State, Southern Brazil.

Taxon	Male	Female	CI
Parapachyloides uncinatus (Sørensen, 1879)	30	24	C
Discocyrtus invalidus (Piza, 1938)	44	43	C
Discocyrtus sp. 1	5	5	R
Geraeocormobius sp. 1	8	16	RC
Promitobates sp. 1	0	2	R

Legend: CI = Constancy Index (C = Common; RC = Relatively Common; R = Rare).

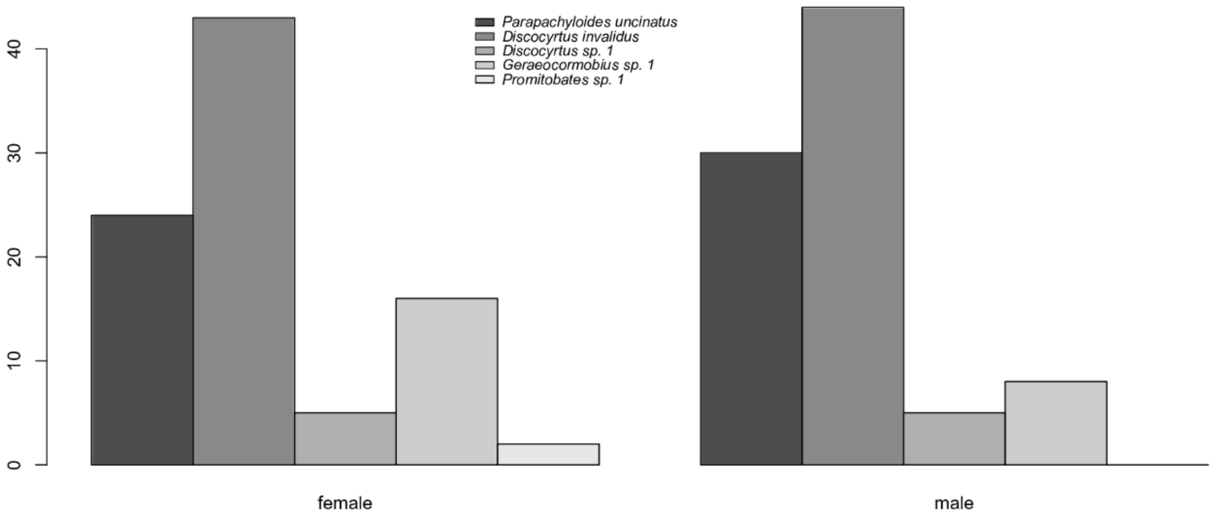

Figure 2. Number of males and females per species of opiliones collected in the Ilha Grande National Park, Paraná State, southern Brazil.

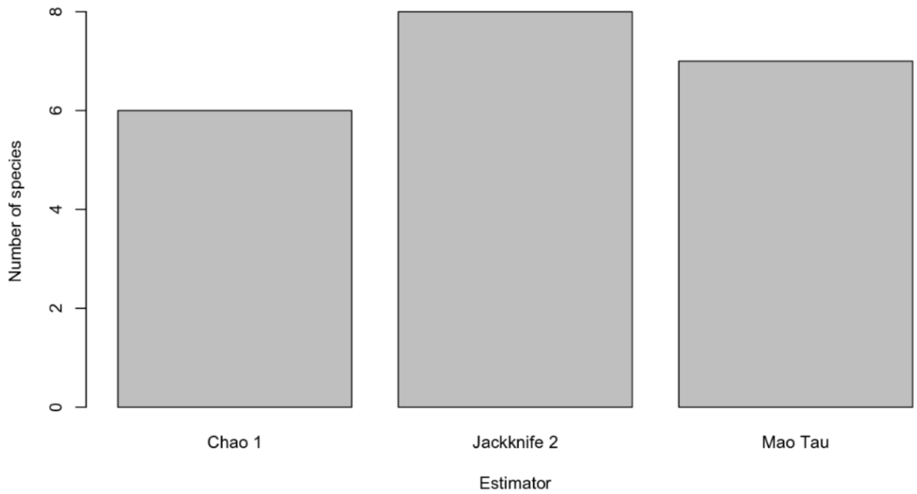

Figure 3. Estimated species richness of opiliones in the Ilha Grande National Park, Paraná State, southern Brazil.

Geraeocormobius is a genus that has 16 species (Kury, 2003) and has a wide distribution in Argentina, being *Geraeocormobius sylvarum* a typical species of most of Mesopotamic Argentina, a humid and sub-humid region between the Paraná and Uruguay Rivers (Acosta et al., 2007). The species also occurs in Brazil, having already been sampled in the Paraná State, more precisely in the Ilha Grande National Park (Acosta et al., 2007). The

Promitobates genus, with 14 species, has distribution in the south and southeast of Brazil with records for the states of São Paulo, Rio de Janeiro, Santa Catarina and Paraná (Kury, 2003). These two morpho-species are still in the identification phase and may even be new species.

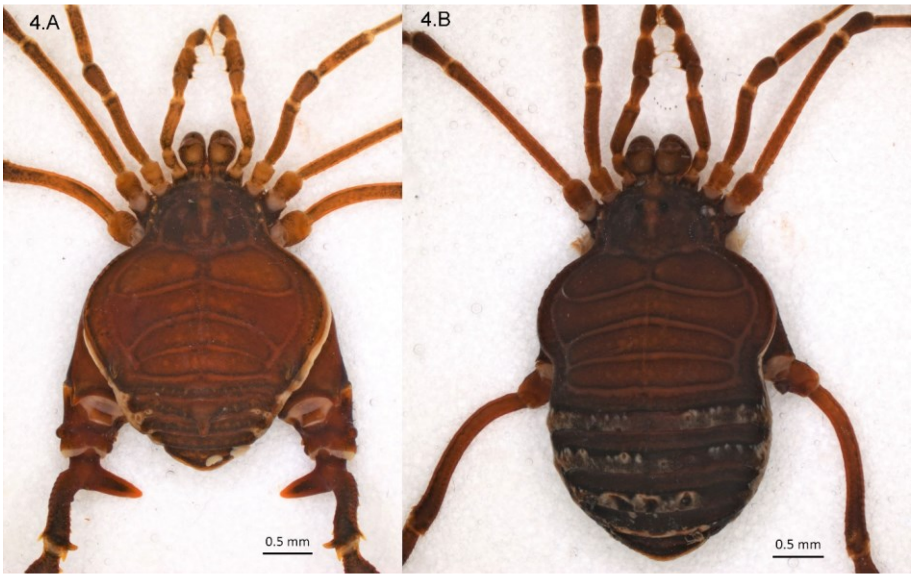

Figure 4. Male (4A) and female (4B) of *Parapachyloides uncinatus* (Sørensen, 1879) collected in the Ilha Grande National Park, Paraná State, southern Brazil. Source: Ludzon Neves de Ázara.

Although harvestmen usually present a restricted distribution and a high degree of endemism (Pinto-da-Rocha et al., 2005; DaSilva et al., 2015), some species may have a wide distribution reach, as is the case of those recorded in this study. According to Curtis and Machado (2007), some species can spread over thousands of km^2, in suitable environments and with no geographic or ecological barriers.

On the other hand, some studies also indicate that many of these arachnids have limited dispersal ability, whose movements can only cover a few tens of meters between 6 and 12 months, which is considered a long period of time for these organisms (Mestre & Pinto-da-Rocha, 2004; Bragagnolo, Nogueira, Pinto-da-Rocha, & Pardini, 2007; DeSouza et al., 2014). Thus, distribution of most harvestmen species seems to depend both on their dispersal ability and the geographical continuity of suitable environments (Acosta, 2008).

The low richness of harvestmen in this study may, therefore, be related to the geological formation of the sampling area. This is because the collections were carried out on islands, which act as biogeographical barriers, preventing the free dispersion of species (Tsurusaki, Takanashi, Nagase, & Shinada, 2005). Due to their low dispersal ability, harvestmen have lower chances to colonize new environments, and consequently, to expand their occurrence areas in the face of geographical barriers, such as mountains, rivers and valleys (Bragagnolo et al., 2007; Nogueira et al., 2019).

The Order Opiliones has been shown a good resource for studying the historical biogeography of a region, since its low capacity for colonization of new environments makes its current distribution a reflection of historical changes (Giribet & Kury, 2007; DaSilva et al., 2011; Nogueira et al., 2019). However, studies on harvestmen in islands are rare (Tsurusaki et al., 2005), with most representing lists of occurrence and taxonomic surveys (Foster, 1964; Soares, 1966; Marusik & Khrulyova, 2011). During a study on Opiliones biogeography in an archipelago off the coast of Japan, similarities between the fauna of the largest island in the archipelago with the continent were observed, which may be because the island was linked to the continent in Pleistocene (Tsurusaki et al., 2005). Therefore, a better understanding of the distribution of these organisms in the Ilha Grande National Park, can be fundamental to understand the biogeographic history of the Environmental Protection Area of the Islands and floodplains of the Paraná River, which encompasses the park and is located in the São Paulo, Mato Grosso do Sul and Paraná States. However, to better elucidate this hypothesis, comparative studies between the continent and the sampled islands are necessary, as well as a better analysis of the islands, which justifies further studies in the Ilha Grande National Park.

A second factor that may explain the low richness of harvestmen species in this study is related to the size of the sampled area, since during the collection period only 0.11% total area of the park was sampled. It is known that different methodologies and the size of the sampling area can strongly influence the species diversity, especially the ability to collect rare species (Bragagnolo & Pinto-da-Rocha, 2003). All richness estimators calculated showed that the number of harvestmen species in the studied area can be higher, ranging from six to eight species. Therefore, a greater number of collection hours, as well as sampling in other islands, would be necessary to increase the number of species occurring in the Ilha Grande National Park.

In addition, the most abundant species in this study, *P. uncinatus* and *D. invalidus*, belong to suborder Laniatores, which has many species with gregarious behavior, probably due to environmental conditions, which may also increase its defensive capacity against predators (Machado, Raimundo, & Oliveira, 2000; Colmenares & Tourinho, 2014). This behavior, added to the island effect and the size of the sampled area, may have facilitated the capture of individuals of these species, thus resulting in greater abundance.

Importantly, strong deforestation that occurred in the park until the mid-nineties, when only 1% native forest was maintained in the region, and the areas adjacent to the Paraná River and its set of islands had their original coverage reduced to small fractions of forest (Motta, 2001). The creation of the park in September 1997 was fundamental to mitigate the degradation in this environment, thus initiating the process of ecological restoration (Motta, 2001). The short period to recover these areas indicates that vegetation is still in the early stages of ecological succession, which may also have influenced the species diversity of harvestmen observed.

Conclusion

Despite the low diversity found, the present study is an important step to fill gaps in knowledge about the distribution of the group in the region, as well as to continue the environmental conservation work at the park. An increase in the number of species registered for the region is expected, as the regeneration processes approach the successional climax and new studies are carried out on site.

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