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Sistemática, biogeografia e ecologia de Arachnida. Parte II

Boletim do Museu Paraense Emílio Goeldi

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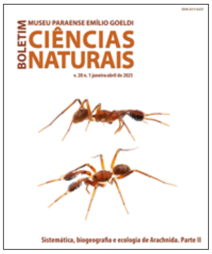

IMAGEM DA CAPA
Aranha que imita formiga (nome científico: *Tapixaua callida*), Paragominas, Pará, Brasil.
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CAPES

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ABEC

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CARTA DOS EDITORES

O primeiro número de 2025 do **Boletim do Museu Paraense Emilio Goeldi. Ciências Naturais** traz a continuação do dossiê sobre "Sistemática, biogeografia e ecologia de Arachnida". Dezesseis artigos foram aprovados para a publicação na edição especial. Os oito primeiros trabalhos foram publicados na última edição de 2024 e os demais compõem o presente sumário, que apresenta contribuições sobre taxonomia de aranhas da família Salticidae, estudos ecológicos sobre riqueza de aranhas e novos dados da distribuição geográfica de uma espécie de escorpião.

O primeiro artigo, de autoria de Reis e colaboradores, discute como a complexidade do *habitat* e a disponibilidade de presas influenciam na riqueza de espécies de aranhas em áreas de sub-bosque no Cerrado brasileiro. Os autores apresentam resultados interessantes sobre como a abundância de presas atua como forte influência para a riqueza de aranhas nessas áreas.

Rojas-Buffet & Viera analisaram as consequências das interações sexuais entre machos adultos e fêmeas subadultas de penúltimo instar da aranha subsocial uruguaia da espécie *Anelosimus vierae* (família Theridiidae). Para facilitar as observações sobre o comportamento, as autoras estabeleceram, em laboratório, grupos experimentais com machos e fêmeas dessa espécie de aranha, permitindo que os comportamentos de cortejo e pseudo-cópula entre os casais fossem descritos detalhadamente.

Na área da taxonomia, Michelotto & Santos descreveram e ilustraram, pela primeira vez, a fêmea de aranha-saltadora da espécie *Corythalia vervloeti* (família Salticidae), e discutiram a posição da espécie em Salticidae, além de proporem uma sinonímia. Os autores ainda apresentaram novos registros que ampliam a distribuição geográfica da espécie para diferentes biomas brasileiros e ainda para o Equador.

Ainda sobre aranhas-saltadoras, Ruiz e colaboradores discorrem sobre o gênero *Nycerella* no Brasil, fornecendo registros geográficos adicionais para três espécies do gênero, estendendo sua distribuição até o Nordeste brasileiro, e descrevendo a fêmea da espécie *Nycerella melanopygia* pela primeira vez.

Xavier e colaboradores forneceram novas informações sobre a história natural da aranha da espécie *Tapixaua callida* (família Corinnidae), até então pouco conhecida. Eles apresentaram registros geográficos que ampliam a distribuição da espécie para mais localidades no Peru e no Brasil, além de um novo registro para a Colômbia. Dados inéditos sobre a história natural, com fotografias e vídeos, também foram apresentados, bem como a proposição de uma nomenclatura distinta para a solução de mimetismo de formigas dessa espécie de aranha.

No artigo de Sá e colaboradores, também foram apresentados dados sobre a história natural, mas sobre a aranha-marrom (*Loxoscelis chapadensis*; família Sicariidae). As autoras coletaram espécimes em sete localidades do estado da Bahia (Brasil) e discutiram sobre sua distribuição especialmente cavernícola em ambientes da Caatinga brasileira. Elas ainda destacam a importância de haver um cuidadoso plano de manejo das cavernas onde a espécie ocorre, que têm grande fluxo turístico, por se tratar de uma aranha de importância em saúde.

Na área da ecologia, Pantoja e colaboradores demonstraram que um pequeno fragmento florestal em uma área urbana pode guardar ricas informações acerca da araneofauna. Neste estudo, foi apresentada uma lista de espécies/

morfoespécies de aranhas do *Campus* de Pesquisa do Museu Paraense Emílio Goeldi, em Belém do Pará (Brasil). Os autores publicaram 16 novos registros locais e três novos registros para o Brasil, e ilustraram o trabalho com fotografias de espécimes vivos dos vários táxons encontrados.

Goldoni e colaboradores disponibilizam novos registros para o escorpião *Tityus* (*Tityus*) *confluens* (família Buthidae), expandindo a sua distribuição para o estado do Paraná, no Brasil.

Encerrando esta carta, agradecemos novamente aos avaliadores de várias instituições do Brasil e do exterior, pela dedicação à leitura dos artigos publicados nesta edição, bem como a Rafaele Lima, Adrienny Souza, Luiz Ramiro Cardoso e Talita do Vale, pela dedicação no trabalho de editoração.

Alexandre Bragio Bonaldo, Cláudia Xavier & Leonardo Sousa Carvalho
Editores Convidados

Fernando da Silva Carvalho-Filho
Editor Científico

LETTER FROM THE EDITORS

Continues the special dossier on "Systematics, Biogeography, and Ecology of Arachnida." A total of sixteen articles were accepted for publication in this special issue. The first eight papers were published in the final issue of 2024, and the remaining eight comprise the present issue. This edition features contributions on the taxonomy of spiders from the family Salticidae, ecological studies on spider richness, and new data on the geographical distribution of a scorpion species.

The opening article, authored by Reis and collaborators, discusses how habitat complexity and prey availability influence spider species richness in understory areas of the Brazilian Cerrado. The authors present compelling results showing that prey abundance exerts a strong influence on spider richness in these environments.

Rojas-Buffet and Viera analyzed the consequences of sexual interactions between adult males and penultimate instar subadult females of the subsocial Uruguayan spider *Anelosimus vierae* (family Theridiidae). To facilitate behavioral observations, the authors established experimental groups in the laboratory with males and females of this species, allowing for a detailed description of courtship and pseudo-copulation behaviors.

In the field of taxonomy, Michelotto and Santos described and illustrated, for the first time, the female of the jumping spider *Corythalia vervloeti* (family Salticidae). They discussed the species' placement within Salticidae and proposed a synonymy. Additionally, the authors presented new records that extend the species' distribution to different Brazilian biomes and even to Ecuador.

Also focusing on jumping spiders, Ruiz and collaborators examined the genus *Nycerella* in Brazil, providing additional geographic records for three species, extending their known distribution to the Brazilian Northeast, and describing the female of *Nycerella melanopygia* for the first time.

Xavier and collaborators contributed new information on the natural history of the spider *Tapixaua callida* (family Corinnidae), a species previously poorly studied. They reported geographic records that extend its distribution to additional localities in Peru and Brazil, as well as a new record for Colombia. The authors also presented unprecedented natural history data, including photographs and videos, and proposed a distinct nomenclature for the ant-mimicry solution observed in this species.

In the article by Sá and collaborators, further natural history data are presented, this time on the brown recluse spider *Loxosceles chapadensis* (family Sicariidae). The authors collected specimens from seven locations in the state of Bahia, Brazil, and discussed the species' distribution, which is particularly associated with cave environments in the Brazilian Caatinga. They also highlighted the importance of implementing careful management plans for the caves where this species occurs, especially considering the significant tourist activity in these locations and the public health relevance of this spider.

In the field of ecology, Pantoja and collaborators demonstrated that a small forest fragment within an urban area can harbor valuable information about local spider fauna. Their study presents a checklist of spider species/morphospecies from the Research Campus of the Museu Paraense Emílio Goeldi, in Belém, Pará, Brazil. The authors published 16 new local records and three new records for Brazil, complemented by photographs of live specimens representing the various taxa found.

Goldoni and collaborators provided new distribution records for the scorpion *Tityus (Tityus) confluens* (family Buthidae), expanding its known range to the state of Paraná, Brazil.

In closing, we would like to once again express our gratitude to the reviewers from various institutions in Brazil and abroad for their dedication in reviewing the articles published in this issue. We also extend our sincere thanks to Rafaele Lima, Adrienny Souza, Luiz Ramiro Cardoso, and Talita do Vale for their commitment to the editorial work.

Alexandre Bragio Bonaldo, Cláudia Xavier & Leonardo Sousa Carvalho
Guest Editors

Fernando da Silva Carvalho-Filho
Scientific Editor

Dossiê

Sistemática, Biogeografia e Ecologia de Arachnida. Parte II

Spider species richness is driven by insect diversity rather than habitat complexity in the understory of the Brazilian *Cerrado*

A riqueza de espécies de aranhas é influenciada pela diversidade de insetos, em vez da complexidade do habitat, no sub-bosque do Cerrado brasileiro

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Abstract: Habitat complexity is determined by the variation of physical and biological components within an environment. More complex habitats generally provide a greater diversity of shelters, food, and reproduction sites, contributing to richer biodiversity. In this study, we investigated how habitat complexity, provided by understory plants in natural areas of the Brazilian *Cerrado*, influences spider species richness. We assessed structural variables such as leaf number, plant size, and herbivory incidence, as well as prey availability measured by insect richness. Our results revealed that spider richness was positively correlated with insect richness, highlighting the role of prey diversity in supporting predator communities. However, an inverse relationship between spider richness and leaf number suggests that denser foliage may limit accessibility for some spider species or favor dominance by specialists. These findings emphasize the importance of conservation strategies focused on preserving plant diversity and structural heterogeneity to maintain ecological balance and biodiversity in the *Cerrado*.

Keywords: Arachnida. Tropical savanna. Habitat structure. *Cerrado* conservation. Spider richness.

Resumo: A complexidade do hábitat é determinada pela variação dos componentes físicos e biológicos presentes em um ambiente. Hábitats mais complexos geralmente oferecem maior diversidade de abrigos, alimento e sítios de reprodução, contribuindo para uma biodiversidade mais rica. Neste estudo, investigamos como a complexidade do hábitat, fornecida pelas plantas do sub-bosque de áreas naturais do Cerrado brasileiro, influencia a riqueza de espécies de aranhas. Avaliamos variáveis estruturais, como número de folhas, tamanho das plantas e incidência de herbivoria, além da disponibilidade de presas, medida pela riqueza de insetos. Nossos resultados indicaram que a riqueza de aranhas está positivamente correlacionada com a riqueza de insetos, evidenciando o papel da diversidade de presas na sustentação de comunidades predadoras. Contudo, foi observada uma relação inversa entre a riqueza de aranhas e o número de folhas das plantas, sugerindo que arranjos foliares mais densos podem limitar o acesso de algumas espécies ou favorecer a dominância de espécies especializadas. Esses achados ressaltam a importância de estratégias de conservação que priorizem a preservação da diversidade vegetal e da heterogeneidade estrutural, assegurando o equilíbrio ecológico e a biodiversidade no Cerrado.

Palavras-chave: Arachnida. Savana tropical. Estrutura do hábitat. Conservação do Cerrado. Riqueza de aranhas.

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INTRODUCTION

Species diversity is shaped by a complex interplay of abiotic and biotic attributes within ecosystems, with species turnover reflecting variations across different physiognomies within the same biome (Tews et al., 2004; Ferreira et al., 2020; Torres-Pulliza et al., 2020). Such turnover underscores the dynamic relationship between biodiversity and environmental heterogeneity, as community composition varies across vertical and horizontal gradients (Molina et al., 2016; Peng et al., 2020; Edeline et al., 2023; Delarue et al., 2015). These gradients include attributes such as soil composition, understory vegetation, and canopy structure. For instance, biological communities associated with the understory often respond to the structural complexity and resources provided by plants occupying this ecological niche (Bartels & Chen, 2010; Lira et al., 2021; Tian et al., 2023).

The Brazilian *Cerrado* is among the richest savanna ecosystems globally, hosting extraordinary biodiversity. This biome spans a mosaic of physiognomies that range from open grasslands to dense forests, each offering unique ecological conditions that support diverse arthropod assemblages (Ratter et al., 1997; Del-Claro & Torezan-Silingardi, 2019). Within this gradient, physiognomies such as semideciduous forests are characterized by taller and denser vegetation, while areas like *campo sujo* and *cerrado sensu stricto* exhibit sparse tree and shrub cover with a more open structure (Eiten, 1972). These variations influence arthropod communities, as lower vegetative structure in open environments often results in greater exposure of the soil and reliance on understory vegetation for shelter, foraging, and reproduction (Diniz el al., 2012; Nogueira et al., 2005).

Spiders, a highly diverse and ecologically significant group of arthropods, exhibit strong responses to habitat structure, with species composition often reflecting resource availability and microhabitat complexity (Podgaiski & Rodrigues, 2017; Potapov et al., 2022). Vegetation structure, including the density, height, and composition of plant species, serves as a critical determinant of spider assemblages by influencing microclimatic conditions, prey abundance, and web-building opportunities (Souza & Martins, 2004, 2005; Malumbres-Olarte et al., 2013). In areas with increased vegetative complexity, spider diversity tends to be higher, likely due to the availability of microhabitats and ecological niches that reduce interspecific competition and enhance prey capture efficiency (Barton et al., 2017).

The role of understory vegetation in shaping spider communities has been extensively documented in forested ecosystems, where plant architecture, including features such as branches, leaves, flowers, and galls, provides crucial structural complexity (Spears & MacMahon, 2012). These elements not only influence the physical space available for web construction but also mediate interactions between spiders and other arthropod species, which serve as prey or competitors (Robinson & Robinson, 1972; Birkhofer et al., 2007). Additionally, galls, often induced by gall-inducing insects, create microhabitats that attract secondary arthropods, potentially altering the composition and behavior of local spider assemblages (Sanver & Hawkins, 2000; López-Núñez et al., 2019).

Despite the recognized importance of habitat structure, relatively few studies have explored how specific understory characteristics influence spider diversity within savanna ecosystems such as the *Cerrado* (Souza & Martins, 2004, 2005; Diniz et al., 2012; Dias & Stefani, 2024). Given its transitional nature and the wide range of vegetation physiognomies it encompasses, the *Cerrado* represents an ideal model system for examining these relationships (Ribeiro & Walter, 1998; Oliveira & Marquis, 2002; Vale et al., 2004). Previous studies have primarily focused on canopy-dwelling spiders or open-ground communities, leaving a gap in understanding the ecological role of understory habitats in supporting spider diversity (Carvalho & Avelino, 2010; Mineo et al., 2010).

The southeastern region of Goiás, Brazil, provides a valuable setting for investigating these dynamics (Oliveira, 2014; Ferreira et al., 2021). This region features a continuum of *Cerrado* physiognomies within conservation areas, offering an opportunity to examine how spider assemblages respond to variations in understory structure. Understanding these patterns has implications for both biodiversity conservation and the management of arthropod communities in increasingly fragmented landscapes, where habitat heterogeneity may be compromised by human activity (Silva et al., 2006). So, the present study aimed to assess how spider species richness is influenced by understory habitat structure, measured by the dimension and complexity of understory plants, in a *Cerrado* conservation area. We hypothesized that spider species richness would be positively correlated with the structural complexity of plants, represented by greater abundance of branches, leaves, flowers, and galls, as well as higher richness and abundance of associated arthropods. These predictions are based on the premise that increased structural complexity offers more niches, supports diverse prey communities, and enhances microhabitat stability, thereby fostering higher spider diversity (Smith et al., 2014; Pierre & Kovalenko, 2014). By elucidating the relationship between understory structure and spider diversity, this study seeks to contribute to the broader understanding of arthropod ecology in tropical savannas.

MATERIAL AND METHODS

The study was conducted in a *Cerrado* area within the Municipal Natural Park of Orchids of Piracanjuba José Pinheiro de Souza (Figure 1), located in Piracanjuba, Goiás, Brazil (17° 14’ 34.18” S and 48° 51’ 26.44” W). The area comprises the typical vegetation of the Brazilian savanna (*Cerrado* biome), which is characterized by a seasonal tropical climate (Alberto-Bustamante et al., 2012; Costa et al., 2020). The rainy period spans from October to April, with a dry spell from May to September (Cordeiro et al., 2021). The annual precipitation averages between 1,300 and 1,650 mm, with monthly peaks ranging from 13 to 228 mm, and the average temperature ranges from 18 °C to 25 °C (Piracanjuba, 2012). Sampling was conducted at the onset of the dry season, between April 12 and 13, 2024, from 08:00 to 17:00. Plants from various families, ranging in height from 1 to 3 meters, were randomly selected, maintaining a minimum distance of 2 meters between them (Costa et al., 2014).

A total of 31 plants were selected and sampled. Initially, arthropods present on each plant were collected by tapping each branch five times onto a plastic tray (35 cm long × 30 cm wide × 5 cm deep) containing water and 10% detergent. The tapping method is particularly effective for capturing arboreal spiders, as it dislodges individuals inhabiting foliage or branch crevices. Subsequently, all the collected arthropods were placed in labeled tubes for subsequent laboratory analysis (Lopes et al., 2019). Following arthropod collection, which took approximately 10 to 15 minutes per plant, variables related to habitat structure were recorded. This included the coordinates of each plant’s location, taxonomic family identification by removing a branch, and the following variables: (a) number of branches; (b) number of leaves per branch; (c) number of flowers per branch; (d) plant length; (e) crown width; (f) number of galls; and (g) proportion of incidence of herbivory and leaf damage. We expected that the degree of floristic complexity, expressed as the quantity of branches, leaves, and fruits, would influence the species richness of spiders. Additionally, we consider the structural characteristics of the environment and the season, along with the number of galls present on each plant, as determining factors of the total spider species richness found.

The number of leaves, flowers, and fruits per plant were estimated by counting them on three branches of each plant and then calculating the average, which was multiplied by the total number of branches on each plant. The average was calculated by summing the total counts from the sampled branches and dividing by the number of branches sampled per plant, ensuring consistency in estimates. We then plotted the variables against the total number of branches on each plant. The galls present on the plant were quantified, and a sample was taken for later identification of their type, shape, and occurrence (Isaias et al., 2013; Bergamini et al., 2017). Herbivory incidence was estimated using Bioleaf software (Machado et al., 2016) by photographing five damaged and five intact leaves per plant and calculating the proportion of leaf damage. The average leaf damage was then multiplied by the estimated number of leaves on each plant.

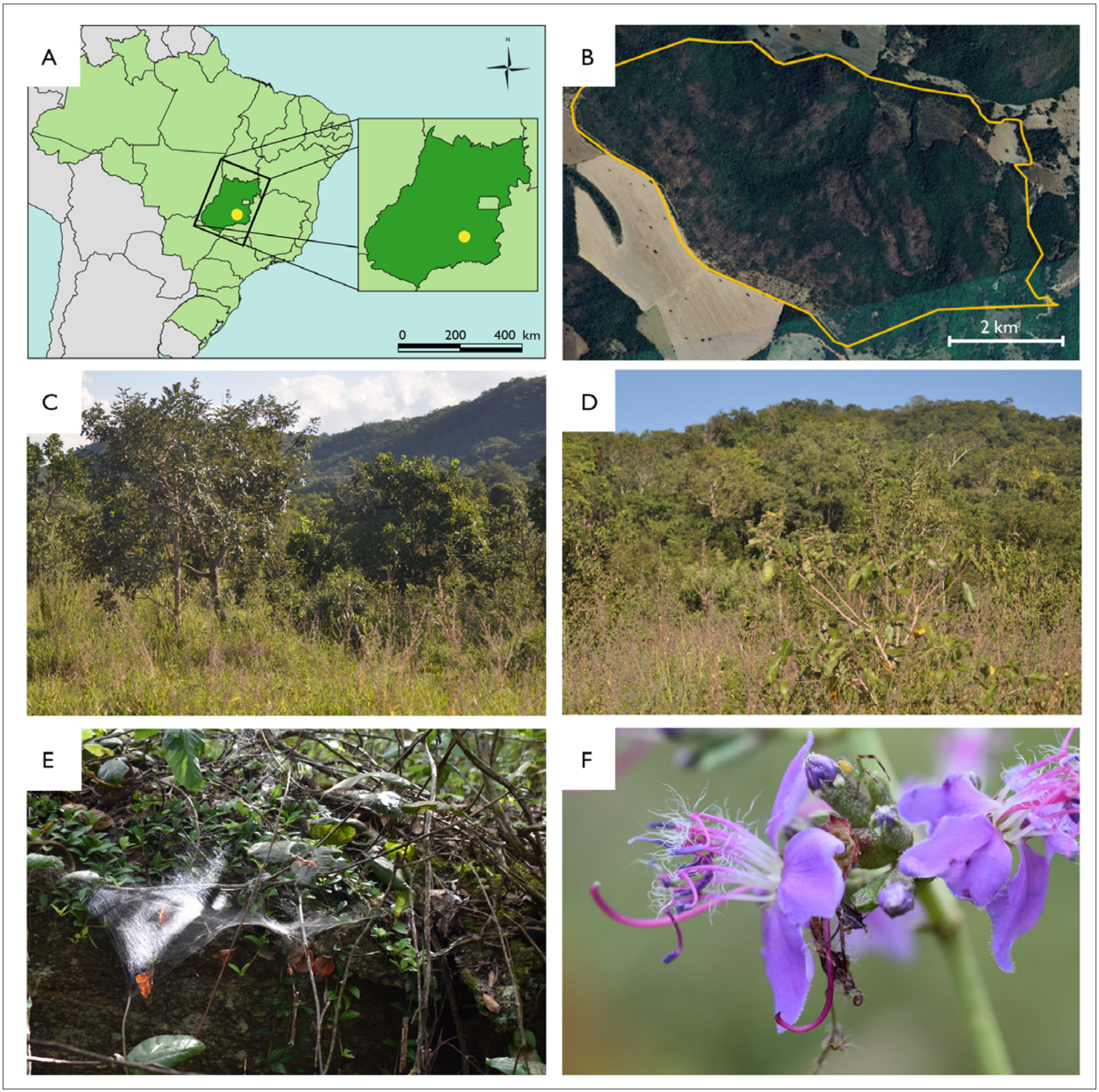

Figure 1. Characterization of the study area in Brazil, State of Goiás: A) geographic location of the Municipal Natural Park of Orchids of Piracanjuba 'José Pinheiro de Souza' (marked by the yellow circle) in the municipality of Piracanjuba, Goiás State, Brazil; B) delimitation of the conservation unit surrounded in yellow. The localities where the collections were made, highlighting the region's vegetation (C and D). Examples of spiders that use this type of habitat, such as web spiders (*Aglaoctenus lagotis* Holmberg, 1876, Lycosidae) (E) and a Thomisidae spider on a flower (F). Maps: edited by J. S. Reis. Photos: E. Tizo-Pedroso.

The collected arthropods were preserved in 70% alcohol, quantified, and identified to the family level for spiders and the order level for insects. Species richness was quantified as the number of morphospecies per plant. The number of species was divided by the number of branches on the plant to preserve proportionality between the variables. The arthropods were then incorporated into the biological collection of the Laboratory of Diversity, Behavior, and Conservation of Arachnids (Curator: Dr. Everton Tizo-Pedroso) at the State University of Goiás, in Anápolis, Goiás, Brazil. The herborized plant materials will be included in the HUEG collection (Herbário da Universidade Estadual de Goiás) (Curator: Dr. Mirley Luciene dos Santos).

The species richness and abundance of spiders and insects were quantified per plant, and principal component analysis was used to evaluate the following variables: (a) the number of branches per plant; (b) the mean number of leaves and flowers per plant branch; (c) plant size; (d) the number of galls per plant; and (d) the estimated proportion of foliar damage by herbivory per plant. Since the variables had different values, they were transformed into scores by subtracting the value of each replicate per variable from the variable's mean and dividing by the standard deviation. The analyses were carried out using Statistica software (version 11) and Past software (version 4.17c) (Hammer et al., 2001). Firstly, we tested whether spider species richness varied significantly among plant families. This analysis aimed to determine whether one or more plant families tend to harbor a greater number of spider species. Additionally, we examined whether insect richness and abundance varied across plant families, as plants that attract a greater number of insects (potential prey) could also support a higher number of spiders. These analyses were conducted using the Kruskal-Wallis test.

Next, a multiple regression analysis was performed to investigate the relationship between spider species richness (dependent variable) and explanatory variables related to habitat structure ((a) the number of branches per plant; (b) the mean number of leaves and flowers per branch; (c) plant size; (d) the number of galls per plant; and (e) the estimated proportion of leaf damage due to herbivory per plant), as well as variables associated with food availability (insect richness and abundance). The analyses were carried out using Past software (version 4.17c) (Hammer et al., 2001).

RESULTS

Thirty-one plants from nine families were sampled (Asteraceae, Bignoniaceae, Fabaceae, Malpighiaceae, Melastomataceae, Myrtaceae, Piperaceae, Rutaceae, Smilacaceae). The two most frequent families were Fabaceae and Asteraceae, with 12 individuals (39%) and 6 individuals (19%), respectively. The richness of arthropods per plant varied from one to 15 species (X = 5; SD = 3). While the abundance per plant ranged from one to 241 (X = 15; SD = 43). The richness of arthropods was 139 species, with a total abundance of 476 individuals (Table 1).

Among the sampled arthropods (a total of 476 individuals), ants, beetles, dipterans, hemipterans and homopterans were present, with a predominance of Hemiptera (63.42%), Hymenoptera (19.48%) and Coleoptera (8.55%). Seven spider families were identified, namely, Theridiidae (29.41%), Salticidae (19.61%), and Thomisidae (17.65%), being the most abundant families (Table 1). Most of the spiders sampled were adult individuals, around two thirds of the spiders collected. Juveniles were disregarded in these analyses due to the imprecision of their species confirmation.

The richness of spiders varied between the taxonomic families of plants, being higher in plants of the Rubiaceae family (Kruskal-Wallis H (8, N = 31) = 16.07, p = 0.04). Insect richness responded more significantly in relation to plant families, with the greatest richness being found in plants from the Asteraceae (KW H (8, N = 31) = 22.79, p = 0.003). However, the greatest abundance of insects was recorded in plants from the Melastomataceae family (KW H (8, N = 31) = 15.65, p = 0.04).

Table 1. Richness and abundance of insects (according to taxonomic orders) and spiders (according to taxonomic families) sampled from understory plants in a restricted *Cerrado* preservation area in southeastern Goiás, Brazil.

	Species	%	Abundance	%
Insect				
Coleoptera	24	24.24	36	8.55
Dermaptera	1	1.01	1	0.24
Diptera	13	13.13	16	3.80
Hemiptera	12	12.12	267	63.42
Homoptera	2	2.02	3	0.71
Hymenoptera	32	32.32	82	19.48
Lepdoptera	6	6.06	6	1.43
Orthoptera	9	9.09	10	2.38
Total	99	100	421	100
Arachnida				
Araneae				
Araneidae	7	17.50	9	16.36
Caponidae	1	2.50	2	3.64
Oxyopidae	3	7.50	7	12.73
Pholcidae	1	2.50	1	1.82
Salticidae	7	17.50	10	18.18
Theridiidae	12	30.00	16	29.09
Thomisidae	9	22.50	10	18.18
Total	40	100	55	100

Although the number of flowers was measured, as well as the shape and type of galls, only 9 plants had flowers during the sampling period and only 13 plants contained galls, so these variables were disregarded for the multiple regression analysis due to the low sample representativeness. However, we tested, using the Mann-Whitney, whether spider richness varied in relation to the reproductive state of the plants, with flowers or without flowers, and we also tested for the presence of galls on the plants. In both cases, the richness did not vary significantly (flowers, $U = 47.50$; $p = 0.82$; galls, $U = 55.00$; $p = 0.60$).

The insect abundance data behaved as an outlier for some plants and was therefore removed from the multiple regression analysis. The abundance of spiders was relatively low, with few replicates per species (Table 1). Therefore, the abundance of spiders could not represent a suitable variable for analysis. So, spider abundance was not included in the multiple regression analyses. We then carried out a multiple regression, analyzing the relationship between spider richness and the explanatory variables. The analysis indicated a significant result ($R^2 = 0.71$; $F(7.14) = 4.91$; $p = 0.005$). However, spider species richness responded significantly to only two explanatory variables, first in relation to insect species richness and then to the number of leaves per plant sampled (Table 2). Spider richness was inversely proportional to the number of leaves. Thus, plants with a greater number of leaves had a lower number of spider species. On the other hand, spider species richness was proportional to insect species richness (Table 2; Figure 2).

Table 2. Results of multiple regression analysis between spider species richness and structural variables related to understory plants and insect richness and abundance in a *Cerrado* area in Goiás, Brazil. Legend: * = indicate significant differences.

Regression R = 0.84; R^2 = 0.71; Adjusted R^2 = 0.56; F(7.14) = 4.91; p = 0.005						
N = 22	b	SE of b	b	SE of b	t(14)	p
Intercept			0.47	0.21	2.19	0.04
Branches	-0.26	0.18	-0.18	0.12	-1.43	0.17
Leaves	-0.58	0.23	-0.17	0.06	-2.49	0.02*
Plant size	0.03	0.23	0.01	0.09	0.12	0.90
Defoliation	0.02	0.18	0.01	0.08	0.10	0.92
Leaf area	0.02	0.17	0.01	0.13	0.12	0.90
Insect richness	1.22	0.38	0.87	0.27	3.22	< 0.01*
Insect abundance	-0.52	0.34	-0.22	0.14	-1.53	0.15

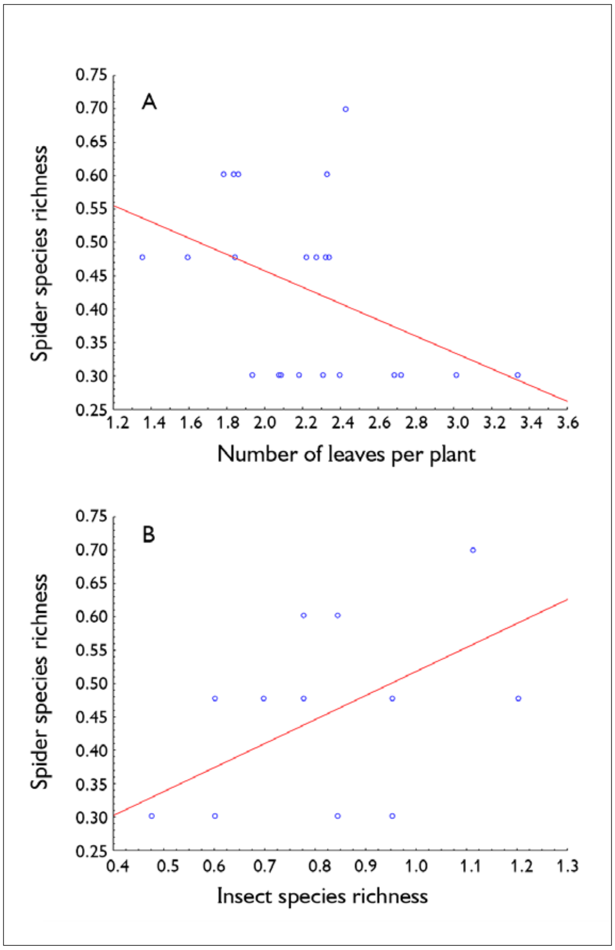

Figure 2. Relationship between the variables spider species richness and the number of leaves per plant (A) and insect species richness (B), in an area of *Cerrado* sensu stricto in southeastern Goiás, Brazil.

DISCUSSION

Our results demonstrated that spider species richness in the *Cerrado* understory is strongly influenced by prey availability and plant structural traits. Spider richness was positively correlated with insect richness, emphasizing the role of prey diversity in supporting predator communities. Insect richness varied significantly among plant families, with Asteraceae hosting the highest richness. This is likely due to their structural and chemical traits, which attract a variety of herbivores and pollinators (Levin, 1976; Carmona et al., 2010). Interestingly, Rubiaceae plants supported the highest spider richness, suggesting that specific plant traits, such as architectural complexity or chemical defenses, create favorable habitats for spiders (Villanueva-Bonilla et al., 2024). This decoupling between insect and spider richness highlights the complex interactions shaping predator-prey dynamics in the *Cerrado*, where plant traits may independently influence different arthropod guilds.

The inverse relationship between spider richness and the number of leaves per plant contrasts with the expectation that greater structural complexity promotes higher species richness (Rodrigues et al., 2014, 2016). One possible explanation is that denser leaf arrangements may reduce accessibility for some spider species or favor dominance by specialized species, thereby decreasing overall diversity. This finding suggests that leaf density, while a component of structural complexity, does not always result in increased habitat suitability for predators. Alternatively, plants with denser foliage may concentrate particular spider families, which could predominate in these microhabitats and limit niche availability for other species (Rocha-Filho & Rinaldi, 2011; Arvidsson et al., 2022; Hamřík et al., 2023; Hesselberg et al., 2023; Villanueva-Bonilla et al., 2024; Vasconcellos-Neto et al., 2017; Dias & Stefani, 2024). Further studies are needed to investigate whether such patterns reflect interspecific competition or differences in microhabitat preferences.

The positive relationship between insect richness and spider diversity reinforces the interconnectedness of trophic levels and highlights the critical role of prey availability in shaping predator assemblages (Del-Claro et al., 2017; Sousa-Lopes et al., 2019; Del-Claro & Torezan-Silingardi, 2019). This finding is consistent with studies in other ecosystems, where prey diversity has been shown to be a key determinant of predator community structure (Schirmel et al., 2016; Barton et al., 2017). In the *Cerrado*, the variety of plant families and their associated arthropod communities likely contributes to the overall biodiversity of the biome, emphasizing the importance of preserving plant diversity to maintain ecological balance (Kuchenbecker & Fagundes, 2018; Siqueira & Silva, 2022).

The *Cerrado*'s mosaic of phytophysiognomies, ranging from sparse vegetation to dense forests, provides unique opportunities to study how habitat characteristics influence arthropod communities (Carmignotto et al., 2022; Oliveira & Marquis, 2002; Macedo et al., 2014; Sano et al., 2019). While this study focused on understory plants in a conservation area, future research should expand to other *Cerrado* environments, including disturbed areas and regions with varying levels of preservation. Such studies could help determine how environmental changes, such as habitat fragmentation and vegetation degradation, affect the relationships between plants, prey, and predators. Furthermore, investigating how seasonal variations influence resource availability and habitat use could provide a more comprehensive understanding of these ecological interactions.

CONCLUSION

Our study showed that spider species richness in the *Cerrado* understory is shaped by a combination of prey availability and plant structural traits. While insect richness had a positive influence on spider diversity, an unexpected inverse relationship with leaf number suggests that denser foliage may limit spider accessibility or favor specialized species. These findings emphasize the complex interplay between habitat structure and trophic interactions in diverse ecosystems. To preserve the ecological balance of the *Cerrado*, conservation efforts should prioritize maintaining plant diversity and structural heterogeneity, ensuring the persistence of both predator and prey communities in this biodiversity hotspot.

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J. S. Reis contributed to project management, formal analysis, data curating, writing (original draft, review and editing); A. F. S. Tizo contributed to project management, formal analysis, data curating, writing (original draft, review and editing); R. F. Barroso contributed to project management, formal analysis, data curating, writing (original draft, review and editing); V. L. C. Pereira contributed to project management, formal analysis, data curating, writing (original draft, review and editing); M. H. A. Deus contributed to project management, formal analysis, data curating, writing (original draft, review and editing); and E. Tizo-Pedroso contributed to project management, formal analysis, conceptualization, data curating, writing (review and editing), methodology, validation.

Sexual interactions between adult males and immature females in the subsocial spider *Anelosimus vierae*

Interações sexuais entre machos adultos e fêmeas imaturas na aranha subsocial *Anelosimus vierae*

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Abstract: This study aimed to analyze the consequences of sexual interactions between adult males and penultimate females of the Uruguayan subsocial spider *Anelosimus vierae* Agnarsson, 2012 (Theridiidae). In the laboratory, several experimental groups were formed consisting of unrelated adult males and penultimate females of the species. The courtship and pseudo-copulation behaviors that occur between adult males and penultimate females were described in detail. These sexual behaviors were shown to have positive effects on future sexual encounters.

Keywords: Courtship. Pseudo-copula. Subadult females. Communal spider. Uruguayan spider.

Resumo: Este estudo teve como objetivo analisar as consequências das interações sexuais entre machos adultos e penúltimas fêmeas da aranha subsocial uruguaia *Anelosimus vierae* Agnarsson, 2012 (Theridiidae). No laboratório, foram formados vários grupos experimentais compostos por machos adultos não relacionados e penúltimas fêmeas da espécie. Os comportamentos de cortejo e pseudo-cópula que ocorrem entre machos adultos e penúltimas fêmeas foram descritos em detalhes. Esses comportamentos sexuais mostraram ter efeitos positivos em futuros encontros sexuais.

Palavras-chave: Cortejo. Pseudo-cópula. Fêmeas subadultas. Aranha comunal. Aranha uruguaia.

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INTRODUCTION

The strategies used by males to achieve dominance in the fertilization of females are very varied (Tomkins & Simmons, 2002; Parker, 2006). In both vertebrates and invertebrates, males may guard the females with whom they recently mated to avoid copulation with other males, thus ensuring their paternity (Parker, 1970; Birkhead, 1998; Simmons, 2001). Another male strategy is to guard females before they mature to monopolize the partners until they are receptive to mating (Andersson, 1994; Simmons, 2001). In this sense, in some spiders with sperm priority, males cohabit with subadult females to ensure their paternity by copulating with virgin females that have recently molted (Fernández-Montraveta & Cuadrado, 2003; Viera & Albo, 2008; Uhl et al., 2015; Moura & Gonzaga, 2017).

In many spiders, it is common for adult males to detect subadult females and guard them until they reach adulthood (Jackson, 1986; Bukowski & Christenson, 1997; Fernández-Montraveta & Cuadrado, 2003; Klein et al., 2005; Albo et al., 2007). The males of some spider species even fight among themselves in the webs of penultimate females to monopolize them (Albo et al., 2007; Aisenberg et al., 2015). The attractiveness of subadult females can vary during the penultimate instar, becoming more attractive just before the final molt (Schneider & Lubin, 1998). In cases where there is sperm priority, it is expected that males prefer to associate with subadult females rather than adults, mating with them as soon as they mature to ensure paternity (Eberhard et al., 1993; Elgar, 1998). In extreme cases, males of the theridiids *Latrodectus hasselti* Thorell, 1870 and *L. geometricus* C. L. Koch, 1841 increase their reproductive successes and avoid cannibalization by copulating with penultimate females. Males pierce the exoskeleton of females with their chelicerae to access females 'newly developed spermathecae. Females retain sperm through their final molt and achieve fecundity similar to adult females (Biaggio et al., 2016).

Male guards try to reduce female polyandry, so this behavior has typically been considered as a form of sexual conflict (Parker, 1979; Birkhead, 1998; Jormalainen, 1998; Zeiss et al., 1999; Rodríguez-Muñoz et al., 2011). However, females may obtain direct benefits from mating with guarding males, such as reduced predation (Rodríguez-Muñoz et al., 2011; Cothran et al., 2012) and sexual harassment by other males (Davis, 2002). They might also gain indirect genetic benefits (Prenter et al., 2003), by selecting for costly traits in males that indicate greater heritable variability for their offspring (Williams, 1966). Females who mate with males who guard efficiently would pass that ability on to their offspring.

Finally, cohabiting with a male during the pre-copulatory guard allows the female to evaluate the partner as a potential mate for the future (Hebets, 2003; Johnson, 2005; Hebets & Vink, 2007; Rutledge et al., 2010; Kasumovic & Seebacher, 2013). For example, Hebets (2003) conducted laboratory experiments with the wolf spider *Schizocosa uetzi* Stratton, 1997 (Lycosidae). He formed two groups of males, one with tibia I and patella I brown painted and the other with tibia I and patella I black painted, and exposed each group to juvenile females. When females matured, they were exposed again to these two groups of males. It was observed that females mated more frequently with males with familiar traits and cannibalized males with unfamiliar traits (Hebets, 2003).

Anelosimus vierae Agnarsson, 2012 is a Uruguayan subsocial spider. Individuals live in communal nests in evergreen trees. The mother cares for the young, and the juveniles show a lack of conspecific aggression. Males mature earlier and consistently disperse, resulting in inbreeding avoidance (Viera et al., 2007). Females can display one of two reproductive tactics depending on the availability of resource: they may remain in the nest with the mother and share the web with other sisters or they may disperse as subadults and build individual nests (Viera et al., 2007). Therefore, when males disperse from their natal nest, they may encounter one of two scenarios: a nest with many subadult females and one or a few adult females, or a nest made up of a single subadult female. These two scenarios will determine the reproductive tactics and mate preferences of males (Viera & Albo, 2008). Viera and Albo (2008) performed an experimental design simulating a nest made up of several females of *A. vierae*, which gave the males the possibility of choosing between females of different ages and reproductive status. These nests were made up of two adult females of different ages and a penultimate subadult female. All males courted at least one adult female, but no courtship was observed towards subadult females. On the other hand, Albo et al. (2007) simulated a nest made up of a single subadult female. In this scenario, the subadult female was exposed to two males. Subadult females were attractive to males, who courted and even fought among themselves. They also observed that the subadult females courted the males and adopted a receptive posture. In this position, males faced their pedipalps towards the epigynum area of the females and made several insertion attempts by drumming the epigynum of subadult females. They called this behavior 'pseudo-copula' because males were could not insert their copulatory organs due to a mechanical impediment, linked to the sexual immaturity of the female (Albo et al., 2007; Viera & Albo, 2008; Rojas-Buffet & Viera, 2015). Pseudo-copula has also been reported in the subsocial species *A. studiosus*, where authors have referred to these behaviors as "nonconceptive sexual behaviors" (Pruitt & Riechert, 2011, p. 790).

In this study, we described in details the courtship of *A. vierae* males towards penultimate females and their pseudo-copulatory behavior. We also evaluated the consequences and possible benefits of pre-copulatory sexual interactions between males and penultimate females. The following specific objectives were proposed: (1) to determine when, after the penultimate molt, females are receptive and/or pseudo-copulate with adult males; (2) to describe courtship and pseudo-copula in details; (3) to investigate whether penultimate females can modulate their development rates until reach adulthood, according to the occurrence of previous sexual experience; (4) to determine if there are differences in copulation latency between couples with previous sexual experience and sexually naïve couples; and (5) to determine if males prefer females that had sexual experience during their penultimate stage or sexually naïve females.

MATERIAL AND METHODS

COLLECTION AND MAINTENANCE

Nests of *A. vierae* were collected from several evergreen trees located in Parque Rodó, Montevideo, Uruguay (34° 54' 48" S, 56° 10' 2" W). The nests were transported in nylon bags to the laboratory of the Sección Entomología, Facultad de Ciencias, Montevideo, Uruguay. In the laboratory, individuals were sexed and raised separately in Petri dishes (4 cm in diameter and 1.2 cm high). All spiders were fed *ad libitum* with *Drosophila* spp. (Diptera) and were supplied with moisture, using cotton wool soaked in water.

EXPERIMENTAL STAGE

Receptivity, courtship, and pseudo-copula of penultimate females (specific objectives 1 and 2)

Penultimate females were used to form four groups (n = 30 per group), according to their age (i.e., number of days) since they molted to the penultimate stage:

- Group 1: three days after molting to penultimate.
- Group 2: ten days after molting to penultimate.
- Group 3: 20 days after molting to penultimate.
- Group 4: 25 days after molting to penultimate.

Each female was placed individually in a Petri dish (4 cm diameter and 1.2 cm high) she was exposed to an adult virgin male of a different nest (non-siblings) 24 h later. Each individual was used only once. The interactions between both individuals were recorded for 1 h, using a video camera (Sony DCRA-C151, 2.7" Wide Hybrid LCD, Handycam Station Supplied, 12x optical zoom, 800x digital zoom). The occurrence of courtship by males and females and the occurrence and number of instances of pseudo-copulations were recorded for each group. Courtship behavior was considered from the first courtship behavioral unit to the first pseudo-copula behavioral unit. The behavioral units involved in courtship and pseudo-copula were defined and described. Unit transition matrices were constructed for each sex in each couple and then the overall transition matrix was calculated for each sex (by consolidating all matrices). A flow chart was constructed to visualize the degree of association between the units. Z-value was calculated to determine which transitions occur more frequently than expected by chance. Z = values > 1.96 occur significantly more or less frequently than expected by chance. Based on the generally observed matrix and the expected matrix, Z is calculated as Z = [(observed frequency B|A ± 1 /2) – expected frequency B|A)]/standard deviation (Blumstein & Daniel, 2007). The durations and frequencies of behaviors were recorded. The videos were analyzed with the behavioral analysis program JWatcher (Blumstein et al., 2000).

After each trial, cephalothorax width of all individuals was measured to relate it to the characteristics of courtship and pseudo-copula. After the experiences where pseudo-copula occurred, the epigynous area of ten females were observed under a stereoscopic magnifying glass to rule out traumatic inseminations that the males could have carried out on the integument during pseudo-copula. After the experiments, the same females were raised individually in Petri dishes, until they naturally died, to record the day of molting to adulthood and the possibility of laying oothecae during the adult stage.

Modulation of the development rate until adulthood according to the occurrence of previous sexual experience (specific objective 3)

Females and males were reared individually in Petri dishes from juveniles. In the beginning, cotton was supplied with water and ENSURE supplement, because they cannot capture prey on their own during the first stages (Ghione et al., 2004). From the third instar, each individual was fed twice a week with the same amount of fruit flies (*Drosophila* spp.).

Two experimental groups were formed (n = 30 each):

- Group 1: a penultimate female 25 days after molting and an adult male.
- Group 2: a penultimate female 25 days after molting and a penultimate female.

Penultimate females were placed individually in Petri dishes (4 cm in diameter and 1.2 cm high), and after 24h, an adult male (group 1) or another penultimate female (group 2) was placed with her. In group 2, it was decided to place another penultimate female instead of an adult one to avoid their territorialism and the risk of cannibalism. Furthermore, it is common for penultimate females to coexist in nature (Viera et al., 2007).

The occurrences of receptive postures of penultimate females were recorded: ventral area up, and body axis inclined approximately 45° (Albo et al., 2007) and the occurrence of pseudo-copula. After 1 h, focus females were separated and returned to their Petri individual dishes. The development time of sexually experienced penultimate females (i.e., those that engaged in pseudo-copula or at least were receptive to male courtship) was monitored between (1) molting to the penultimate instar to adulthood and (2) from the day of the mating experience to adulthood. Both periods were compared with those of the females of the group 2. Cephalothorax width was measured and the weight of all focus females were measured to rule out that the latency to reach adulthood was related to the size and/or weight of the females.

Copulation latency as a consequence of previous sexual experience (specific objective 4)

The following five experimental groups were formed (n = 20 each):

- Group 1: Adult female and male with sexual experience (original dyad).
- Group 2: Adult female and male with sexual experience (new dyad).
- Group 3: Adult female with sexual experience and naive adult male.
- Group 4: Naive adult female and adult male with sexual experience.

- Group 5: Naive adult female and male.

For females, 'sexually experience' means that during their penultimate stage, they were exposed to adult males, and the 'naive' are those who, as penultimate, were never exposed to adult males. For males, 'sexually experience' means that during their adult stage, they were exposed to penultimate females, and the 'naive' are those who, as adults, were never exposed to penultimate females. All used individuals were virgins. For each experimental group, the female was placed in a Petri dish (4 cm in diameter and 1.2 cm high). After 24 h, the adult male was placed. Copulation latency was compared between the five experimental groups. Copulation latency was measured from the moment the male was placed in the Petri dish until the first palp was inserted into the female's genital opening.

Male preference (specific objective 5)

Three experimental groups were formed (n = 15 each):

- Group 1: Adult female and male with sexual experience (original dyad) and a sexually naive female.
- Group 2: Adult female and male with sexual experience (new dyad) and a sexually naive female.
- Group 3: Adult female with sexual experience and sexually naïve male and female.

The two females of each experimental group were placed at the same time in a Petri dish (5 cm in diameter and 1.2 cm high). After 24 h, the adult male was placed, as equidistant as possible from the females in all trails. We evaluated (1) male choice through the occurrence of copulation in the presence of both females and (2) competition between females through the occurrence of agonistic behavioral units such as chasing, chelicerae confrontation or biting that have been reported for this species (Santana et al., 2017). Both male choice and competition between females were evaluated during 2 h of observation. After each experience, cephalothorax widths of the experienced and non-experienced females of each group were compared to rule out that the male copulation with one or another female was affected by this variable.

STATISTICAL ANALYSIS

The results were analyzed with the PAST v program. 4.09 (Hammer et al., 2003). The normal distribution of the data was examined using the Shapiro-Wilk test and the homogeneity of variances with the Levene test. In cases with normality and homogeneity of variances, the parametric Student's t test was applied; otherwise, the Mann-Whitney U test was applied. To compare frequencies, Fisher's Exact test (used when expected frequencies in any cell of a contingency table are less than 5) or Chi-square test (used when all expected cell frequencies in the contingency table are greater than 5) were used.

RESULTS

RECEPTIVITY, COURTSHIP, AND PSEUDO-COPULA OF PENULTIMATE FEMALES

All the males courted all groups of females. But females of groups 1, 2, and 3 did not accept the courtship of the males, they did not court and there was no pseudo-copula. In the group 4, 80% of the penultimate females were receptive to the males' courtship and 54% of the receptive females pseudo-copulated. Courtship latency was 3.33 ± 4.72 min (mean and standard deviation). In all cases, courtship was initiated by the males. Courtship behavior had a total duration of 12.96 ± 9.68 min (range = 1.10 - 33.37 min; minimum and maximum).

Table 1 details the behavioral units involved in courtship. In summary, males approached the potential partners, while females approached or moved away from males. Males remained motionless in front of both females and then they began to tighten silk threads with their front legs. Receptive females responded to the males' courtship by approaching them and stretching threads in their direction. Following this, males and females extended their legs and palps, and females adopted the receptive posture, with the ventral area up, and body axis inclined approximately 45°, similar to that of adult females. In this position, males touched females with their front legs until pseudo-copula occurs (Figure 1).

The most frequent behavioral units of courtship in both sexes were: stillness (♂ = 18.61 ± 14.11 times/individual; ♀ = 25.77 ± 24.69 times/individual), silk thread tension (♂ = 16.92 ± 15.14 times/individual; ♀ = 15.54 ± 19.94 times/individual) and walk (♂ = 8.46 ± 8.71 times/individual; ♀ = 6.61 ± 10.36 times/individual).

Table 1. Description of the courtship behavioral units of males and penultimate of *A. vierae* females. Who performs each unit is indicated, whether male (♂), female (♀), or both sexes (♂, ♀).

Behavioral unit	Description	Sex
Abdominal vibration	Vertical oscillations of the abdomen	♂
Insertion attempt	Repeatedly touching the female's epigynum with one of the copulatory organs	♂
One leg extension	While still, extends and rotation one of the legs	♀
Silk thread tension	Tension and release of silk threads with leg I, II and III	♂, ♀
Touch	Touches the other sex with front legs	♂, ♀
Palps and legs extension	Extension of palps and anterior legs towards the other sex	♂, ♀
Stillness	Absence of movement	♂, ♀
Remoteness	Walks in the opposite direction from the couple	♂, ♀
Approach	Walks towards the couple	♂, ♀
Walk	Movement from one place to another sometimes also moving palps alternately	♂, ♀
Place silk threads	Walks and leaves silk threads	♂, ♀
Clean of legs and/or palps	Carries some of its legs or palps towards the chelicerae	♂, ♀

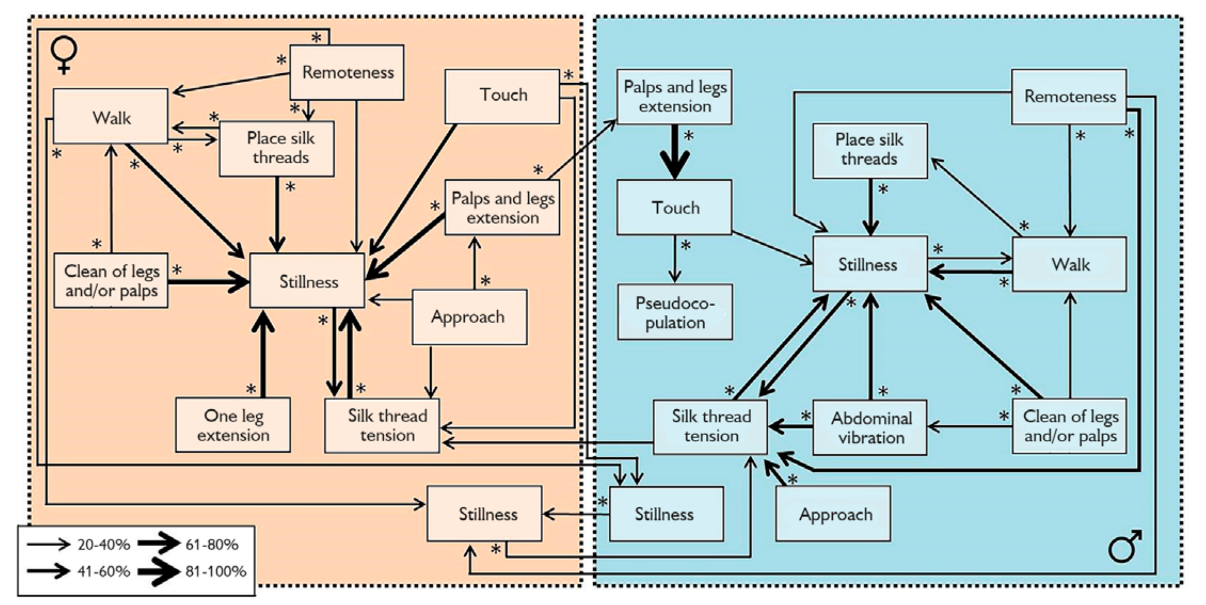

Figure 1. Flow diagram of courtship in *A. vierae* in pairs of an adult male and a penultimate female of 25 days after molting. The orange box represents the units performed by the females and the light blue box by the males. The thickness of the arrows indicates the probability of transition from one unit to the next. Only probabilities greater than or equal to 20% are represented for intra-sexual transitions, and those greater than or equal to 25% for inter-sexual transitions are represented. Asterisks indicate transitions that occur more frequently than expected by chance (with Z values > 1.96).

They are followed by abdominal vibration (6.31 ± 6.18 times/individual) in males; palps and legs extension (6.08 ± 7.26 times/individual) in females and one leg extension (5.77 ± 7.06 times/individual), also in females. The longest behavioral unit was stillness for both sexes (♂ = 6.79 ± 7.69 min; ♀ = 8.22 ± 6.31 min), followed by silk thread tension (2.13 ± 1.97 min) in males, and walk (1.44 ± 3.05 min) in females (Figure 2).

When investigating the influence of cephalothorax width of males and females on the duration of courtship, no significant relationship was found neither for males (F = 0.11; DFn = 1, DFd = 11; p = 0.74), nor for females (F = 0.51; DFn = 1, DFd = 11; p = 0.49). Only considering group 4, thirteen of the 30 dyads pseudo-copulated, and the latency was 16.00 ± 12.90 min from the beginning of the experience. Strictly, pseudo-copula involved three behavioral units. In males: attempt to insert the left palp and attempt to insert the right palp onto the epigynum; in females: extension of legs and palps in a receptive position. During each encounter, pseudo-copulations occurred in an average of 2.25 ± 0.87 instances. The duration of pseudo-copula (the sum of the durations of the pseudo-copulations instances) was 18.41 ± 11.64 s (range = 6.88 - 50.14 s) (Figure 3).

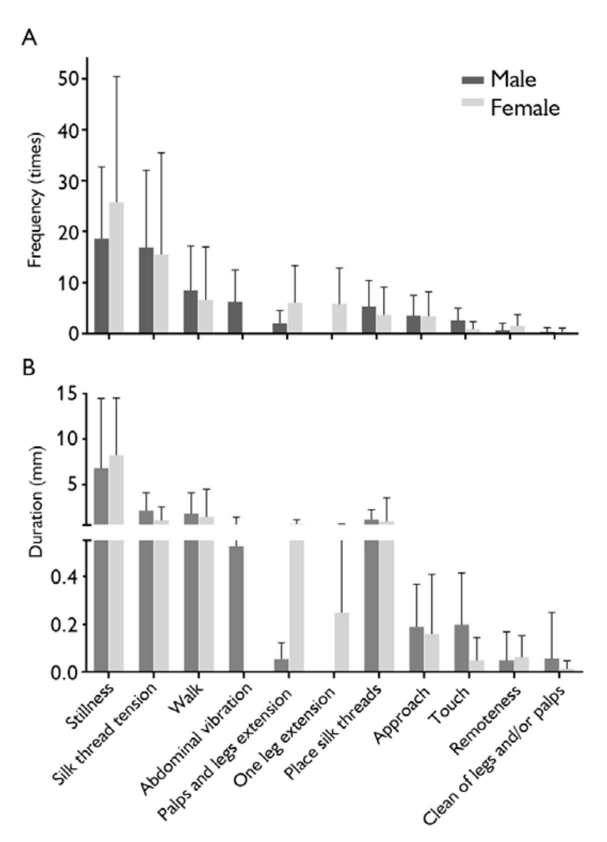

Figure 2. (A) Frequency and (B) duration of each behavioral unit involved in the courtship of adult males and penultimate females in *A. vierae*. The mean and standard deviation of the values are plotted.

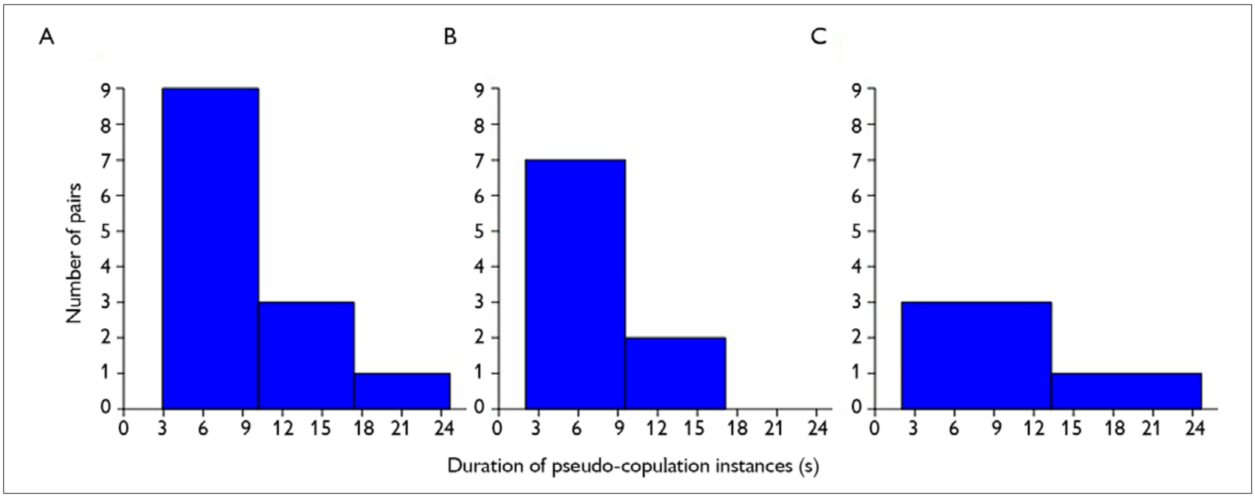

Figure 3. Histogram of pseudo-copula duration, during the first (A) (n = 13), second (B) (n = 9), and third instance (C) (n = 4). The 4th instance of pseudo-copulation is not depicted because it occurred in only one pair.

For the description of pseudo-copula, we considered all that occurred between the first unit involved during the first instance of pseudo-copulation to the last unit of the last instance of pseudo-copulation. Table 2 describes the units involved throughout the process and details of the units performed by both sexes. In summary, once the penultimate female accepted the male's courtship, she adopted the typical receptive posture of an adult female. In this position, the male made several insertion attempts, drumming the female's epigynum with one or both copulatory organs until one of the sexes moved away from the other. Pseudo-copulations may occur more than once during the same encounter, and in that case, the male continued with a new cycle of drumming until they moved away from each other and remained still. The units left palp insertion attempt and right palp insertion attempt had a frequency of 1.61 ± 1.12 times/individual for the left palp and 1.46 ± 1.26 times/individual for the right one, and a duration of 9.66 ± 7.46 s and 10.95 ± 9.30 s, respectively.

When investigating the influence of the cephalothorax widths of males and females on the duration of pseudo-copula, no significant relationship was found for males (F = 1.43; DFn = 1, DFd = 11; p = 0.26), or for females (F = 0.89; DFn = 1, DFd = 11; p = 0.36). No significant differences were found in the cephalothorax width of females that pseudo-copulated (0.99 ± 0.07 mm) and those that did not pseudo-copulate (1.01 ± 0.06 mm) (U = 89; p = 0.38). Likewise, no differences were found in the cephalothorax width of males that pseudo-copulated (1.04 ± 0.04 mm) and those that did not (1.03 ± 0.06 mm) (U = 108.5; p = 0.95).

No evidence of traumatic inseminations was observed in the 13 females analyzed and none of them laid egg sacs after reaching the adult stage. During the experiments, two females began the molting process into adults 27.82 ± 6.36 min after being exposed to the adult males (Figure 4A). Previously, both had been receptive to the males' courtship, but pseudo-copula did not occur. Females molted during the filming and males remained most of the time, immobile, although on some occasions both males carried out courtship units but not copulation attempts. Molting process lasted 28.10 ± 0.16 min. At the end, males approached females and courted them. Females were receptive and copulated (Figure 4B).

Table 2. Description of the pseudo-copula behavioral units of *A. vierae*. Who performs each unit is indicated, whether male (♂), female (♀), or both sexes (♂, ♀). RP: right palp; LP: left palp.

Behavioral unit	Description	Sex
LP insertion attempt	Makes several insertion attempts on the female's epigynum with the left palp	♂
RP insertion attempt	Makes several insertion attempts on the female's epigynum with the right palp	♂
Abdominal vibration	Vertical oscillations of the abdomen	♂
One leg extension	While still, extends and rotates one of the legs	♀
Touch	Touches the other sex with front legs	♂, ♀
Palps and legs extension	Extension of palps and anterior legs towards the other sex	♂, ♀
Silk thread tension	Tension and release of silk threads with leg I, II and III	♂, ♀
Clean of legs and/or palps	Carries some of its legs or palps towards the chelicerae	♂, ♀
Stillness	Absence of movement	♂, ♀
Remoteness	Walks in the opposite direction from the couple	♂, ♀
Approach	Walks towards the couple	♂, ♀
Walk	Walks and moves palps alternately	♂, ♀
Place silk threads	Walks and places silk threads	♂, ♀

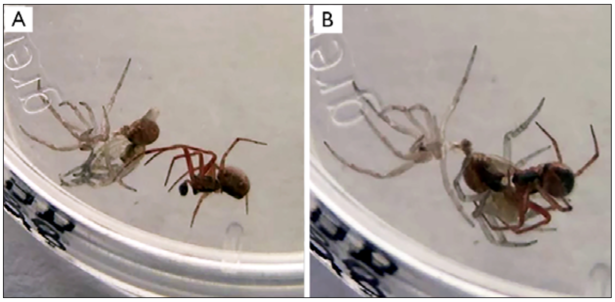

Figure 4. (A) Penultimate female molting into adult and adult male close to her. (B) Copulation of recently molted female. Photos taken from the filming.

The latency of copulation after molting differed greatly between both pairs, one of the pairs copulated after 1.67 min and the other after 55.13 min. The male of this last pair made numerous insertion attempts, and the difficulty was evident in inserting any of his copulatory organs into the still soft epigynum of the female. The total duration of copulation for one couple was 84.96 min and for the other couple was 93.78 min. Only one of the females laid an egg sac, and it was the female of the couple with the shortest copulation. The female laid the egg sac after 23 days of copulation, from which 23 viable offspring were born.

Modulation of the development rate until adulthood according to the occurrence of previous sexual experience (specific objective 3)

In the group 1, 90% of penultimate females were receptive and 10 of them performed pseudo-copula, so the development times of these 27 females were compared with those of the 30 females of group 2. Female maturation time from the penultimate instar in group 1 was 30.67 ± 5.06 days, and in group 2, was 31.10 ± 2.47 days (Figure 5). Besides, the time from the day of experience to adulthood was 5.67 ± 5.06 days for females of group 1 and 6.10 ± 2.47 days for females of group 2.

No significant differences were found between the maturation times since the females' penultimate molting in both groups (U = 319; p = 0.17). There were also no differences in the times from the day of the experiences to adulthood (U = 319; p = 0.17). Therefore, the latency towards the last molt in penultimate females with and without sexual experience was similar.

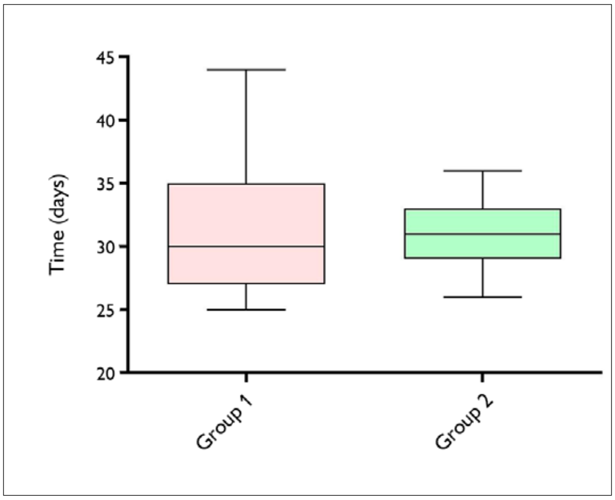

Figure 5. Box plot showing the time it took for the penultimate females of *A. vierae* to reach adulthood in both experimental groups.

When investigating the existence of significant differences in maturation times from the penultimate molting, separating within group 1 the females that pseudo-copulated (n = 10) from those that were receptive but did not pseudo-copulate (n = 17), no significant differences were found (U = 74; p = 0.42). No differences were found either between receptive females of group 1 and females of group 2 (U = 149.5; p = 0.13), or between pseudo-copulated females of group 1 and females of group 2 (U = 169.5; p = 0.51).

No significant differences were found in the groups between the cephalothorax width (Group 1 = 1.01 ± 0.06 mm; Group 2 = 0.99 ± 0.05 mm; U = 378; p = 0.67) and between the weight of females (Group 1 = 3.67 ± 0.63 mg; Group 2 = 3.39 ± 0.56 mg; t = 1.65; df = 55; p = 0.10).

Copulation latency as a consequence of previous sexual experience

Copulation occurred in all trials, and the copulation latencies for each experimental group were: group 1 (known experienced female and male) = 23.90 ± 14.48 min;

group 2 (unknown experienced female and male) = 24.07 ± 12.28 min; group 3 (experienced female and naïve male) = 37.36 ± 20.97 min; group 4 (naïve female and experienced male) = 47.37 ± 31.96 min; and group 5 (naïve female and male) = 44.12 ± 26.78 min.

When comparing copulation latency between the five experimental groups, significant differences were found (H = 13.03; p = 0.011). The copulation latency of group 1 was significantly lower than that of group 3 (U = 112; p = 0.018), group 4 (U = 113; p = 0.019), and group 5 (U = 111; p = 0.017). The copulation latency of group 2 was significantly lower than that of group 3 (U = 125.5; p = 0.045), group 4 (U = 118; p = 0.027), and group 5 (U = 114; p = 0.021). Figure 6 shows the copulation latency of the different experimental groups.

When evaluating differences in copulation latency between pairs in which at least one of the sexes previously pseudo-copulated (n = 36) and couples that were receptive but did not reach pseudo-copula (n = 44), no significant differences were found (U = 758.5; p = 0.75).

Male preference

All males in the three experimental groups courted at least one of the females. The males courted one of the two females more frequently, both in total, taking into account the three groups (χ^2 = 54.44, n = 45, p < 0.0001), and by group (Group 1: Fisher's Exact Test, n = 15, p = 0.0001; Group 2: Fisher's Exact Test, n = 15, p > 0.0001; Group 3: Fisher's Exact Test, n = 15, p = 0.0009). Likewise, males courted experienced females more frequently than sexually naive females, both in total (taking into account the three groups) (χ^2 = 35.28, n = 45, p > 0.0001), and by group (Group 1: Fisher's Exact Test, n = 45, p = 0.0001; Group 2: Fisher's Exact Test, n = 45, p = 0.0092; Group 3: Fisher's Exact Test, n = 45, p = 0.0025).

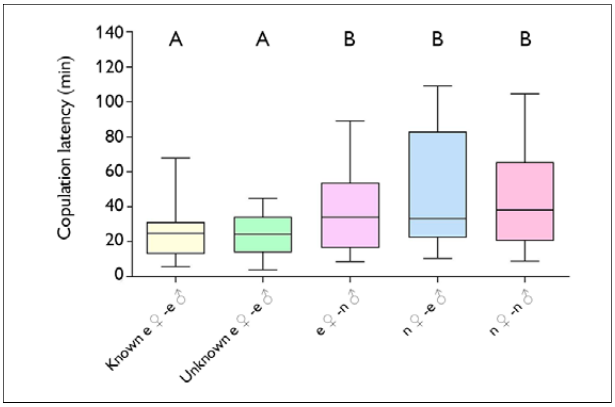

Figure 6. Box plot comparing copulation latency among the five experimental groups (test U for Mann Whitney). ♀: female; ♂: male; e: sexually experienced; n: sexually naive. Different Letters above the boxes denote significant differences between groups (p < 0.05).

In 29 experiences out of 45, it was exclusively the experienced females who courted the males (Group 1: n = 10; Group 2: n = 11; Group 3: n = 8), and in eight experiences it was exclusively the naive females (Group 1: n = 2; Group 2: n = 3; Group 3: n = 3). Only in two experiences of group 1 both females courted. In six trials, none of the females courted (Group 1: n = 1; Group 2: n = 1; Group 3: n = 4). The experienced females courted more frequently than the sexually naive ones in the total, taking into account the three groups (χ^2 = 20.84, n = 45, p < 0.0001), in Group 1 (Fisher's Exact Test, n = 15, p = 0.0025) and in Group 2 (Fisher's Exact Test, n = 15, p = 0.0092). In Group 3, there were no differences between the courtship frequency of both females (Fisher's Exact Test, n = 15, p = 0.128).

Copulation occurred in 93.3% of the pairs in group 1, in 86.7% of the pairs in group 2, and in 73.3% of the pairs in group 3. In cases where copulation did not occur, all males courted but none of the females were receptive. All the males that copulated did so with a single female. When analyzing the total (taking into account the three groups), it was observed that copulations were more frequent between sexually experienced males and females (χ^2 = 19.95, n = 45, p < 0.0001). Similarly, in groups 1 and 2, copulations occurred more often between sexually experienced males and females (Group 1: Fisher's test, n = 15, p = 0.0007; Group 2: Fisher's test, n = 15, p = 0.025). In all experiences in which experienced males and females copulated, both individuals courted. In eight experiments the experienced females were the ones that actively began courtship (Group 1: n = 5; Group 2: n = 3). In two experiments in Group 2, naive females initiated courtship, but males copulated with experienced females. In all cases of copulations between males and naive females, only the naive females courted. In Group 3, no differences were found in the frequency of copulations with experienced and naive females (Fisher's Exact Test, n = 15, p = 0.128) (Figure 7). In this group, in all cases of copulations between males and experienced females, only the experienced females courted, and in all cases of copulations with naïve females, only the naïve females courted. So females courted males in all copulation cases. The duration of courtship and copulation (in minutes) of the three experimental groups are shown in Table 3.

No significant differences were found between the body sizes of the experienced females and the naive ones in each group (Table 4). During the experiments, no disturbances of the copulating pair by the other female were recorded, as well as no agonistic behavioral units such as chasing, chelicerae confrontation or biting between the adult females.

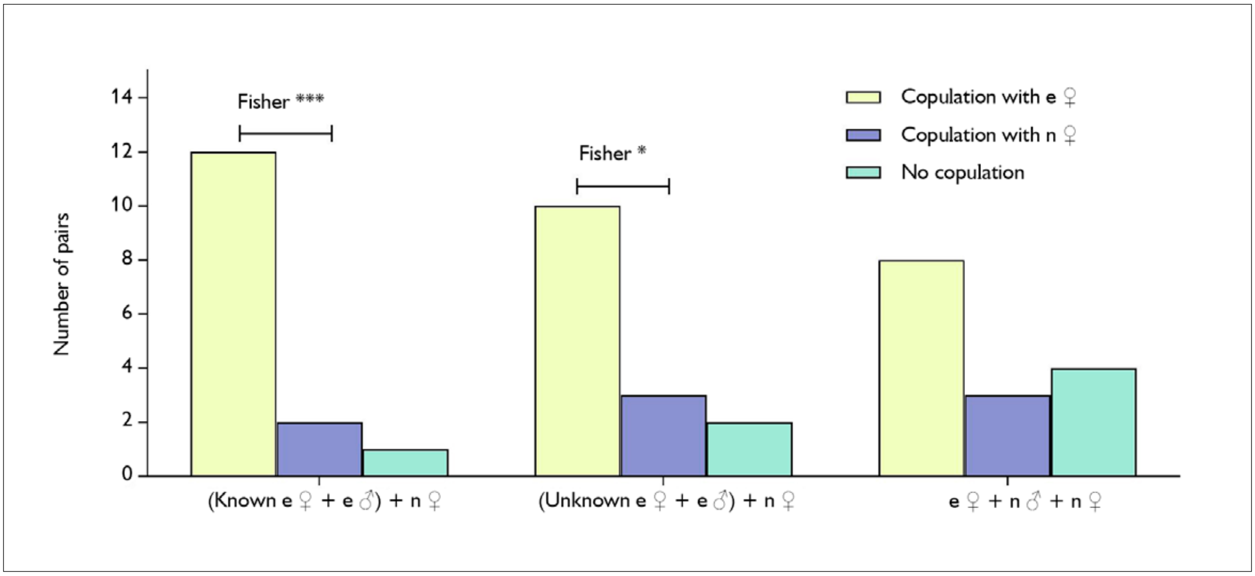

Figure 7. Number of copulations for each experimental group, between males and experienced females (e♀) and naïve females (n♀). Significant differences are shown with asterisks: * = p < 0.05; *** = p < 0.005.

Table 3. Courtship and copulation durations (in minutes) in males with experienced females (e♀) and with naïve females (n♀) for each experimental group. Values are shown as the mean ± standard deviation.

	Group 1		Group 2		Group 3	
	e♀	n♀	e♀	n♀	e♀	n♀
Courtship latency	4.34 ± 11.09	11.10 ± 8.88	3.29 ± 3.88.09	0.75 ± 0.62	1.73 ± 1.70	9.49 ± 12.73
Courtship duration	27.73 ± 17.95	17.00 ± 6.20	32.86 ± 19.12	10.65 ± 6.41	13.14 ± 8.83	12.93 ± 7.60
	n = 14	n = 3	n = 12	n = 4	n = 13	n = 4
Copulation latency	27.23 ± 21.22	21.62 ± 8.84	36.20 ± 21.47	13.81 ± 5.40	11.22 ± 6.96	23.85 ± 13.53
Copulation duration	106.86 ± 54.07	95.49 ± 4.62	69.39 ± 21.32	115.17 ± 88. 13	77.79 ± 10.55	76.89 ± 14.21
	n = 12	n = 2	n = 10	n = 3	n = 8	n = 3

Table 4. Comparison (Mann Whitney U test) of body size (cephalothorax width) between experienced females (e♀) and naïve females (n♀) from the three experimental groups. Values are shown as the mean ± standard deviation.

	Group 1		Group 2		Group 3	
	e♀	n♀	e♀	n♀	e♀	n♀
Cephalothorax width (mm)	1.04 ± 0.05	1.04 ± 0.06	0.99 ± 0.25	0.98 ± 0.25	0.97 ± 0.24	0.99 ± 0.25
Statistic	U = 103.5; p = 0.72		U = 108.5; p = 0.88		U = 96; p = 0.51	

DISCUSSION

All penultimate females of *A. vierae* at 3, 10, 20, and 25 days were attractive to males. In nature, it is common to observe males of this species cohabiting nests made up of penultimate females (Viera et al., 2007). This is because, although the primary sex ratio of *A. vierae* is 1:2, biased towards females, females mature asynchronously and later than males. Consequently, at the beginning of the reproductive season, the operational sex ratio is biased towards males, with second-to-last females being common (Viera et al., 2007). For this reason, penultimate females can be attractive to males. The attractiveness of penultimate females varies between species. For example, in the subsocial species of the same genus, *A. arizona*, penultimate females are unattractive to males, and male guardings are not very common in nature (Klein et al., 2005).

Although males courted penultimate females of all four ages, 3, 10, and 20-day-old, females were not receptive and rejected courtship from adult males. Coexistence between adult males and penultimate females in nature could be costly for young penultimate females, since males do not cooperate in communal activities (Viera et al., 2007), therefore, there would be costs associated with time and/or energy by rejecting them (Albo et al., 2007). There are studies on spiders that show that, although some females are attractive to males, they are not necessarily receptive. For example, *Schizocosa malitiosa* (Tullgren, 1905) males are highly attracted to chemical trails of virgin females, but they are also attracted to non-receptive females carrying oothecae (Baruffaldi & Costa, 2010).

Only the penultimate females close to maturity (i.e., 25 days after molting to penultimate) accepted the courtship of the males and were receptive to mating attempts. Males began the courtship and carried out the same courtship units as in the presence of adult females (Viera & Albo, 2008). As in adult pairs, the behavioral unit most used during the courtship of males exposed to penultimate females was the tension of the silk threads with front legs. Penultimate females were active during the encounters, courted and indicated their receptivity by approaching and extending their legs and palps towards males. They also exhibit the receptive posture characteristic of the adult female.

Although many of the penultimate females close to the next molt were receptive to the males' courtship and adopted the copulatory posture typical of adult females, pseudo-copula behavior did not turn out to be as frequent as expected. Pseudo-copula occurred only in cases in which males got close enough to females and made multiple insertion attempts. Therefore, males would be the ones promoting pseudo-copula behavior. No behaviors of males that seemed to be forcing females to pseudo-copulate were observed. Thus, sexual conflict (Arnqvist & Rowe, 2005; Chapman, 2006) in relation to this behavior would be ruled out in this species). It would be interesting to evaluate the circumstances that cause this behavior to occur in the future. Considering that no significant differences were found between the size of the individuals involved in pseudo-copulations and those who did not, this variable would be ruled out as influential in this behavior occurrence.

The pseudo-copula duration in *A. vierae* was, comparatively, of very short duration as none of the couples reached a minute. This differs from what was found by Albo et al. (2007) for the same species, in which pseudo-copula had a duration of 13.8 ± 17.7 min. Some of the causes of this inequality could be differences in the age of the penultimate females used (in Albo et al., 2007, they were penultimate in general, while they were penultimate after 25 days of molting in this study); and in the duration of the observations (in Albo et al., 2007, it was 4 h, while it was 1 h in this study). In the species *Anelosimus studiosus* (Henz, 1850), Pruitt & Riechert (2011) also found a longer duration of pseudo-copula (more than half an hour). In this work the observations also had the same duration as in Albo et al. (2007).

Pseudo-copula in *A. vierae*, in addition to being a short-term behavior, was an intermittent behavior and occurred in several instances throughout the observations. This is expected due to the simple contact that the male's copulatory bulb has with the female's epigynum, which is not introduced because the genital openings are not fully developed. Pseudo-copulation frequencies of *A. vierae* also varied in relation to those found by Pruitt and Riechert (2011) in *A. studiosus.* Instances of pseudo-copulation in *A. vierae* averaged two per pair, while in *A. studiosus* there were eight.

Albo et al. (2007) suggested that pseudo-copula could have benefits for both sexes. The penultimate females that have this physical stimulus would accelerate their maturation and synchronize the couple's mating. However, the results of this study show that females that pseudo-copulate, as well as those that have sexual experience without pseudo-copulating and those that are sexually naive, had similar maturation rate. Thus, in this species, there would be no effect of early sexual experience on the rate of female development.

In two cases, mating occurred after the maturation molt process. Mating just after the final molt of females is a common strategy in male spiders to avoid sexual cannibalism. Males copulate with these females while their exoskeleton is still soft, and their ability to move and attack them is diminished (Robinson & Robinson, 1980; Foelix, 2011; Uhl et al., 2015). However, this does not seem to be the case in *A. vierae*. In the first instance, females began the molting process sometime after we placed the males in their containers. The most surprising thing was that, after molting, they were receptive and copulated easily, without having their exoskeleton completely sclerotized. Despite not having found that penultimate females accelerate their maturation molt by having sexual contact with adult males, these two cases of maturation in the presence of males could be a sexual strategy that females adopt to copulate quickly. Males would also gain benefits from staying close to these females waiting for them to molt into adults. On the one hand, males would ensure that they were the first to copulate with these females, and on the other hand, they would avoid the risks of predation when moving from one nest to another. In addition, males could avoid the high probability of encountering other male(s) by dispersing to another nest and having to compete for access to the female (Viera & Albo, 2008).

Copulation latency in couples with sexual experience, both known and unknown, is lower than in couples consisting of at least one of the sexes had no previous sexual experience. In *A. vierae*, it is not enough for either sex to have had previous sexual experience for copulation latency to decrease, but both individuals must have had it. If pseudo-copula were a sexual rehearsal, it was expected that in pairs made up of at least a single experienced individual, copulation latency would also decrease (Burghardt, 2005).

Early sexual experience in *A. vierae* could confer benefits for both sexes. Mating earlier would be a benefit for males due to their behavioral strategies. Satellite males usually try to supplant dominant males and/or disturb their copulations (Foellmer & Fairbairn, 2005; Albo et al., 2007; Rojas-Buffet & Viera, 2015; Stoffer et al., 2016). Therefore, males that mate more quickly with females are less likely to be supplanted before mating. On the other hand, Pruitt and Riechert (2009) found that high mating rates in *A. studiosus* are associated with a reduction in the risk of sexual cannibalism. Males that are faster at copulating are more likely to survive and can mate with more females. This would not be happening with *A. vierae* males since no cases of sexual cannibalism have been observed in this species.

A. vierae females would also gain benefits from mating earlier. Because they are polyandrous (Albo et al., 2007; Viera et al., 2007; Rojas-Buffet & Viera, 2015), mating more quickly would allow them to copulate with several males during their reproductive period. Although polyandry is a common phenomenon in a wide range of arthropod taxa (Arnqvist & Nilsson, 2000; Jennions & Petrie, 2000), the benefits for females are not so clear. The costs of having multiple copulations, for both males and females, are well documented in nature. Increased risk of physical injury, predation, and disease transmission are some of the known costs (Daly, 1978; Parker, 1979; Hurst et al., 1995; Blanckenhorn et al., 2002). Therefore, the benefits that females obtain from mating with multiple males must outweigh these costs. Some of these benefits may be to compensate for possible errors in mate choice and/or poor quality of previous copulations (Petrie & Kempenaers, 1998), to promote sperm competition processes and/or cryptic female choice, increasing the probability of fertilization by sperm (males) of high quality (Madsen et al., 1992; Birkhead, 1998) and to increase the genetic variability of the offspring, protecting the progeny against environmental uncertainties (Loman et al., 1988).

Sexually experienced males of *A. vierae* prefer to copulate with experienced females, regardless of whether they are known or unknown. This preference may be mediated by differences in female behavior. Experienced females courted more than naive ones perhaps also used different pheromones. In contrast, naive males do not show a preference in copulating with experienced or naive females. Apparently, there would be recognition between individuals who had sexual experience, but naive males would not distinguish females with and without experience. These results agree with those obtained in copulation latency experiences. Couples made up of both sexually experienced individuals obtain benefits in reproductive terms.

In conclusion, the sexual behavior of mature males and immature females of *A. vierae* has positive implications for future sexual encounters. Firstly, pairs consisting of individuals with prior sexual experience copulated more quickly than pairs in which at least one individual lacked such experience. Secondly, individuals with prior sexual experience showed a preference for mating with others who also had previous sexual experience.

In the future, it would be interesting to evaluate whether pseudo-copulated females invest more energy in the offsprings of the males with whom they pseudo-copulated. This was demonstrated in the species *A. studiosus*, where pseudo-copulated females invest more energy in the ootheca cover, prioritizing the offspring of males that pseudo-copulated with them, suggesting a sexual preference for these males (Pruitt & Riechert, 2011). Two groups of copulations could be carried out: females with males that pseudo-copulated and females with males that did not pseudo-copulate, and compare the number of clutches, eggs, spiderlings, weight of the oothecae and weight of the offspring. Furthermore, it would be interesting to assess the consequences of courtship between penultimate females and adult males, as well as pseudo-copulation, by evaluating not only the presence or absence of these behaviors but also their duration and intensity, as these factors could provide valuable insights into their outcomes, including potential influences on reproductive success or other fitness-related aspects, and serve as important elements for understanding their ecological and evolutionary significance.

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AUTHOR'S CONTRIBUTION

C. Rojas-Buffet contributed to formal analysis, funding acquisition, data curation, writing (original draft), investigation and methodology; C. Viera contributed to project administration, funding acquisition, conceptualization, writing (review and editing), methodology and supervision.

First description of the female and a new junior synonym of *Corythalia vervloeti* Soares & Camargo, 1948 (Araneae: Salticidae: Euophryini)

Primeira descrição da fêmea e um novo sinônimo júnior de *Corythalia vervloeti* Soares & Camargo, 1948 (Araneae: Salticidae: Euophryini)

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Abstract: The female of *Corythalia vervloeti* Soares & Camargo, 1948 is described and illustrated for the first time. *Eustiromastix efferatus* Bauab-Vianna & Soares, 1978 is considered a junior synonym of *Corythalia vervloeti* based on the original description and illustrations of the former. New records expand the known distribution of the species throughout the Atlantic Forest, Pantanal, and the Brazilian and Ecuadorian Amazon. The position of *C. vervloeti* within the genus is discussed.

Keywords: Taxonomy. Neotropical region. Jumping spiders. *Eustiromastix*.

Resumo: A fêmea de *Corythalia vervloeti* Soares & Camargo, 1948 é descrita e ilustrada pela primeira vez. *Eustiromastix efferatus* Bauab-Vianna & Soares, 1978 é considerado um sinônimo júnior de *Corythalia vervloeti* com base na descrição e nas ilustrações originais. Novos registros expandem a distribuição conhecida da espécie pela Mata Atlântica, pelo Pantanal e pelas regiões amazônicas do Brasil e Equador. A posição de *C. vervloeti* dentro do gênero é discutida.

Palavras-chave: Taxonomia. Região neotropical. Papa-moscas. *Eustiromastix*.

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INTRODUCTION

The euophryine genus *Corythalia* C.L. Koch, 1850 is endemic to the Americas and has been the focus of a recent taxonomic revision, in which all South American species were redescribed and 20 new species were described for the region (Bayer et al., 2020). The genus currently includes 89 valid species, of which 46 are known only from either males or females (World Spider Catalog, 2024; Framenau et al., 2024). Finding and matching the unknown opposite sex for each of those species can be challenging, especially due to the lack of geographical, phenological or biological data (see Edwards, 2014).

Corythalia vervloeti Soares & Camargo, 1948 is a remarkable species within the genus, unique in having an extremely long embolus accommodated in a depressed portion of the tegulum (Bayer et al., 2020). The few published distribution records of the species show it is widely distributed from the Central Amazonia to southern Brazil (Bayer et al., 2020; Soares & Camargo, 1948). Surprisingly, despite its wide distribution, *C. vervloeti* is yet known only from the male. In this paper, we describe the female of the species for the first time, add new mapped distribution records, propose *Eustiromastix efferatus* Bauab-Vianna & Soares, 1978 as a new synonymy of the species and discuss its position within the genus.

MATERIAL AND METHODS

The examined material is deposited in the following collections (abbreviations and curators in parentheses): Centro de Coleções Taxonômicas, Universidade Federal de Minas Gerais, Belo Horizonte (UFMG, Adalberto J. Santos), Instituto Butantan, São Paulo (IBSP, Antonio D. Brescovit), Laboratório de Diversidade de Aracnídeos, Universidade Federal do Rio de Janeiro (UFRJ, Renner L. C. Baptista), Museu Paraense Emílio Goeldi, Belém (MPEG, Alexandre B. Bonaldo). For illustration of internal structures of female genitalia, soft tissues were digested in a pancreatin solution, following Álvarez-Padilla and Hormiga (2007), and examined immersed in clove oil. Male palp was expanded in warm latic acid for a few minutes, followed by immersion in de-ionized water until the full inflation of the haematodochae. Images were obtained with a Leica DFC500 digital camera attached to a Leica M205C stereomicroscope. Multifocal images were stacked from subimages using Helicon Focus version 8.0.2 (Helicon Soft, n. d.). The morphological terminology, leg spination pattern and measurements follows Bayer et al. (2020). All measurements are in millimeters and were taken using a linear micrometric reticle attached to the eyepiece of an Olympus SZ40 stereomicroscope, or from digital images using the software ImageJ (Schneider et al., 2012). Lists of examined material and descriptive characters were generated using Magalhães (2019) spreadsheets. Maps were produced using ArcGis version 10.2 (ESRI, 2013). Coordinates missing from specimen labels were inferred using Google Maps and are indicated in brackets instead of parentheses.

TAXONOMY

Family Salticidae Blackwall, 1841
Subfamily Salticinae Blackwall, 1841
Tribe Euophryini Simon, 1901
Genus *Corythalia* C.L. Koch, 1850
Corythalia vervloeti Soares & Camargo, 1948
(Figures 1, 2, 3, 4, 5B, 5D)

Corythalia vervloeti Soares & Camargo, 1948, p. 429, figures 12–14 (♂, description and illustration). ♂, Holotype from Brazil: Espírito Santo: Colatina: Rio São José, [19° 30’ S, 40° 40’ W], B.A.M. Soares coll. 14/IX/1942, deposited in Museu de Zoologia da Universidade de São Paulo (MZUSP E.454-C.1122), not examined. Bayer et al. (2020, p. 108, figures 52A–52B, 60G, 67I–67J, 70J) (description and illustration of ♂).

Eustiromastix efferatus Bauab-Vianna & Soares, 1978, p. 360, figures 7–12 (♂, description and illustration). ♂, Holotype from Brazil: Amazonas: Humaitá, [7° 29’ S, 63° 1’ W], Gasparini & Gogoy coll., 19/III/1976, originally deposited in Departamento de Zoologia do IBBMA, UNESP, lost. syn. nov.

Material examined. BRAZIL. Acre: Rio Branco, Campus Embrapa (10° 1' 30.8" S, 67° 41' 35,9" W), M.S. Costa coll., IX/2013, 2 ♂ (UFMG 19622). Amazonas: Manaus, Reserva Florestal Adolpho Ducke, near the camping site (2° 55' 48.3" S, 59° 58' 26,5" W), A.A. Bustamante & D. Queiroga coll., 29/III/2023, 1 ♀ (UFMG 29983). Bahia: Ilhéus, CEPLAC, Reserva Zoobotânica (14° 46' 22,7" S, 39° 13' 13,8" W), G.H.F. Azevedo & A.J. Santos coll., 8– 9/XII/2010, 1 ♂ (UFMG 9474); Porto Seguro, RPPN Estação Vera Cruz [16° 27' 0" S, 39° 3' 52" W], J.P.S. Alves coll., 2005–2006, 1 ♀ (IBSP 62668); Salvador, Cabula, Campus do 19° Batalhão de Caçadores [12° 57' 1" S, 38° 23' 21" W], C.M. Pinto-Leite coll., 2005, 1 ♀ (IBSP 71589); Parque Joventino Silva [12° 59' 47" S, 38° 28' 25" W], M. Martins coll., 2012, 1 ♀ (IBSP 248246). Espírito Santo: Alegre, Instituto Federal do Espírito Santo, Distrito de Rive (20° 45' 16" S, 41° 27' 11" W), A.S. Michelotto & M.S. Amorim coll., 9/X/2019, 1 ♂ (UFMG 27817); Polo de Educação Ambiental da Mata Atlântica (PEAMA), IFES Campus de Alegre (20° 45' 45" S, 41° 27' 45.6" W), A.S. Michelotto coll., 31/X/2022, 1 ♂ (UFMG 29266); Linhares, Reserva Florestal da Companhia Vale do Rio Doce [19° 6' 17.6" S, 39° 52' 20.6" W], A.D. Brescovit et al. coll., 1 ♂ (IBSP 24395); Sooretama, REBIO Sooretama, trilha informativa [19° 0' 10.8" S, 40° 7' 35.4" W], D.T. Castro coll., 7/XI/2009, 1 ♀ (UFRJ 2238). Mato Grosso do Sul: Corumbá, Passo do Lontra (19° 30' S, 56° 55' W), J. Raizer coll., 1 ♂ (IBSP 239610). Minas Gerais: Marliéria, Parque Estadual do Rio Doce (19° 39' 30.7" S, 42° 34' 32,2" W), 1–8/VII/2003, 1 ♂ (UFMG 16491); 19–26/X/2000, 1 ♂ (UFMG 16490); (19° 39' 30.7" S, 42° 43' 32.2" W), VII– XI/2002, 2 ♀ (UFMG 16424); 2–9/XI/2000, 1 ♀ (UFMG 16421). Pará: Altamira, Novo Progresso (7° 7' 41" S, 55° 25' 31" W), J.O. Dias coll., 19/XI/2005, 1 ♂ (MPEG 4383); Belém, Mata da UFRA [1° 27' 23" S, 48° 26' 26" W], G. Nerino coll., 18/VIII/2006, 1 ♂ 1 im. (MPEG 4167). Rio de Janeiro: Cachoeiras de Macacu, Poço do Anil, Povoado de Guapiaçu (22° 29' 37.1" S, 42° 51' 45.6" W), V.S.R. Diniz & B.T. Faleiro coll., 22/IX/2015, 1 ♀ (UFMG 21021); Reserva Ecológica de Guapiaçu, P2, São José [22° 27' 13" S, 42° 46' 14.5" W], R.L.C. Baptista coll., 2/IX/2017, 1 ♀ (UFRJ 2194); Macaé, Restinga de Jurubatiba, Fazenda São Lázaro [22° 12' 12.6" S, 41° 30' 0.4" W], 27/III/2010, 1 ♀ (UFRJ 2241); Terminal Cabiúnas, mata da Odebei, P3 [22° 17' 0.6" S, 41° 43' 4.8" W], D.R. Pedroso coll., 14/VIII/2014, 1 ♂ (UFRJ 2243). Rondônia: Candeias do Jamari, Usina Hidrelétrica de Samuel, Rio Jamari [8° 45' 2.7" S, 63° 27' 18.7" W], Equipe IBSP coll., XII/1988, 1 ♀ (IBSP 6687). ECUADOR. Sucumbíos: Shushufindi, Cabañas Limoncocha (0° 22' 29.50" S, 76° 35' 37.3" W), A. Anker & P.H. Martins coll., 25-28/I/2018, 1 ♀ (UFMG 34485).

Diagnosis. Males can be distinguished from any other *Corythalia* species by the following combination of characters: an extremely long embolus that wraps around its own axis twice over a recessed tegular region, a broad and dorsally serrated retrolateral tibial apophysis, and a tegular lobe less than half the maximum width of the tegulum (cf. Bayer et al., 2020, figures 52A–52B). Females can be distinguished from any other *Corythalia* species by the following combination of characters: epigynal window forming an inverted heart shape of continuous margins. Copulatory openings located on the inner parts of the posterior margins of the epigynal window (Figures 1A, 1C). Secondary spermathecae reduced. Extremely long and complex connecting ducts, which loop around their own axis three times and ventrally meet the primary spermathecae (Figures 1B, 1D–1F), visible through cuticle (Figure 2G).

Description. Male. See Bayer et al. (2020).

Female (UFMG 16421). Total length 4.65, carapace length 2.12, maximal width 1.10, height 1.05; width of ocular rectangle 1.38, fovea length 0.13. Opisthosoma length 2.23, width 1.68. Eye diameters and interdistances: anterior median eye (AME) 0.40, anterior lateral eye (ALE) 0.25, posterior median eye (PME) 0.05, posterior lateral eye (PLE) 0.25, AME–AME 0.05, AME–ALE 0.05, PME–PME 1.18, PME–PLE 0.23, ALE–PLE 0.60, PLE–PLE 0.98. Clypeus height at

AME 0.13, at ALE 0.48. Spination: palp, no spines. Legs, femur I 0200, II 0100, III–IV 0600; patella I–II, III–IV 1010; tibia I–II 2002, III 2123, IV 2112; metatarsus I 3042, II 3021, III 3132, IV 4220. Measurement of palp and legs: palp 1.76 [0.60, 0.33, 0.28, 0.55]. Leg I 3.17 [1.03, 0.53, 0.63, 0.60, 0.38], II 3.17 [1.05, 0.53, 0.58, 0.63, 0.38], III 3.98 [1.25, 0.60, 0.78, 0.95, 0.40], IV 4.48 [1.35, 0.60, 0.95, 1.13, 0.45]. Leg formula: 432=1. Copulatory organs: epigynal field slightly wider than long, the connective ducts visible through cuticle (Figure 2G). Epigynal windows shaped like an inverted heart, continuous margins with a very thin septum, diverging anteriorly into a 'Y', the copulatory openings start in the inner part of the posterior margins of the windows (Figures 1A, 1C), copulatory ducts 2x longer than wide, secondary spermatheca conical, longer than wide, heads positioned postero-laterally, connective ducts (between primary and secondary spermathecae) starting in touch to the edge of anterior margins of the epigynal windows, rising upwards near to the limits of the epigynal field, running a half turn, descending to the posterior part of the septum of the windows, looping around their own axis two times, running a half turn, twisting into an S-shape, looping once more through the center (Figures 1E–1F) and finally ventrally meeting the primary spermatheca. Primary spermathecae 1.5x wider than the connective ducts, bean-shaped, longer than wide. Fertilisation ducts, visible arising centro-anteriorly, comma-shaped, bent ectally (Figure 1D). Coloration: *pars cephalica* of carapace black with greenish iridescent scales (Figure 2D), *pars thoracica* dark-brown, chelicerae dark brown. Labium and endites yellow. Palps yellow. Sternum brown.

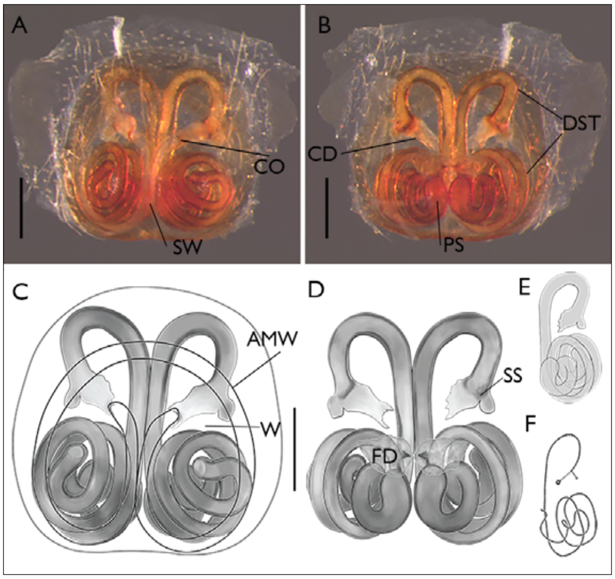

Figure 1. Female genitalia of *Corythalia vervloeti* Soares & Camargo, 1948 (UFMG 21021): A) epigyne (ventral view); B) vulva (dorsal view); C) epigyne (cleared, ventral view); D) vulva (same, dorsal view); E) same, with transparency; F) schematic course of internal duct system, the circle shows copulatory opening, the dashed line indicates copulatory duct, the bifurcation indicates the start of the connection to the secondary spermatheca, and the arrow points to the base of fertilisation duct. Abbreviations: W: epigynal window; AMW: anterior margin of epigynal window; SW: septum of the epigynal windows; CO: copulatory opening; CD: copulatory duct; PS: primary spermathecae; SS: secondary spermathecae; DST: connective duct between secondary spermathecae and primary spermathecae; FD: fertilisation ducts. C–E, Drawings by Leonardo Ferreira-Sousa. Scale bars: A–D: 0.2 mm.

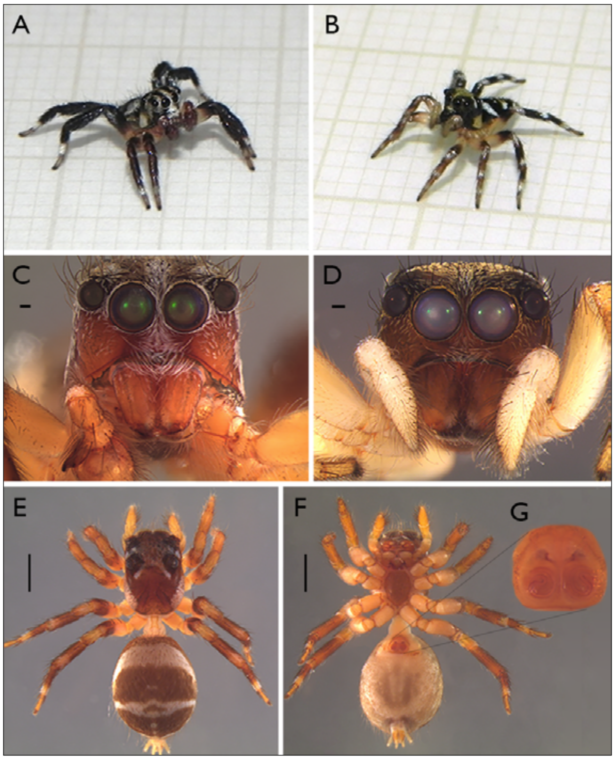

Figure 2. Habitus of *Corythalia vervloeti* Soares & Camargo, 1948: A) male on graph paper (UFMG 29266); B) female on graph paper (UFMG 29983); C) male frontal view (UFRJ 2243); D) female frontal view (UFMG 29983); E) female, dorsal view (UFMG 16424); F) same, ventral view; G) detail of undissected epigyne. Scale bars: C–D: 0.1 mm; E–F: 1 mm.

Legs predominantly yellow at coxae, trochanteres, metatarsi and femur (only anteriorly), the rest of the articles brown with whitish posterior tips. Opisthosoma brown, with 3 longitudinal white markings build of pigmentation and light scales, the medial form somewhat like a black chevron inside, ventrally grayish-yellow (Figures 2E–2F).

Natural history. Specimens were found in low shrub vegetation and in lianas more than 2 meters above the ground.

Synonymy note. *Eustiromastix efferatus* Bauab-Vianna & Soares, 1978 was misclassified within the Freyina and is indicated as a probable member of Euophryini, according to Edwards (2015). It is herein considered a junior synonym of *C. vervloeti* based on the published illustrations of the original description (Bauab-Vianna & Soares, 1978), which shows the extremely long embolus that wraps around its own axis twice over a recessed tegular region, a broad and dorsally serrated retrolateral tibial apophysis, and a proximal tegular lobe less than half the maximum width of the tegulum (Figures 3A–3B), in addition to the same white markings that adorn the carapace and opisthosoma (Figures 2A–2D; Bauab-Vianna & Soares, 1978, figures 7–12; Bayer et al., 2020, figures 52A–52B, 60G, 67I–67J, 70J). All these characters are all diagnostic of *C. vervloeti*, and are not seen in any other species of the genus.

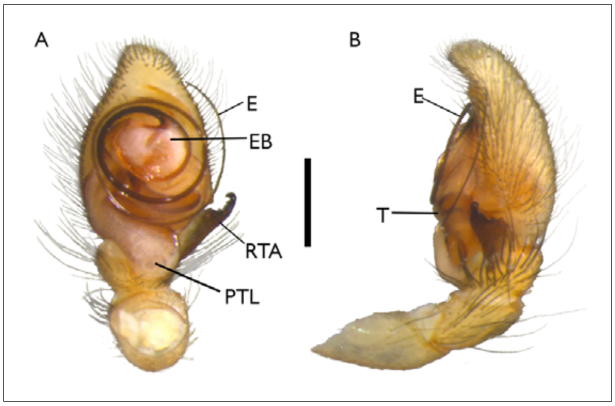

Figure 3. Male left palp of *Corythalia vervloeti* Soares & Camargo, 1948 (UFMG 29266): A) ventral view; B) retrolateral view. Abbreviations: E: embolus; EB: embolus base; T: tegulum; PTL: proximal tegular lobe; RTA: retrolateral tibial apophysis. Scale bars: A–B: 0.2 mm.

Remarks. The female was matched with the male based on records in the same locality and microhabitats. Furthermore, its extremely long connective ducts correspond well to the extremely long embolus of males (Figure 3), as well its somatic characters, colouration and markings (Figure 2).

Distribution. Known from Brazil, in the coastal and mountainous regions of the Atlantic Rainforest, from Bahia to Paraná, in the Pantanal of Mato Grosso do Sul, and in the Amazonian states of Acre, Amazonas, Pará, and Rondônia (Figure 4). It has also been recorded in the Amazon region of Ecuador, in Sucumbíos Province. Previously, the species was known only from Brazil, in the states of Amazonas, Espírito Santo, and Paraná (Bayer et al., 2020).

Comparative material. *Corythalia latipes* (C.L. Koch, 1846) (Figures 5A, 5C).

Material examined. BRAZIL. Bahia: Contendas do Sincorá, Floresta Nacional Contendas do Sincorá, Y.G. Santos coll., X–XI/2007–2008, 1 ♂ (IBSP 126792); Ibicoara, Parque Natural Municipal do Espalhado,

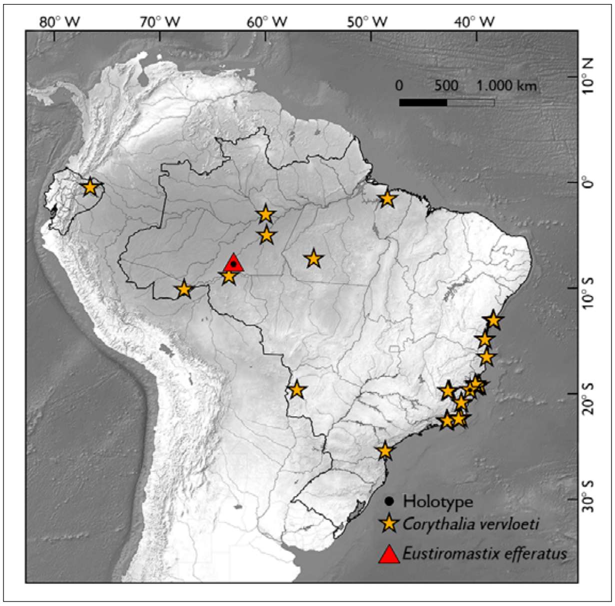

Figure 4. Distribution records of *Corythalia vervloeti* Soares & Camargo, 1948, including the type-locality of *Eustiromastix efferatus* Bauab-Vianna & Soares, 1978. Data based on material examined in this study, Bauab-Vianna & Soares (1978) and Bayer et al. (2020).

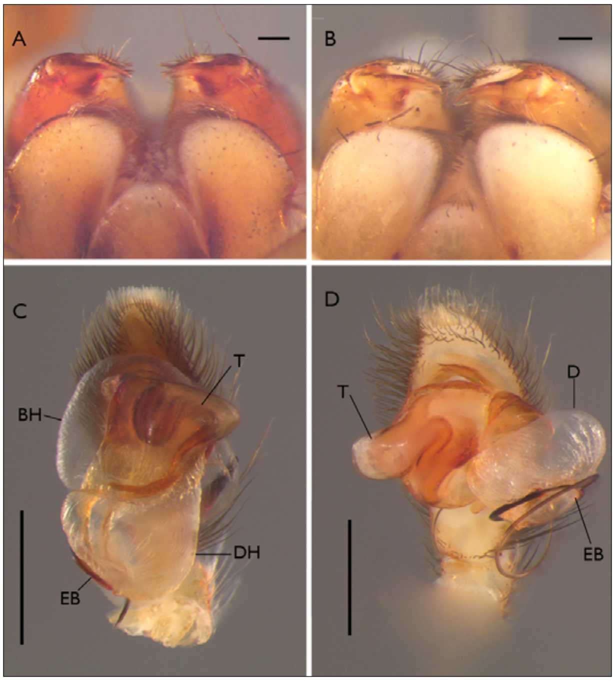

Figure 5. Diagnostic characters of *Corythalia* C.L. Koch, 1850: A) Chelicerae in resting position, ventral view of *C. latipes* (C.L. Koch, 1846) (IBSP 85549); B) same, *C. vervloeti* Soares & Camargo, 1948 (UFMG 29983); C) expanded male left palp of *C. latipes* in ventral view (UFMG 28386); D) same, *C. vervloeti* (UFMG 29266). Abbreviations: BH: basal haematodocha; DH: distal haematodocha; EB: embolus base; T: tegulum. Scale bars: A–B: 0.1 mm; C–D: 0.5 mm.

Serra do Espalhado, M.O. Silva coll., 6/X/2017, 1 ♂ (IBSP 213665); VI/2016, 1 ♂ (IBSP 213750); Ilhéus, Olivença, M.F. Dias coll., VIII/1998, 1 ♀ (IBSP 35916); 20/XII/2001, 1 ♂ (IBSP 57486); Jequié, L. Bocardo coll., VIII–I/2004–2005, 1 ♂ (IBSP 342901); Jussari, RPPN Serra do Teimoso, Cabruca Abandonada (15° 9' 18.67" S, 39° 31' 35.3" W), P.H. Martins et al. coll., 9/III/2022, 1 ♂ (UFMG 28386); Lafaiete Coutinho, J. Romão coll., VII/2006–2007, 1 ♂ (IBSP 140448); VII/2006–2008, 2 ♂ (IBSP 140449); VII/2006–2009, 1 ♂ (IBSP 140450); VII/2006–2010, 3 ♂ (IBSP 140453); VII/2006–2011, 1 ♀ (IBSP 140454); VII/2006–2012, 1 ♀ (IBSP 140455); VII/2006–2013, 1 ♂ (IBSP 140456); VII/2006–2014, 1 ♂ (IBSP 140457); Mata de São João, Fazenda Camurujipe, C. Machado coll., 2006, 1 ♀ (IBSP 85440), 1 ♂ (IBSP 85549); Praia Imbassaí; litoral norte, M. Peres et al. coll., I/2009, 1 ♀ (IBSP 153546); Milagres (12° 54.54' S, 39° 51.27' W), M.A. Ulysséa, A.M. Media & E.M. Campos coll., 12–16/VI/2010, 1 ♂ (IBSP 224386); Una, M.F. Dias coll., X/1999, 1 ♂ (IBSP 35868).

DISCUSSION

The position of *C. vervloeti* within the genus was considered very difficult to assess by Bayer et al. (2020), probably due to the lack of a female specimen. In a unique yet corresponding manner to the type species, *Corythalia latipes* (C.L. Koch, 1846), *C. vervloeti* also possesses short fangs that do not reach each other in resting position (Figures 5A–5B); males exhibit dark, long fringe setae on the metatarsi and tibiae of the third pair of legs (Figure 2A), an extremely long but coiled embolus, a proximal tegular lobe partially covering the palpal tibia, a ventral bump on the palpal tibia (Figure 3A; Bayer et al., 2020, figures 6A–6B, 52A–52B), and a well-developed distal haematodocha (Figures 5C–5D). The latter feature was corroborated as diagnostic of the genus in a more extensive, within-tribe comparative study by Zhang and Maddison (2015). The description of a female with epigynal windows separated by a longitudinal septum, (extremely) long and narrow ducts, and a primary spermatheca larger than the secondary one, leaves no doubt about its placement within the genus and clarifies its possible positioning. The initial course of the connective ducts and the shape of the epigynal windows (except for their discontinuity) resemble those of *C. luctuosa* Caporiacco, 1954 and *C. xanthopa* Crane, 1948. However, without an appropriate phylogenetic tree, it is impossible to determine whether these similarities indicate a closer relationship.

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AUTHORS' CONTRIBUTION

A. S. Michelotto contributed to formal analysis, conceptualization, data curation, writing (original draft, review and editing), investigation, methodology, resources, software and visualization; and A. J. Santos contributed to project administration, acquisition of funding, conceptualization, writing (original draft, review and editing), methodology, resources, supervision, validation and visualization.

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The jumping spider genus *Nycerella* Galiano, 1982 in Brazil, with description of the female of *Nycerella melanopygia* Galiano, 1982 (Araneae: Salticidae: Freyina)

O gênero de aranhas papa-moscas *Nycerella* Galiano, 1982 no Brasil, com descrição da fêmea de *Nycerella melanopygia* Galiano, 1982 (Araneae: Salticidae: Freyina)

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Abstract: Three species of *Nycerella* Galiano, 1982 have been recorded from Brazil: *N. aprica* (Peckham & Peckham, 1896), *N. melanopygia* Galiano, 1982 and *N. volucripes* Galiano, 1982. The female of *N. melanopygia*, however, remains undescribed. Herein, we describe the female of *N. melanopygia* for the first time, and give additional geographical records for the three species mentioned above, extending their distributions all the way to northeastern states of Brazil.

Keywords: Aellurillini. Amazon. *Cerrado*. Neotropical. Salticinae. Taxonomy.

Resumo: Três espécies de *Nycerella* Galiano, 1982 foram até hoje registradas no Brasil: *N. aprica* (Peckham & Peckham, 1896), *N. melanopygia* Galiano, 1982 e *N. volucripes* Galiano, 1982. A fêmea de *N. melanopygia*, entretanto, ainda permanece desconhecida. Aqui, descrevemos a fêmea de *N. melanopygia* pela primeira vez e damos registros geográficos adicionais para as três espécies mencionadas, estendendo suas distribuições até estados do Nordeste do Brasil.

Palavras-chave: Aellurillini. Amazônia. Cerrado. Neotropical. Salticinae. Taxonomia.

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INTRODUCTION

Salticinae Blackwall, 1841 is the most diverse subfamily of jumping spiders (Maddison, 2015). The group is divided into two large clades, the Amycoida, mostly restrict to the Neotropics, and the Salticoida, distributed worldwide. The Salticoida include almost 20 tribes, among which we find the Aelurillini Simon, 1901. This tribe gathers three subtribes: the Afro-Eurasian Aelurillina Simon, 1901; the Afrotropical Thiratoscirtina Bodner & Maddison, 2012; and the Neotropical Freyina Edwards, 2015. The Freyina include presently almost 30 genera, one of which, *Nycerella* Galiano, 1982, is targeted in this paper.

Nycerella was proposed (Galiano, 1982) as a replacement name for *Cyrene* Peckham y Peckham, 1893, preoccupied by *Cyrene* Lamarck, 1818 (Mollusca). Its type species is *Cyrene decorata* Peckham & Peckham, 1894.

The genus presently gathers nine species (World Spider Catalog, 2024) and was revised by Galiano (1982). According to Galiano (1982), the genus could be close to *Phiale* C. L. Koch, 1846, from which it would differ by the shape of the genitalia. The relationships among freyine genera, however, are still poorly understood. Presently, the genus is understood as including small, colorful spiders with the dorsum of the abdomen covered with red or yellow patterns, with many white markings (Edwards, 2015). The sexual dimorphism in color pattern is strong in some species (Galiano, 1982).

Among the nine species, three occur in Mexico and/or Central America: *N. delecta* (Peckham & Peckham, 1896) has been recorded from Mexico to Panama, *N. sanguinea* (Peckham & Peckham, 1896) from Guatemala to Panama, and *N. donaldi* (Chickering, 1946) from Panama (World Spider Catalog, 2024). Other three species occur in western South America and have not been recorded from Brazil: *N. decorata* (Peckham & Peckham, 1894), recorded from Panama, Colombia, and St. Vincent, *N. neglecta* Galiano, 1982 from Ecuador and Peru, and *N. vestita* (Taczanowski, 1878), recorded from Peru and Ecuador (Galapagos Islands). The remaining three species, namely *N. aprica* (Peckham & Peckham, 1896), *N. melanopygia* Galiano, 1982, and *N. volucripes* Galiano, 1982, have already been recorded from Brazil and neighbor countries (see distributions below).

Among all the nine species, only *N. donaldi* and *N. melanopygia* are known only by males, meaning that the females of all the other species have been properly described. Herein, we describe the female of *N. melanopygia* for the first time, and give additional geographical records for the three species already recorded from Brazil, extending their distributions all the way to northeastern states of Brazil.

MATERIAL AND METHODS

The material is deposited in the Museu Paraense Emílio Goeldi, Belém, Brazil (MPEG.ARA, curator: Alexandre Bonaldo) and in Instituto Butantan, São Paulo, Brazil (IBSP, curator: Antonio Brescovit). The photographs of fixed specimens were taken using a Leica DFC420 digital camera connected to an M205A stereomicroscope. Male palps were dissected and photographed in alcohol in different positions to show the diagnostic structures. Epigynes were also photographed in alcohol in ventral view. For the details of the epigyne of *N. melanopygia*, this was dissected, immersed in clove oil (Levi, 1965), and illustrated under a microscope with a camera lucida. The descriptions and lists of material examined were prepared using the spreadsheets developed by Magalhães (2019), with a few obvious modifications. The measurements are expressed in millimeters. Localities in bold and italic letters in the 'Distribution' paragraphs refer to new records. Geographic coordinates and elevation were taken directly from labels; in cases when the label did not give information about geographic coordinates, these were approximated with Google Earth® and marked with square brackets. The geographic distribution map was made using the software QGIS 3.16 Hannover and the plugin QuickMapServices (QGIS, n. d.).

RESULTS

TAXONOMY

Nycerella Galiano, 1982

Diagnosis update. According to Galiano (1982), the genus may be closely related to *Phiale* C. L. Koch, 1846, from which it differs by 1) epigynal plate smooth, bearing only the small copulatory openings, with a median coupling pocket on the posterior border; the copulatory ducts are cylindrical, slenderer than in *Phiale*; and 2) male palp with simple bulb, the embolus with no processes. Edwards (2015) gives a complex combination of male features as the genus diagnosis that does not help much further. As for the females, Edwards (2015) mentions small submedial copulation openings, a small, dorsal coupling pocket, and spherical submedial spermathecae with short narrow copulatory ducts connected anteriorly (but see diagnosis of *N. melanopygia* female below, with copulatory ducts connected posteriorly on the spermathecae).

Nycerella aprica (Peckham & Peckham, 1896)
(Figures 1-8, 25)

Cyrene aprica Peckham & Peckham, 1896, p. 66, pl. 6, figure 1 (description of male and female); F. O. Pickard-Cambridge, 1901, p. 239, pl. 20, figures 12-13 (description of male and female).

Ilargus albomaculatus Mello-Leitão, 1939, p. 86, figure 76 (description of female; synonymized by Galiano, 1982).

Phiale pseudaprica Caporiacco, 1947, p. 31 (description of male; synonymized by Galiano, 1982).

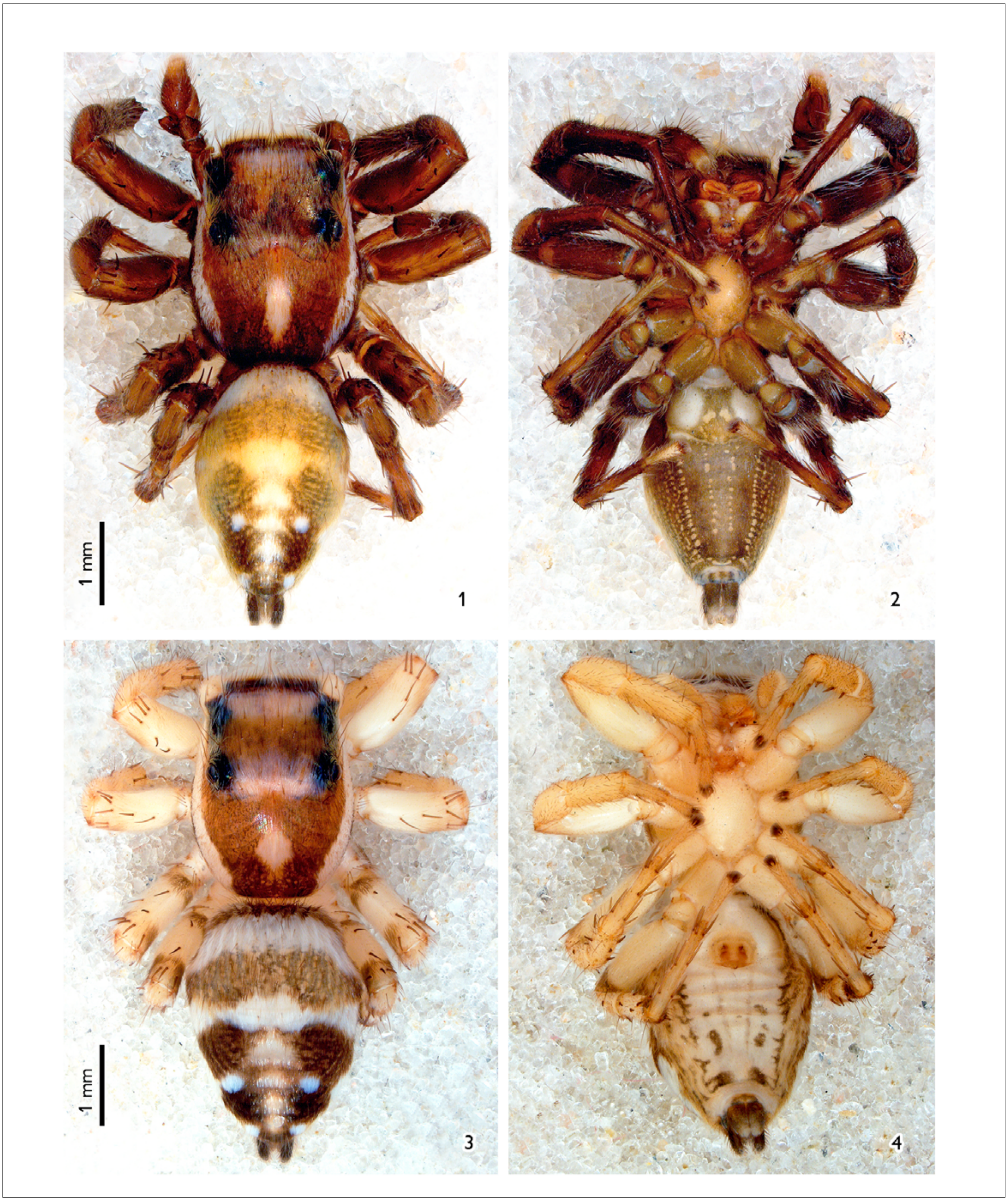
Phiale bristowei Caporiacco, 1948, p. 709, figure 135 (description of male; synonymized by Galiano, 1982).

Nycerella aprica: Galiano, 1982, p. 56, figures 1-3, 27-28, 43-44 (new combination, synonyms, redescription of male and female).

Description and diagnoses for both sexes. See Galiano (1982) and Figures 1-8 of fresh material for comparison.

Note. Galiano (1982, figures 43-44) tried to synthetize the description of the dorsal coloration of the male and female abdomen of *N. aprica* in a scheme composed of tegument and scale coloration. The scheme, however, seems artificial when compared to freshly collected material (Figures 1, 3) and is of limited use.

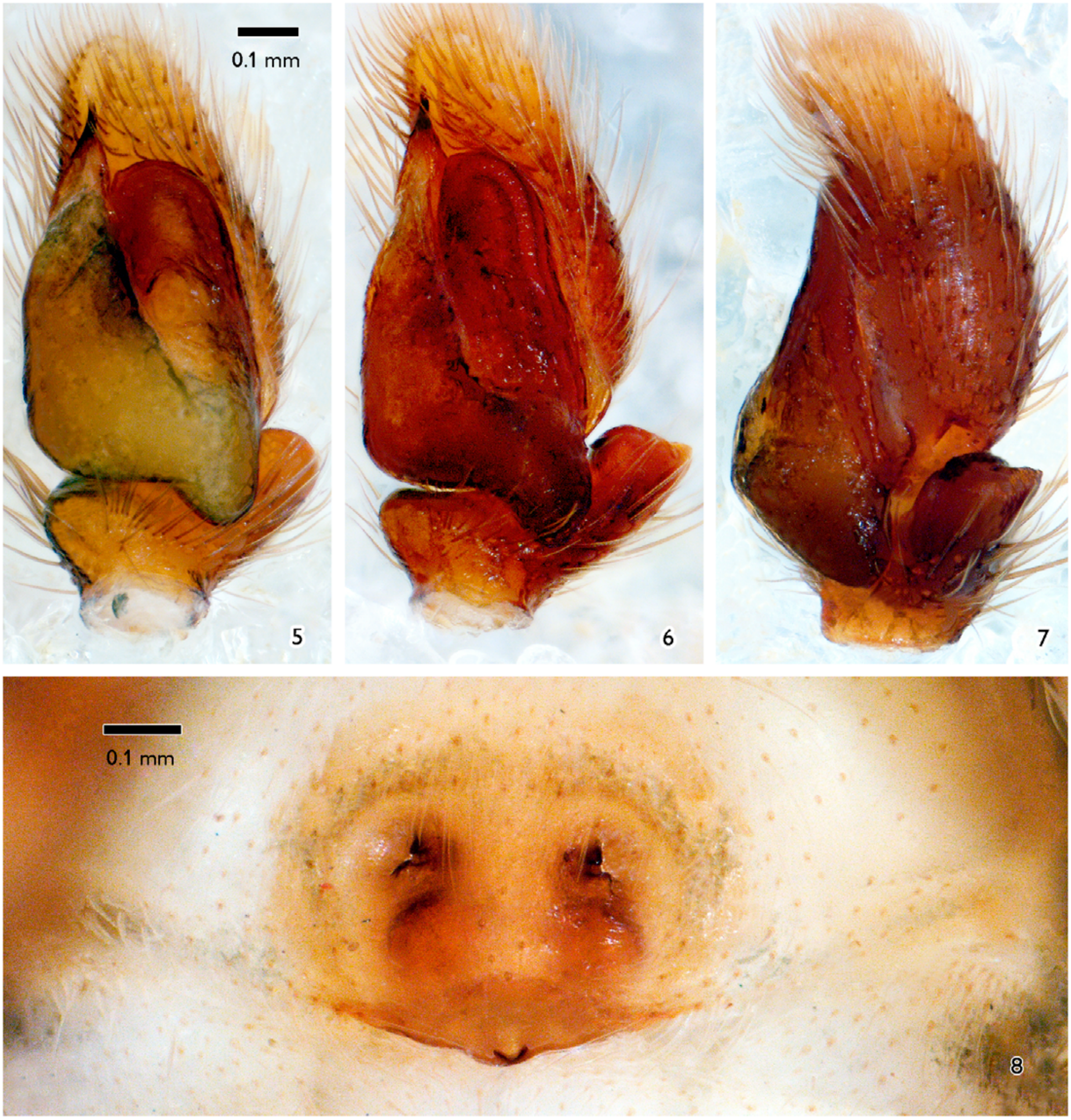
Material examined (new records). BRAZIL: Pará: Marabá, Mina do Sossego, Serra Norte, Carajás (S6.450°, W50.092°), E. Wanzeler leg., 23.II-06.III.2004, 1 #m (MPEG.ARA 4078); Novo Progresso (S7.164°, W55.315°), A.A. Pinheiro leg., 25.XI.2005, 1 #f (MPEG.ARA 4350), J.O. Dias leg., 26.XI.2005, 1 #m (MPEG.ARA 2760), Castelo dos Sonhos (S8.218°, W55.016°), D.R. Santos-Souza leg., 16.XI.2005, 1 #f (MPEG.ARA 4355); Rondônia: Guajará Mirim [S10.78°, W65.33°], M. Carvalho leg., VII.2000, 1 #m (IBSP 80495), 1 #m (IBSP 80494); Maranhão: Caxias, Riacho Limpezaz, MA 349, 70 m.a.s.l. (S4.645°, W43.450°), beating sheet, G.S. Lustosa et al. leg., 10.XII.2021, 1 #m (MPEG.ARA 39492), 1 #m 1 #f (MPEG.ARA 39493); Aldeias Altas, Riacho Feijão, Fazenda Feijão, 78 m.a.s.l. (S4.709°, W43.395°), beating sheet, G.S. Lustosa et al. leg., 11.XII.2021, 1 #f (MPEG.ARA 39494); Caxias, Riacho Chapada, povoado Chapada, 104 m.a.s.l. (S4.945°, W43.506°), beating sheet, G.S. Lustosa et al. leg., 31.XII.2021, 1 #f (MPEG.ARA 39502), Riacho Arain, povoado Miranda, 95 m.a.s.l. (S4.951°, W43.544°), beating sheet, G.S. Lustosa et al. leg., 29.XII.2021, 1 #f (MPEG.ARA 39501); Sergipe: São Cristóvão, Campus UFSE [S10.92°, W37.10°], alunos UFSE leg., no date, 1 #f (IBSP 10344); Mato Grosso do Sul: Anaurilândia [S22.18°, W52.72°], F.S. Cunha & C.R. Souza leg., 05-11.III.2001, 6 #m 6 #f (IBSP 53356), same collector, 12-19.III.2001, 3 #m 2 #f (IBSP 53332); Corumbá, Morro do Azeite [S19.48°, W57.31°], J. Raizer et al.



Figures 1-4. *Nycerella aprica*. 1-2 male (MPEG.ARA 39492) (1 dorsal view, 2 ventral view); 3-4 female (MPEG.ARA 39493) (3 dorsal view, 4 ventral view).

◆

leg., IV.1998, 1 #m (IBSP 22001), 1 #m (IBSP 22002); Santa Rita do Pardo [S21.3°, W52.83°], D. Candiani & F. Lini leg., 02-05.VII.2001, 1 #m 2 #f (IBSP 53296); São Paulo: Pereira Barreto, Usina Hidrelétrica Três Irmãos [S20.66°, W51.30°], Costa & Bertim leg., X.1990, 1 #m (IBSP 4818); Primavera, Usina Hidrelétrica Sérgio Motta [S22.53°, W52.94°], Equipe IBSP leg., 2001, 2 #f (IBSP 53043), 1 #m 1 #f (IBSP 53104), 1 #m (IBSP 53192).



Figures 5-8. *Nycerella aprica*. 5-7 left male palp (MPEG.ARA 39492) (5 ventral view, 6 retroventral view, 7 retrolateral view); 8 epigyne (MPEG.ARA 39493), ventral view.

Distribution. GUYANA: Demerara (Galiano, 1982). BRAZIL: Amapá, Amazonas, Pará, Mato Grosso, Espírito Santo (Galiano, 1982), Maranhão, Rondônia, Sergipe, Mato Grosso do Sul, São Paulo. PARAGUAY: San Pedro (Galiano, 1982). ARGENTINA: Misiones, Chaco, Formosa (Galiano, 1982) (Figure 25).

Biology. Specimens from Maranhão were collected with beating sheet, meaning that they forage on lower vegetation. Given the broad distribution of the species, with records from the Amazon rainforest, Atlantic Forest and from the drier diagonal (Argentina/Paraguay to Brazil: Maranhão), this species does not seem to be endemic of any biome and may be expected to be found in several other localities in South America.

Nycerella melanopygia Galiano, 1982
(Figures 9-17, 26)

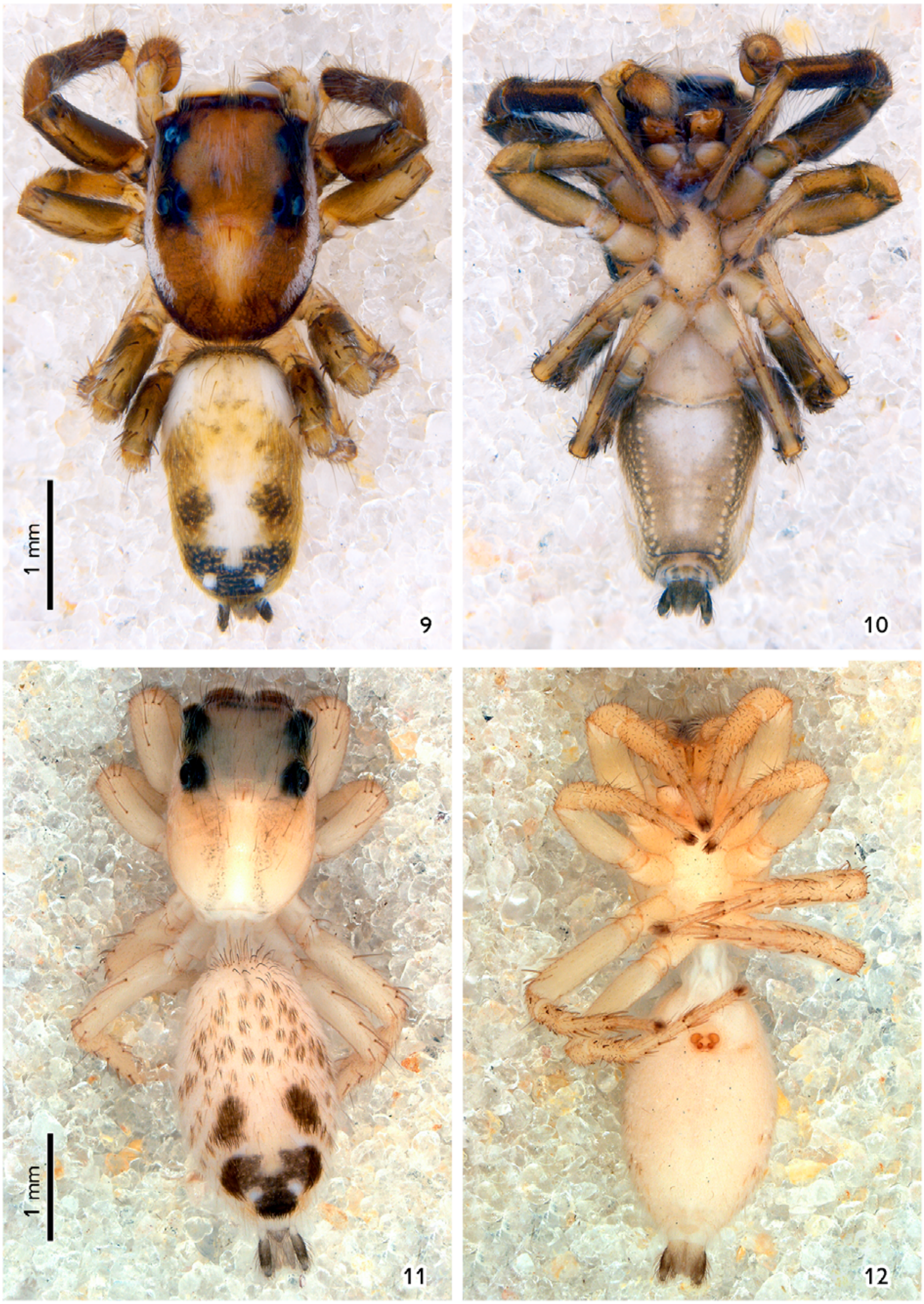
Nycerella melanopygia Galiano, 1982, p. 60, figures 4-6, 46 (description of male).

Description and diagnosis for the male. See Galiano (1982) and Figures 9-10, 13-14 of fresh material for comparison.

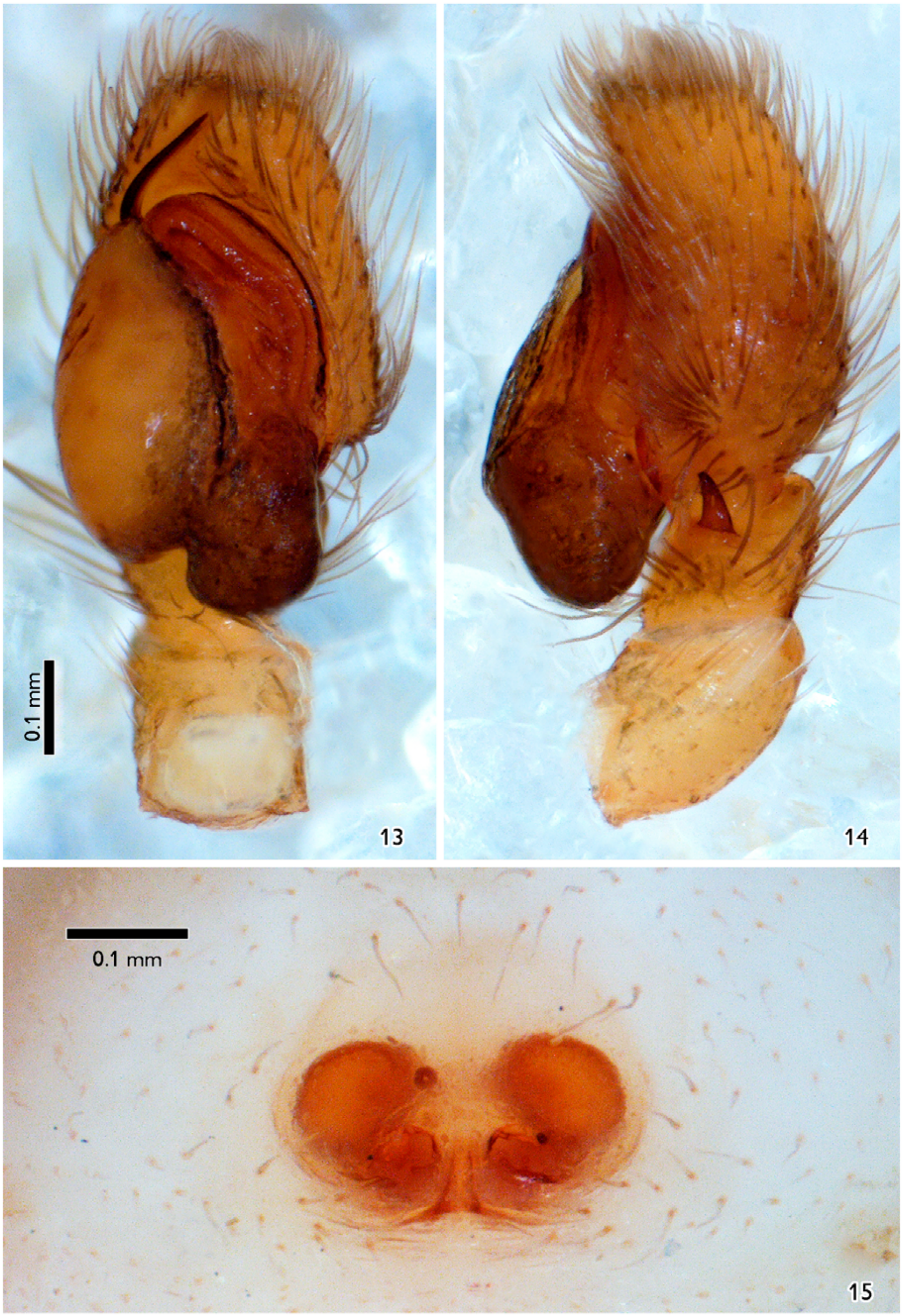
Note. Galiano (1982, figure 46) tried to synthetize the description of the male abdomen of *N. melanopygia* in a scheme composed of tegument and scale coloration. The coloration of the dorsum of the male abdomen observed in the new material does not agree completely with Galiano's (1982) description. In the two males she examined, from the Brazilian states of Amapá and Amazonas (i.e. Amazon rainforest), she described the dorsolateral portions as having blackish tegument covered with red scales and only the tip on the abdomen as shiny black. In our specimens, we can observe two additional pairs of dark markings on the abdomen (as in the distal marking described by her), one pair at the middle of the abdominal length and a second pair fused with the median distal dark portion described by Galiano (1982) (Figure 9). The examination of the male palp (Figures 13-14), however, does allow the identification of the species (compare with Galiano, 1982, figures 4-6).

Diagnosis for the female (Figures 11-12, 15-17). This female differs from those of all the remaining species (female of *N. donaldi* still undescribed) for having the copulatory openings completely posterior to the spermathecae (Figures 15-17) (copulatory openings anterior or at the same position than the spermathecae in the others). Unlike stated by Edwards (2015) for the genus, the coupling pocket is rather deep in this species and the copulatory ducts connect posteriorly on the spermathecae (Figures 16-17).

Description of the female (MPEG.ARA 39500). Measurements. Total length 4.41. Carapace length 1.95, width 1.29, height 0.75. Anterior median eye (AME) diameter 0.42. Ocular quadrangle length 1.02. Anterior eye row width 1.14. Posterior eye row width 1.17. Abdomen length 2.46. LEGS. Leg I: femur (fe) 0.95, patella (pa) 0.61, tibia (ti) 0.63, metatarsus (mt) 0.46, tarsus (ta) 0.35. II: fe 0.84, pa 0.50, ti 0.49, mt 0.40, ta 0.34. III: fe 1.05, pa 0.53, ti 0.61, mt 0.66, ta 0.41. IV: fe 1.07, pa 0.53, ti 0.75, mt 0.78, ta 0.44. Leg formula 4312. Coloration. The carapace is pale yellow with reminiscent of a pair of longitudinal stripes composed of tiny dark markings (Figure 11). Chelicera, endite, labium, sternum and legs pale yellow (Figures 11-12). The abdomen agrees in coloration with that of the male, but less colored, as follows: dorsally pale yellow, with the anterior half covered with several small clusters of black setae (Figure 11); one pair of dark markings at the middle of the abdominal length and a second pair fused with the median distal dark portion described by Galiano (1982) for the male (Figure 11); between the middle-length dark markings and the second pair of lateral dark markings there is a pair of small clusters of white scales, and a second pair right in front of the median dark marking at the end, composing the traditional four white dots present in the genus (Figure 11); ventrally pale yellow (Figure 12). Anal tubercle and posterior lateral spinnerets black;



Figures 9-12. *Nycerella melanopygia* (MPEG.ARA 39500). 9-10 male (9 dorsal view, 10 ventral view); 11-12 female (11 dorsal view, 12 ventral view).



Figures 13-15. *Nycerella melanopygia* (MPEG.ARA 39500). 13-14 left male palp (13 ventral view, 14 retrolateral view); 15 epigyne, ventral view.

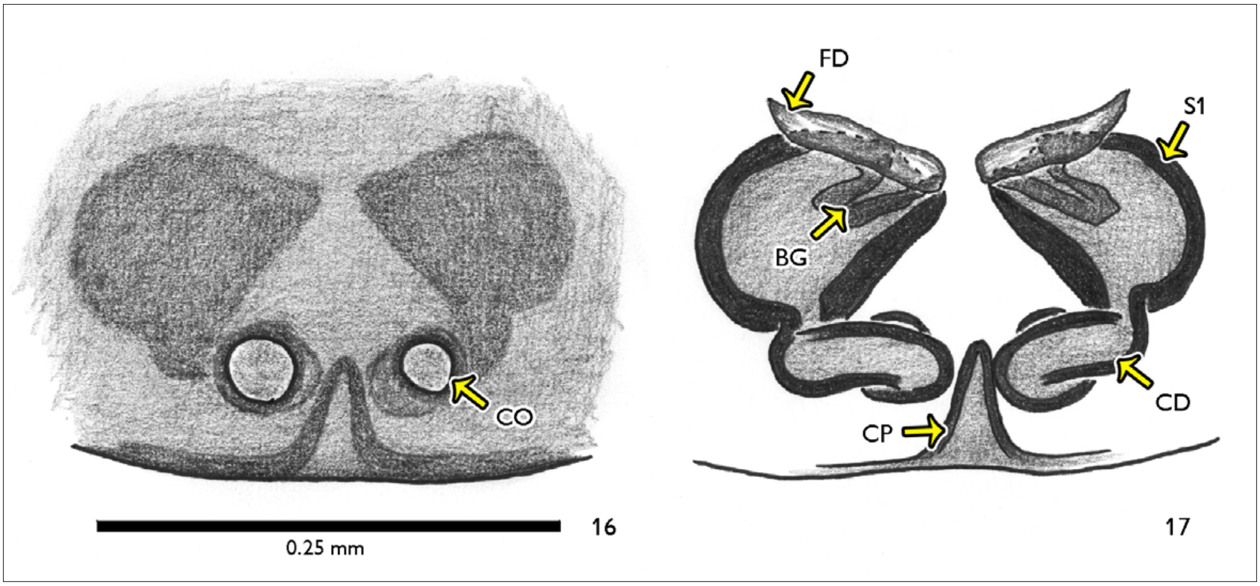
remaining spinnerets pale yellow (Figures 11-12). Epigyne. The plate is smooth (Figure 15), with a pair of roundish copulatory openings near the posterior margin, and a median, deep coupling pocket (similar in shape as the retrolateral tibial apophysis of the male; see Figures 14, 16); the copulatory ducts extend from the openings to the center briefly, then diverge transversally until they reach the drop-shaped spermathecae (Figure 17) (the length of the copulatory duct seems to agree with the embolus length in the male palp); at the tip of the spermatheca, there is a Bennett's gland that extends inside the lumen of the spermatheca, the extension apparently with no spikes or projections; right posteriorly to the extension of the Bennett's gland into the lumen there is a thin duct that leads to the fertilization duct, which is well developed and extends laterally and anteriorly (Figure 17).

Male-female matching. Besides having the same abdominal color pattern (see Figures 9, 11), the males and females mentioned below from Maranhão were collected side by side.

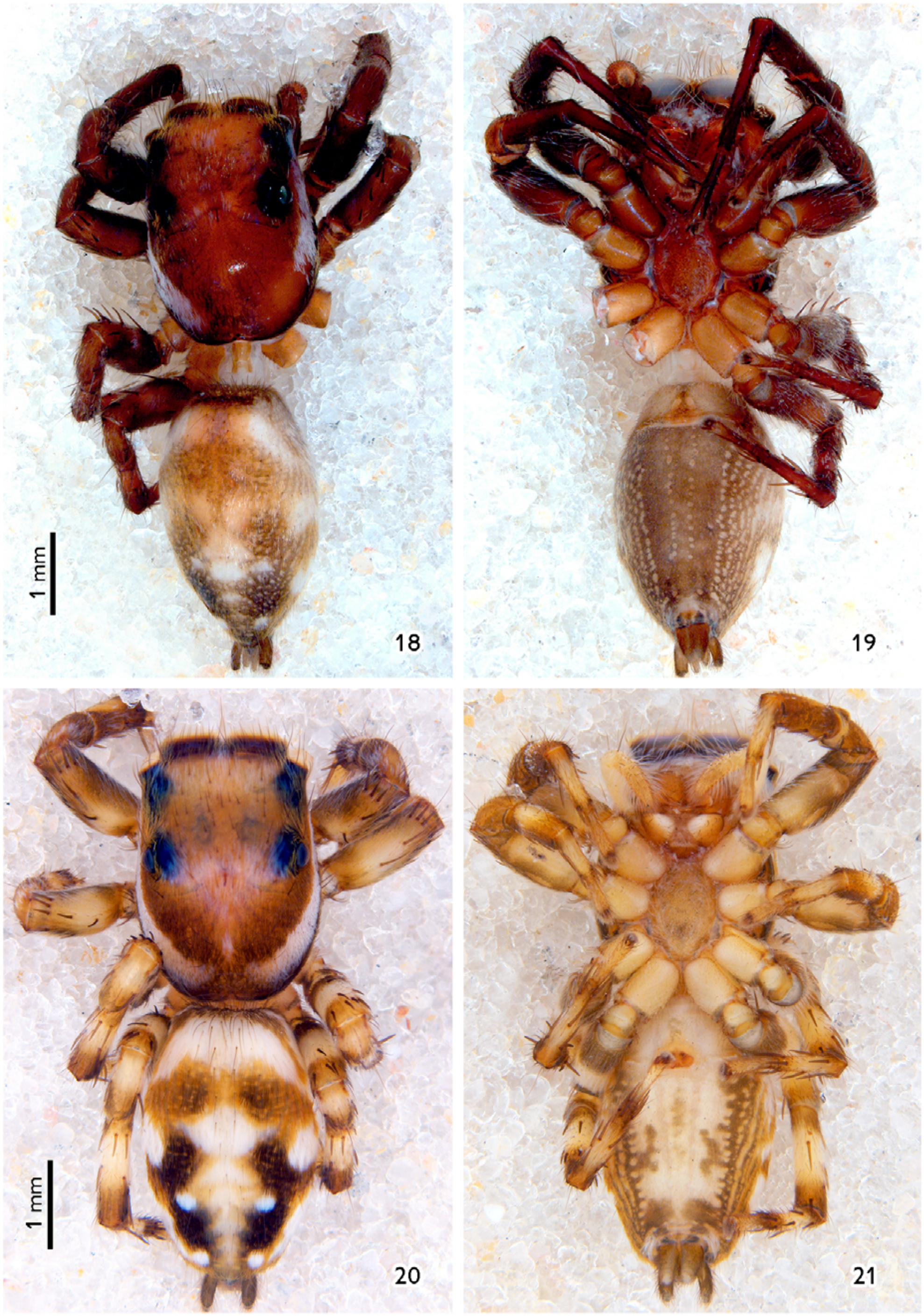
Material examined (new records): BRAZIL: Pará: Marabá, Mina do Sossego, Serra Norte, Carajás (S6.441°, W50.081°), E. Wanzeler leg., 23.II-06.III.2004, 1 #m (MPEG.ARA 4092); same locality but (S6.443°, W50.916°), A. Marreco-Pedroso leg., 05-06.III.2004, 3 #m (MPEG.ARA 4075). Maranhão: Caxias, Riacho Favaca, povoado Garrafas, 81 m.a.s.l. (S4.904°, W43.301°), beating sheet, G.S. Lustosa et al. leg., 27.XII.2021, 2 #m (MPEG.ARA 39498), 2 #f (MPEG.ARA 39499), 1 #m 1 #f (MPEG.ARA 39500); Caxias, Riacho Batatal, povoado Batatal, 66 m.a.s.l. (S4.951°, W43.386°), beating sheet, G.S. Lustosa et al. leg., 14.XII.2021, 1 #m (MPEG.ARA 39495). Piauí: José de Freitas, Riacho Gusmão, bairro Gusmão, 128 m.a.s.l. (S4.739°, W42.565°), beating sheet, G.S. Lustosa et al. leg., 6.VI.2021, 1 #m (MPEG.ARA 39490).

Distribution. BRAZIL: Amapá, Amazonas (Galiano, 1982), Pará, Maranhão, Piauí (Figure 26).

Biology. Specimens from Maranhão and Piauí were collected with beating sheet, meaning that they forage on lower vegetation. This species has been recorded from the Amazon rainforest and is herein recorded from lower latitudes in the drier diagonal (Maranhão/Piauí), which correspond to the biome *Cerrado*.



Figures 16-17. *Nycerella melanopygia* (MPEG.ARA 39500), epigyne. 16 ventral view, 17 cleared, dorsal view. Abbreviations: BG: Bennett's gland; CD: copulatory duct; CO: copulatory opening; CP: coupling pocket; FD: fertilization duct; S1: primary spermatheca.



Figures 18-21. *Nycerella volucripes*. 18-19 male (MPEG.ARA 39497) (18 dorsal view, 19 ventral view); 20-21 female (MPEG.ARA 39491) (20 dorsal view, 21 ventral view).

No record of this species has been published or found from the Atlantic Forest of higher latitudes in South America, but hitherto we cannot tell whether the species is limited to more equatorial localities in South America or this is simply the result of poor collection.

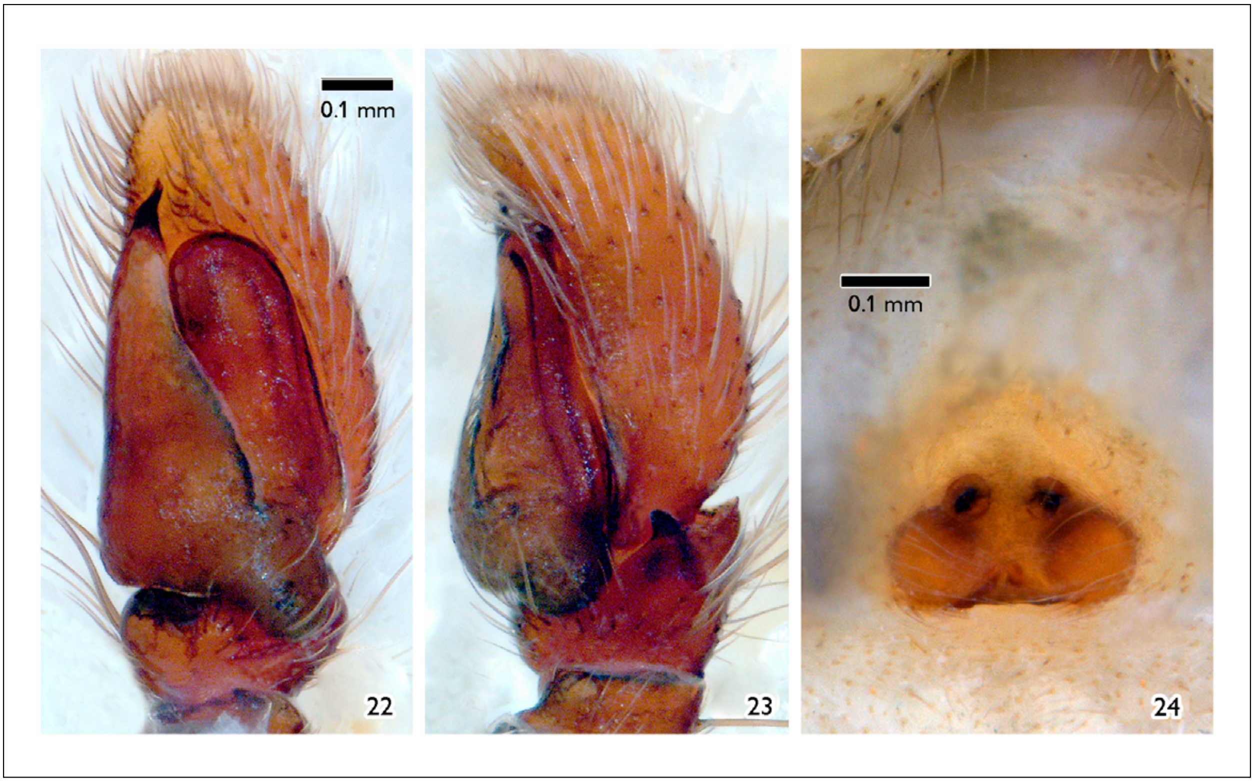
Nycerella volucripes Galiano, 1982
(Figures 18-24, 27)

Nycerella volucripes Galiano, 1982, p. 62, figures 20-22, 31-32, 45 (description of male and female).

Description and diagnoses for both sexes. See Galiano (1982) and Figures 18-21 of fresh material for comparison.

Note. Galiano (1982, figure 45) tried to synthetize the description the dorsal coloration of the male abdomen of *N. volucripes* in a scheme composed of tegument and scale coloration. The scheme, however, seems artificial when compared to freshly collected material (Figure 18) and is of limited use.

Material examined (new records). BRAZIL: Pará: Belém, Museu Paraense Emílio Goeldi - Campus de Pesquisa (S1.451°, W48.444°), P. Pantoja leg., 01.V.2016, 1 #f (MPEG.ARA 34105); Novo Progresso (S7.129°, W56.209°), J.O. Dias leg., 19.XI.2005, 1 #f (MPEG.ARA 2668); Marabá, Serra Norte, Pojuca (S5.963°, W50.400°), M. Zanuto leg., 26.X.1984, 1 #m (MPEG.ARA 4733); Novo Progresso, Campo de Provas Brigadeiro Velloso, Serra do Cachimbo (S9.271°, W54.940°), D.D. Guimarães leg., 20.III.2004, 1 #f (MPEG.ARA 5742); same locality (S9.375°, W55.034°), A.B. Bonaldo leg., 16.IX.2003, 1 #m (MPEG.ARA 5752). Maranhão: Caxias, Riacho Junco, povoado Junco, 93 m.a.s.l. (S4.797°, W43.265°), beating sheet, G.S. Lustosa et al. leg., 17.XII.2021, 1 #m



Figures 22-24. *Nycerella volucripes*. 22-23 left male palp (MPEG.ARA 39497) (22 ventral view, 23 retrolateral view); 24 epigyne (MPEG.ARA 39491), ventral view.

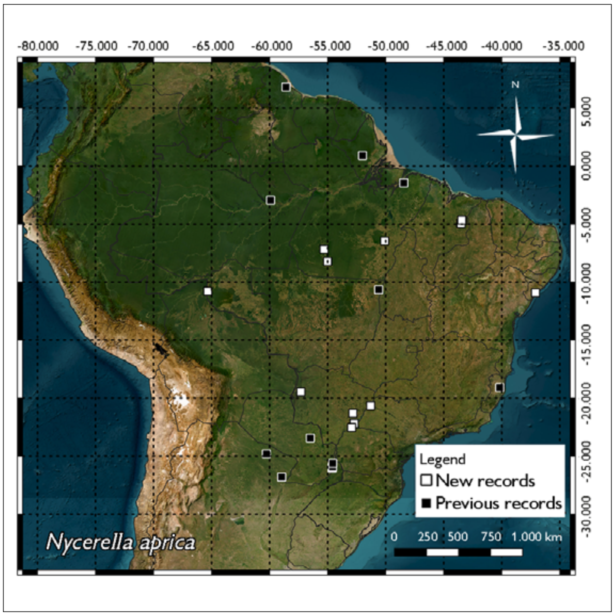


Figure 25. *Nycerella aprica* distribution in South America. Map: A. A. Bustamante & G. R. S. Ruiz (2024).

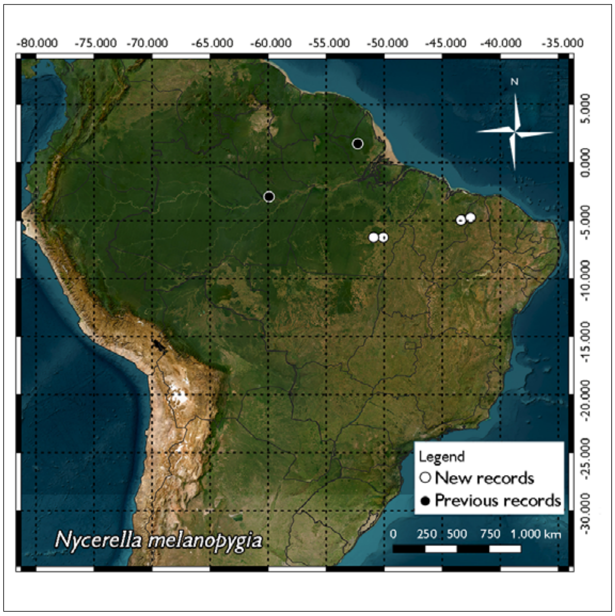


Figure 26. *Nycerella melanopygia* distribution in South America. Map: A. A. Bustamante & G. R. S. Ruiz (2024).

(MPEG.ARA 39496), Riacho Riachão, após entrada do balneário Veneza, 64 m.a.s.l. (S4.936°, W43.357°), beating sheet, G.S. Lustosa et al. leg., 3.VI.2021, 1 #f (MPEG.ARA 39489), Riacho Soledade, Área de proteção ambiental do Inhamum, 100 m.a.s.l. (S4.891°, W43.420°), beating sheet, G.S. Lustosa et al. leg., 1.VII.2021, 1 #f (MPEG.ARA 39491), Riacho Sumidouro do Padre, subestação de energia na MA 127, 99 m.a.s.l. (S4.880°, W43.427°), beating sheet, G.S. Lustosa et al. leg., 27.XII.2021, 1 #m (MPEG.ARA 39497). Mato Grosso do Sul: Brasilândia, Usina Hidrelétrica Sérgio Motta [S21.21°, W52.04°], Equipe IBSP leg., 2000, 1 #f (IBSP 30537).

Distribution. BRAZIL: Pará, Goiás (Galiano, 1982), Maranhão, Mato Grosso do Sul. PERU: Loreto (Galiano, 1982) (Figure 27).

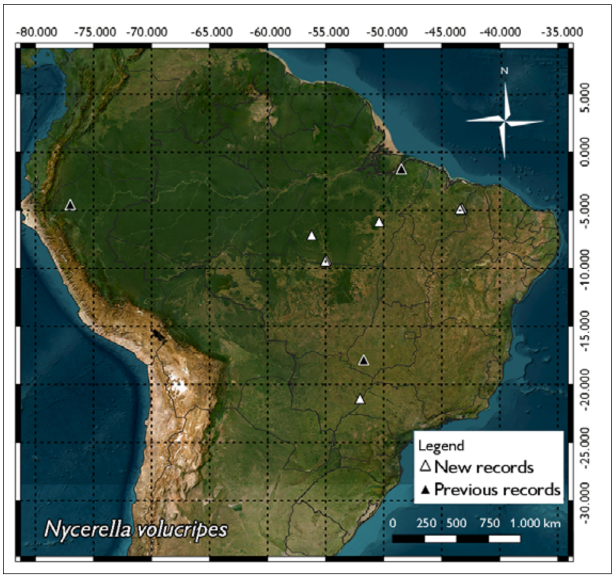


Figure 27. *Nycerella volucripes* distribution in South America. Map: A. A. Bustamante & G. R. S. Ruiz (2024).

Biology. Specimens from Maranhão were collected with beating sheet, meaning that they forage on lower vegetation. This species has been recorded from the Amazon rainforest (Loreto and Pará) and from the center (Mato Grosso do Sul/ Goiás) and north (Maranhão) of the drier diagonal, which correspond to the biome *Cerrado*. No record of this species has been published or found from the Atlantic Forest of higher latitudes in South America, but hitherto we cannot tell whether this is simply the result of poor collection.

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AUTHORS' CONTRIBUTIONS

G. R. S. Ruiz contributed to conceptualization, data curator, writing (original draft, revision and edition), research, methodology, supervision; A. V. Paz contributed to conceptualization, data curator, research, methodology; and A. A. Bustamante contributed to data curator, writing (revision and edition), research.

Deelemanian ant mimicry: on the natural history and new records of *Tapixaua callida* Bonaldo, 2000 (Araneae, Corinnidae, Corinninae)

Mimetismo deelemaniano de formigas: sobre a história natural e novos registros de *Tapixaua callida* Bonaldo, 2000 (Araneae, Corinnidae, Corinninae)

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Abstract: The genus *Tapixaua* Bonaldo, 2000 is known only by a single species, *Tapixaua callida* described by Bonaldo in 2000 from Brazil and Peru. The species can be easily recognized by having abundant modified hairs on the apex of the femora, patellae, and tibiae of leg I, a condition previously suggested as instrumental in simulating the cephalic tagma of ants. Herein, we expanded the knowledge on the geographical distribution of the taxon from Huánuco (Peru), and Amazonas and Mato Grosso (Brazil), to Loreto (Peru) and Caquetá (Colombia), to the north, and to the states of Pará and Maranhão, Brazil, to the east, and provided a distribution map with all the records of *T. callida* obtained so far. Additionally, data on its natural history based on observations, photographs, and videos are presented. The ant-mimiking solution presented by this species, by combining morphological and behavioral elements to trigger resemblance with ants 'as needed,' was previously reported only for the South Asian *Pranburia mahannopi* Deeleman-Reinhold, 1993 and is here named Deelemanian mimicry.

Keywords: Neotropical region. Ant-mimicry spiders. Dionycha. New records.

Resumo: *Tapixaua callida* é a única espécie conhecida do gênero, descrita por Bonaldo em 2000 no Brasil e Peru. Esta espécie é facilmente reconhecida pela presença de pelos modificados no ápice dos fêmures, patelas e tíbias das pernas I, uma condição previamente sugerida como instrumental para simular o tagma cefálico de formigas. Aqui, estendemos o conhecimento da distribuição geográfica do táxon ao norte de Huánuco (Peru), Amazonas e Mato Grosso (Brasil) para Loreto (Peru), Caquetá (Colômbia) e, ao leste, para os estados do Pará e Maranhão (Brasil). Fornecemos um mapa com todos os registros de *T. callida* obtidos até o momento. Além disso, apresentamos, pela primeira vez, dados sobre sua história natural com base em observações, fotografias e vídeos. A solução de mimetismo de formigas apresentada por essa espécie, combinando elementos morfológicos e comportamentais para desencadear a semelhança com as formigas 'quando necessário', foi relatada anteriormente apenas para *Pranburia mahannopi* Deeleman-Reinhold, 1993, do sul da Ásia, e é aqui denominada mimetismo deelemaniano.

Palavras-chave: Região Neotropical. Mirmecomorfia. Dionycha. Novos registros.

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INTRODUCTION

The morphological and behavioral resemblance to ants, known as myrmecomorphy, is common among spiders and is present in at least 15 families (Cushing, 1997, 2012; Pekár, 2014). Myrmecomorphic species can be classified into imprecise mimics, which often exhibit coloration similar to the model ant as a myrmecomorphic trait, and precise mimics, which resemble ants in aspects such as size, shape, and behavior (Cushing, 2012; Haddad, 2013; Pekár et al., 2022).

Several spiders' groups of the family Corinnidae Karsch, 1880 are known for their association with ants (Bonaldo, 2000; Deeleman-Reinhold, 2001; Candiani & Bonaldo, 2017; Bonaldo et al., 2018; García & Bonaldo, 2023). This phenomenon is more frequent in taxa of the subfamily Castianeirinae Reiskind, 1969, which exhibit mimicry in varying degrees of precision. For example, imprecise mimics include several Nearctic species of *Castianeira* Keyserling (Reiskind, 1969, 1974). In contrast, precise mimics include species presenting constrictions on the cephalothorax simulating an extra tagma such as in *Sphecotypus niger* (Perty, 1833) and *Myrmecium ricetti* Candiani & Bonaldo, 2017 (Reiskind, 1969; Candiani & Bonaldo, 2017), abdominal modifications such as constrictions, pedicel collars or spine-like hairs, as in *Mazax* O. Pickard-Cambridge, 1898 (Leister & Miller, 2014; Candiani & Bonaldo, 2017; Silva-Junior et al., 2024), and tufts of hairs on the femora I, simulating the cephalic tagma of ants, as in *Pranburia mahannopi* Deeleman-Reinhold, 1993 (Deeleman-Reinhold, 2001) (Figure 3B). In the subfamily Corinninae, which representatives present a more conservative body morphology, myrmecomorphic species are less common. There are more records of myrmecophilous and myrmecophagous behavior, such as species in the genera *Falconina* Brignoli, 1985, *Attacobius* Mello-Leitão, 1925 and *Ecitocobius* Bonaldo & Brescovit, 1998 (Bonaldo et al., 2018; Mendonça et al., 2019; García & Bonaldo, 2023; Ibarra-Núñez & Marín, 2024). However, *Tapixaua callida* Bonaldo, 2000 is the only known myrmecomorphic species in this subfamily (Figures 1, 2A-2B, 3A).

The genus *Tapixaua* was proposed by Bonaldo (2000) to include a single species, *T. callida* based on males and females from Reserva Florestal Adolpho Ducke, Manaus, Amazonas, Brazil (the type locality), Diamantino, Mato Grosso, Brazil and Estacion Biologica Panguana, Huanuco, Peru. *T. callida* is easily distinguished from other Corinninae genera by presenting a series of unique characteristics. The palpus of the male has the subtegulum divided into two independent parts: a proximal 'T'-shaped part (STp) and a distal part (STd), visible in the expanded bulb, which has a large curved conical process that accompanies the retrolateral margin of the tegulum in the unexpanded bulb (SPT) (Figures 4D-4E). Additional conspicuous features, likely related to myrmecophily, include an abruptly lowered carapace in the posterior region, a high clypeus, and the presence of spatulate hairs at the apex of the femora and on the patellae and tibiae of the first pair of legs (See figures 288-289 in Bonaldo, 2000; Figures 4A-4H). The name of the genus refers to these modified hairs and stands for 'broom' in the Tupi language (Bonaldo, 2000). Bonaldo (2000) suggested that these hairs may play a role in ant mimicry, similar to that described for *Pranburia* Deeleman-Reinhold (Corinnidae, Castianeirinae) by Deeleman-Reinhold (1993), where the simulation of the cephalic tagma is produced by the cluster of hairs formed by the junction of the femora in front of the cephalothorax (Figure 3A-3B).

To date, the only available information on *Tapixaua* is from its original description. In this paper, we provide new geographical records of *T. callida* from Brazil, Peru, and Colombia. Besides, we include new data on its natural history, supported by photographic and video records which corroborate Bonaldo's (2000) hypothesis on the role of the modified hairs in *Tapixaua*. Finally, we discuss the evolutionary convergence of its morphology with that of *Pranburia mahannopi.*

Figure 1. *Tapixaua callida*, juvenile from Paragominas, Pará state, Brazil. Photo: César Favacho (2019).

MATERIAL AND METHODS

The material examined of the new records is deposited in the following institutions (acronyms and curators in parentheses): Museu Paraense Emílio Goeldi, Belém (MPEG, A. Bonaldo, Brazil); Museo de Historia Natural, Universidad Nacional de San Marcos, Lima (MUSM, D. Silva, Peru); Museu de Zoologia da Universidade de São Paulo, São Paulo (MZSP, R. Pinto da Rocha, Brazil) and Instituto de Ciencias Naturales, Universidad Nacional de Colombia, Bogotá (ICN, E. Florez, Colombia).

Specimens were examined in 80% alcohol with a Leica MZ16 stereomicroscope. Morphological terms follow Bonaldo (2000) and Ramírez (2014). The multifocal images were taken using a DFC420 camera attached to a Leica M205A stereomicroscope and compiled with Leica Application Suite. The resulting images and plates were edited and prepared using Adobe Photoshop 2020. Geographical coordinates were obtained from the vial labels, when available. If not, approximate coordinates, marked in [square brackets], were obtained from Google Maps. Ant-mimicry: for the analysis of ant similarity, we considered all available ants collected together with the individuals. The similarity was analyzed based on a qualitative assessment according to the criteria of Perger and Rubio (2020).

Figure 2. *Tapixaua callida*, juvenile from Paragominas, Pará state, Brazil: A) specimen mimicking an ant's head with the scopulas of the leg I; B) live specimen, detail; C) specimen (yellow arrow) walking in the retreat (delimited by yellow pointed line); D) tree trunk where the specimen was collected, yellow circle indicates where the spider was found. Photos: César Favacho (2020).

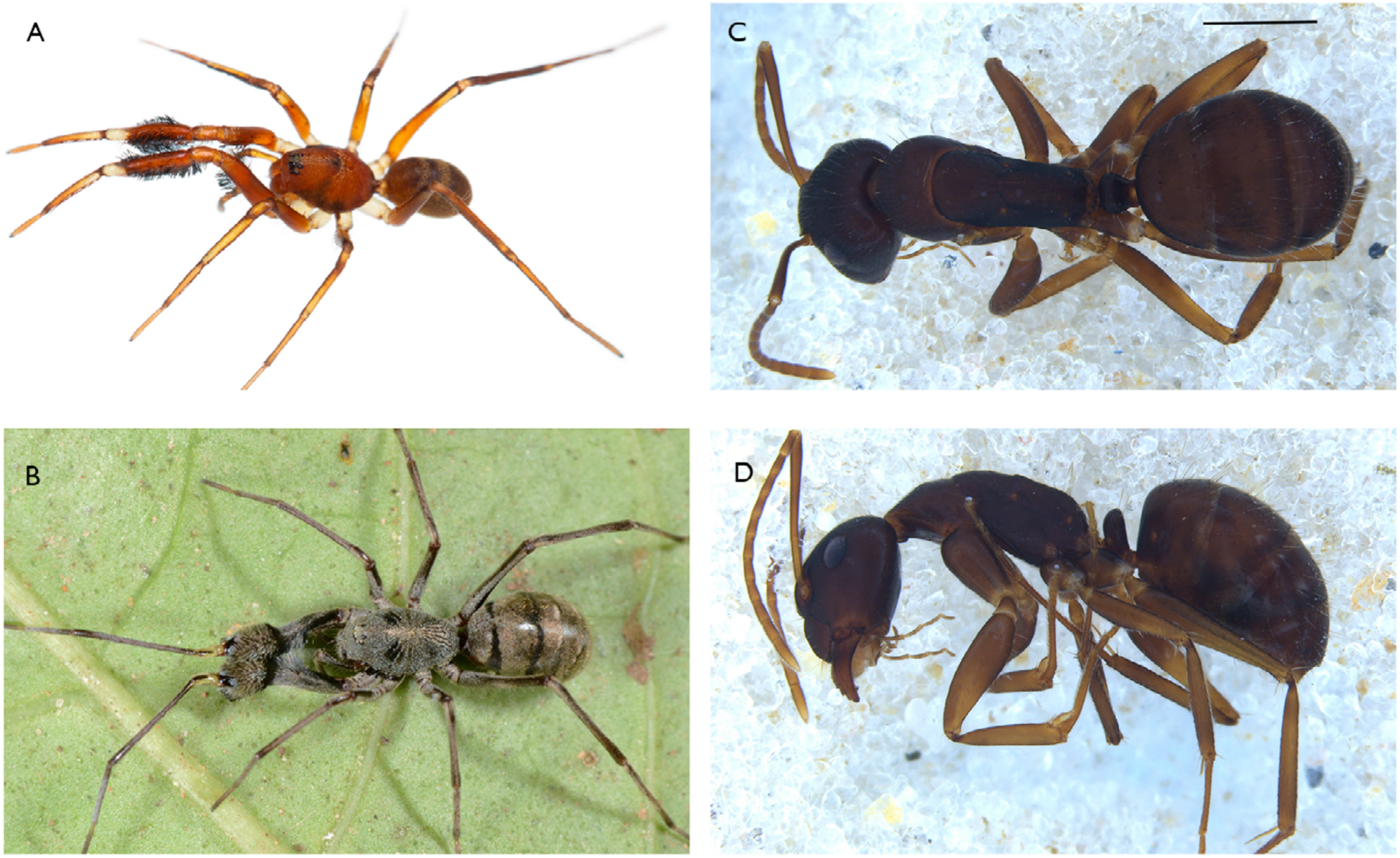

Figure 3. A-B) Living specimens of *Tapixaua callida* Bonaldo, 2000 and *Pranburia mahannopi* Deeleman-Reinhold, 1993: A) *Tapixaua callida* (MPEG), from Paragominas, Brazil, juvenile, photo by C. Favacho (2019); B) *Pranburia mahannopi* (not collected), from Angkor Wat, Cambodia, female, photo by A. Anker (2013). C-D) Ant of the genus *Camponotus* aff. *fastigatus* (MZSP 44994) collected alongside a male of *T. callida* in Abunã Porto Velho, state of Rondônia, Brazil. Possible model of mimicry: C) dorsal view; D) lateral view. Scale bar = 1 mm.

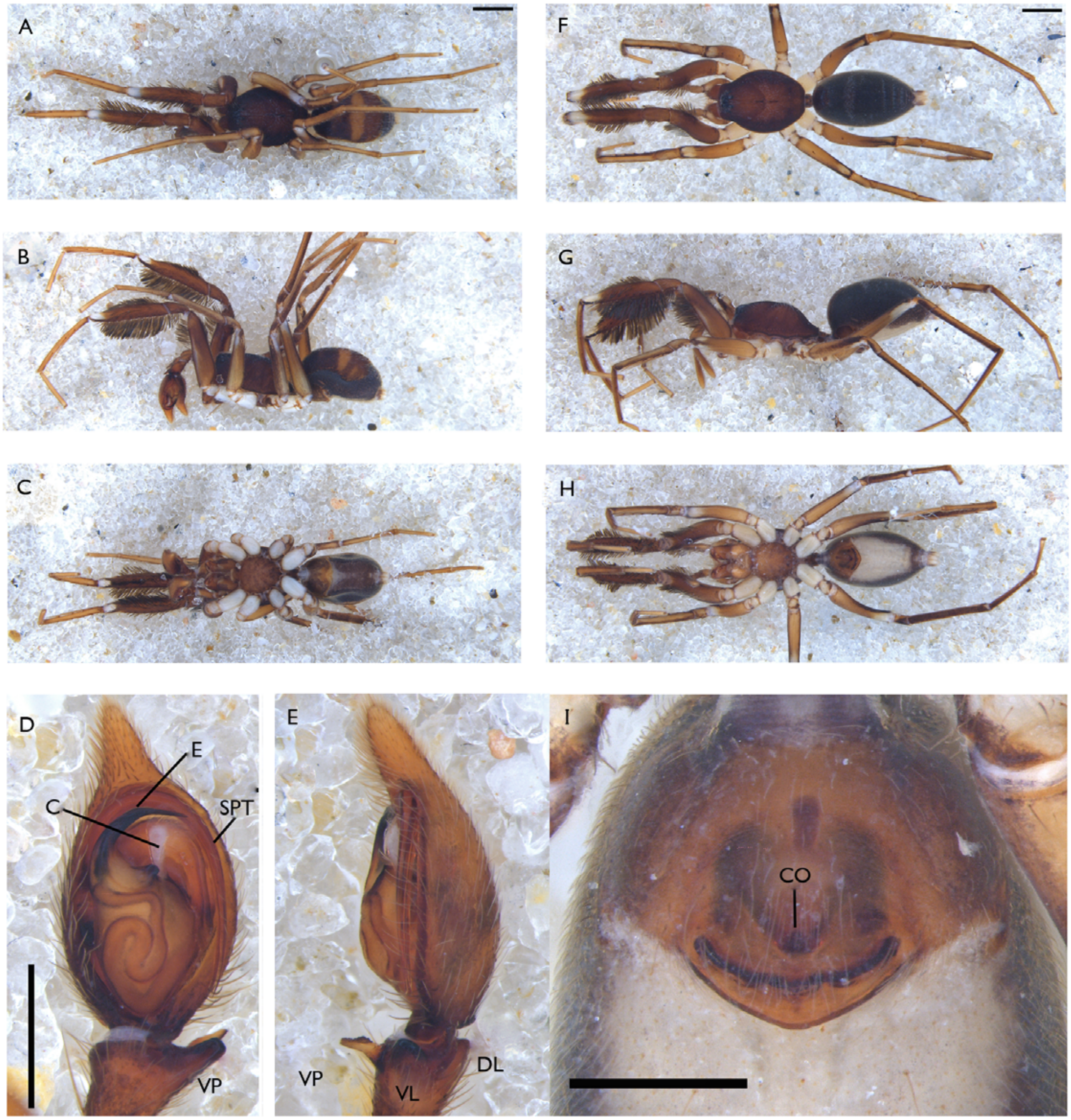

Figure 4. A-I) *Tapixaua callida*. A-E) Male: A) habitus dorsal; B) habitus lateral; C) habitus ventral; D) palp, ventral view; E) palp, retrolateral view. F-I. Female: F) habitus dorsal; G) habitus lateral; H) habitus ventral; I) epigynum, ventral view. Abbreviations: E = embolus; C = conductor; SPT = subtegular process of *Tapixaua*; VP = ventral process of the retrolateral tibial apophysis; DL = dorsal lobe of the retrolateral tibial apophysis; VL = ventral lobe of the retrolateral tibial apophysis; CO = copulatory opening. Scale bar = 1 mm.

RESULTS

So far, *T. callida* was only known from Central Amazonia (Reserva Florestal Adolpho Ducke, Manaus, state of Amazonas, Brazil; type locality), central west of Brazil (Alto Rio Arinos, Diamantino, state of Mato Grosso) and a single locality in Peru (Estación Biológica Panguana, Huánuco) (Bonaldo, 2000). With the new records presented in this paper, we expand the distribution range of the species to the west (Peru and Colombia) and to the east (states of Pará and Maranhão in Brazil). These records depict a pan-Amazon distribution for this species (Figure 5).

NEW RECORDS

The new records refer to three males, two females, and two juveniles collected in five different locations in Brazil, Peru, and Colombia (Figure 5), as follows: BRAZIL: Rondônia, Porto Velho, Abunã, 1 male, 1 ant of the genus *Camponotus,* 19.XI.2011, [9° 41' 52.6" S, 65° 21' 43.8" W], D.F. Candiani leg., sampled at night (MZSP 44994); Pará, Belém, Parque Estadual do Utinga, 1 female, 23.II.2011, 1° 25' 13.24" S, 48° 26' 21.67" W, E.L.S. Costa leg., beating tray (MPEG 39677); Paragominas, 1 juvenile, 20.III.2019, 3° 15' 02.3" S, 47° 45' 46.8" W, C. Favacho leg. (MPEG 39678); 1 juvenile, 21.I.2020, 3° 14' 22.6" S, 47° 47' 00.9" W, C. Favacho leg. (MPEG - lost); 1 male, 03-18.VI.2019, 03° 12' 56.3" S, 47° 43' 08.9" W, R. Silva e equipe, Malaise trap (MPEG 40146); Maranhão, Mirinzal, 1 female, 12.VIII.2011, [2° 04' 06.6" S, 44° 48' 01.3" W], E.L.S. Costa leg. (MPEG 39676); COLOMBIA: Caquetá, Florencia, Centro de Investigaciones Macagual, 1 male, 23.IX.2016, 1° 30' 3.99" N, 75° 36' 22.86" W, beating tray, (ICN); PERU: Loreto, Río Samiria, Cocha Shinguito, 1 female, 1 subadult male, 1 ant of the genus *Azteca*, V-VI.1990, [5° 10' 00.0" S, 74° 39' 00.0" W], T. Erwin & D. Silva leg. (MUSM); BOLIVIA: Beni, Vaca Diez, 525ft: 2 km NW Tumichucua, 1 male, [1° 08' 45.6" S, 66° 09' 55.1" W] (FMNHINS 055001). The male specimen from Bolivia was recorded in GBIF (Grant et al., 2025) and after we received photos of the specimen, we could confirm that it is *Tapixaua callida.*

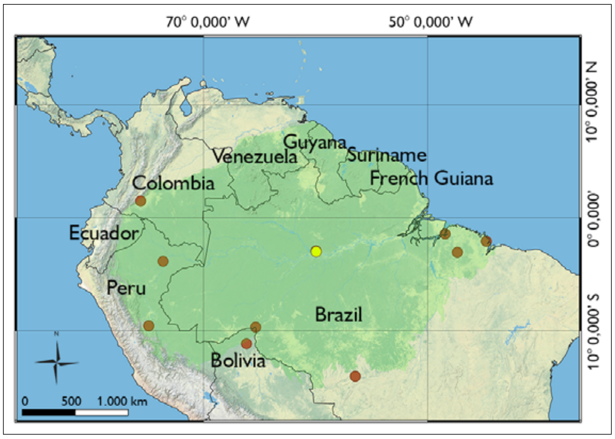

Figure 5. Geographical distribution of *Tapixaua callida* Bonaldo, 2000. Records from published sources and museum collections; the yellow circle denotes the type locality. Area highlighted in darker green represents the Amazon region. Map: Fabián García (2024).

NATURAL HISTORY

On two separate occasions in 2019 and 2020, two juvenile spiders in a fragment of Terra Firme Forest were observed by C.F in the municipality of Paragominas, Pará, Brazil (Figures 1, 2, and 3A). These observations, which lasted between 20 and 30 minutes, are detailed below:

On March 20, 2019, around 2:30 PM, the first spider was found on the stem of a small tree near the entrance of a forest trail (Figure 2D). The spider was walking with short pauses, in a manner very similar to the movement of a similarly sized ant of the genus *Camponotus* Mayr, 1861 (see video in supplementary material)[1]. When it stopped, it extended its front legs forward, moving its tarsi independently to mimic the antennae of an ant, while the modified hairs on its tibia remained static, resembling the ant's head (Figure 2A). The specimen was collected, but it did not survive to adulthood in captivity.

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[1] Link for the video: https://www.youtube.com/watch?v=O4iSL7sWYRA

On January 21, 2020, at approximately 10:30 AM, the second spider was observed walking on one of the tabular roots of a large tree. It was circling a small retreat built into the root wall, about 60 cm above the ground. The retreat was elliptical, about 15 mm long and 10 mm wide, constructed with silk and covered in debris (Figure 2C). After entering the retreat, the spider turned to face the entrance, with the tips of its front tarsi visible. During the observation, the spider repeatedly entered and exited the retreat, briefly patrolling the surrounding area before retreating back inside. The same mimetic behavior as in the previous encounter was observed several times. The specimen was collected but, like the first, it did not survive in captivity until adulthood. It remains to be confirmed whether adult spiders exhibit the same retreat-building behavior.

SEX FORMS ASSOCIATION

Bonaldo (2000) when describing *T. callida* highlighted that the association between males and females of this species needed to be confirmed since they were collected in distant localities. In the original description, the males were found in a single locality in central Amazonia (Reserva Florestal Adolpho Ducke, Manaus, Brazil), while the only female in the type material was collected much further south, more than 1,200 km apart (Alto Rio Arinos, Diamantino, Mato Grosso, Brazil).

We also did not record males and females collected from the same locality in the examined material. However, in the material examined from Rondônia, Brazil (MZSP 44994), a sub-adult male was found alongside an adult female. The shortest distance between the locations of adult males and females was 489.27 km, as observed in the Peruvian specimens. Despite this, no morphological differences were observed in the specimens examined compared to the literature data, and the somatic characters matched flawlessly between males and females. To further validate our findings, it would be interesting to conduct barcoding in the future to confirm that the females are indeed of the same species as the males. This genetic analysis would provide additional evidence to support our hypothesis and address any remaining uncertainties regarding the species' distribution and identification.

Coincidentally, the Asian species *Pranburia mahannopi*, which has a similar morphology to *T. callida*, is also known from males and females collected in different locations. In this case, the males and females were collected more than 1,000 km apart. Cushing (2012) mentions that mimics must be rarer than models for Batesian mimicry to be favored. The presence of only a few individuals (or just one in this case) can be explained by the individual's behavior of mimicry, which involves avoiding other mimics of the same species as a protective strategy. This is a possible explanation for why so few individuals of both *T. callida* and *P. mahannopi* are found and why they are so distant located from each other.

DISCUSSION

ANT MIMICRY

In one of the new records (MZSP 44994), one specimen of *Camponotus* aff. *fastigatus*, Roger, 1863 (Hymenoptera, Formicidae) (Figures 3C-3D) was collected alongside a male of *T. callida*. Besides the similar coloration (brownish-dark carapace and light brown legs), certain morphological characters such as a subglobose abdomen and truncated carapace suggest mimicry of ants from the Camponotini or Dolichoderini tribe (Perger & Rubio, 2020). The field of modified hairs on the first leg, from femur to tibia, may allude to the darker head of this ant, while the lighter metatarsi and tarsi could resemble the model's antennae.

Several Castianeirinae mimics use ants of the genus *Camponotus* as models, such as *Myrmecotypus* O. Pickard-Cambridge, 1894, and *Myrmecium* Latreille, 1824 (Oliveira, 1988; Rubio et al., 2013; Perger & Rubio, 2020). Although the mimic and model have not yet been observed together in situ, here we provide the first evidence of a likely model for *T. callida*.

EVOLUTIONARY CONVERGENCE

Convergent evolution can be understood as the independent evolution of some type of similarity between two taxa that did not arise from common ancestry (Arbuckle & Speed, 2016). Several myrmecomorphic species of spiders can be considered as good models of convergent evolution concerning their body modifications for mimicry.

Both *Tapixaua callida* and *Pranburia mahannopi* seem to have diurnal habits, that exhibit a strikingly similar solution for Batesian mimicry, which is unique by combining morphological and behavioral elements to trigger resemblance with ants 'as needed,' without the constraints of a fixed morphology. Bringing the first pair of legs together and so joining the tufts of tibial modified hairs, provides the necessary volume to produce, the resemblance of an ant head, while the more distal segments, with light colored bases, produces the resemblance with the ant antennae (Figures 3A-3B) (Deeleman-Reinhold, 1993, 2001; Bonaldo, 2000). If we consider both these behavioral and morphological traits as adaptations to ant mimicry, both species can be considered as precise mimics (Haddad, 2013; Pekár et al., 2022).

Despite these similarities, that these characteristics arose independently in these two species is undisputable, since they are phylogenetically distant one from another. *Pranburia mahannopi* shares with other castianeirines the pear-shaped tegulum, a contorted apical embolus and the absence of a conductor (Deeleman-Reinhold, 1993, 2001; Zhang & Jin, 2018). On the other hand, *T. callida* shares with other corinnines the presence of a conductor (Figure 4D) and a double spiral spermophore meander in the tegulum, with ventral folds oriented axially, resembling a double-branched Fermat's spiral (Bonaldo, 2000; Ramírez, 2014; García & Bonaldo, 2023). Furthermore, the modified hairs in *Tapixaua* and *Pranburia* are not homologous, as evidenced by both its fine morphology and distribution. While in *Pranburia* the tibial hairs are long, thin shafts, evenly distributed across the entire perimeter of the article (see Zhang & Jin, 2018, figures 3F-3G), in *Tapixaua* the hairs are spatulated, with papillate surfaces and are unevenly distributed across the article, arranged mainly in latero-ventral and lateral-dorsal rows (Bonaldo, 2000, figures 51-53, 288). These differences suggest that the disguise in *Pranburia*, being efficient from both lateral and dorsal points of view, is more effective than that in *Tapixaua*, which appears to be more efficient from lateral points of view.

This particular ant-mimic syndrome, which we single out here as Deelemanian ant mimicry (in honor of arachnologist Christa Deeleman-Reinhold, who first observed it), may prove to be a much more common phenomena than currently known, occurring in spiders other than Corinnidae. Some *Phrurotimpus* Chamberlin & Ivie, 1935 (Phrurolithidae) species show modifications on leg I (N.I. Platnick, personal communication to ABB, 2015) that could conceivably play such a role and even Salticidae with enlarged tibiae, such as some species of *Tutelina* Simon, 1901 and *Harmochirus* Simon, 1886 may have reached similar solutions (David Hill, personal communication, 2024). The habitus of males of the afrotropical genus *Asceua* Thorell, 1887 (Zodariidae) presents a great similarity to that of an ant with their enlarged palp resembling an ant's head, which might be related to their preference on preying on ants (Jocqué & Henrard, 2024).

On the other hand, the enlargement of Leg I in Salticidae may be related to sexual dimorphism or agonistic display between males. For example, some groups of the subtribe Dendryphantina, which is composed of genera where the males have enlarged Leg I, include ant-mimic species who use Leg II to mimic antennae (as in *Peckhamia* Simon, 1900) (see Cala-Riquelme et al., 2020). The main premise of Deleemanian mimicry proposed here is that it is essentially triggered by certain predator-stimuli. In a strict sense, it involves a mixture of morphology and behavior, making mimicry optional. Salticids with enlarged tibiae may not maintain their first pair of legs joined together due to an anatomical constraint imposed by the cephalothorax shape. In that regard, the antennae-mimic behavior referred to above is not triggered by external stimuli, being part of their walking behavior, as suggested by Shamble et al. (2017). In *Asceua* the ant-resembling morphology is restricted to males, and the body morphology apparently does not make the mimicry optional. Even the most myrmecomorphic spiders also use behavior as a complement to the disguise, but most of the time, the ant-like behavior is stereotyped (or constrained by morphology) and not truly optional. The question would be whether the behavior is variable or constrained by morphology, that is, whatever produces the impression of the ant head (enlarged palps or enlarged or tufted tibiae) should increase or decrease effectiveness depending on behavior. These hypotheses need to be tested by field observations since mimicry, as a dendrnatural phenomenon, is composed of a model-mimic-receptor triad, where understanding how the receptor interprets the message given by the mimic is critical.

CONCLUSION

The *Tapixaua callida* exhibits an interesting behavior of building retreats in tree trunks. Since nothing was known about its behavior until now, it is possible that traditional spider sampling methods failed to capture individuals of this species in arachnofaunistic surveys. The information presented in this manuscript may be useful for future collections of specimens of this genus, potentially revealing whether the behavior observed in juveniles persists in adult individuals (in one or both sexes).

We also confirm the hypothesis of Bonaldo (2000) that the modified hairs on leg I simulate the cephalic tagma of ants (Figure 2A, see Favacho, 2024), highlighting the need of further investigation on the occurrence of Deelemanian ant mimicry in other groups of spiders.

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AUTHOR’S CONTRIBUTION

C. Xavier contributed to conceptualization, data curation, writing (original draft, writing, review & editing), investigation, methodology; C. J. Silva-Júnior contributed to conceptualization, data curation, writing (review & editing), investigation; C. Favacho contributed to data curation, writing (review & editing); F. García contributed to data curation, writing (review & editing), investigation, methodology; L. Martínez contributed to data curation, writing (review & editing); A. A. Bustamante contributed to data curation, writing (review & editing) and A. B. Bonaldo contributed to data curation, writing (review & editing), investigation.

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Checklist of spider species in a urban forest fragment in the Brazilian Amazon with 16 new local records and 3 new records from Brazil

Lista de espécies de aranhas em um fragmento urbano de floresta na Amazônia brasileira com 16 novos registros locais e 3 novos registros para o Brasil

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Abstract: The order Araneae comprises more than 52,000 described species of spiders and despite their high diversity, there is still a lot to study about their taxonomy and biogeography, especially in tropical regions. In this paper, we provide a checklist of spiders from the Research *Campus* of the Museu Paraense Emílio Goeldi, Belém, Pará, Brazil, with new records in different scales. The sampling occurred sporadically between 2011–2018, using different sampling methods. A total of 492 individuals of 172 morphospecies were recorded, distributed in 103 genera and 25 families. It was possible determining 84 species (48.8%), with 16 new records for Belém, including seven for Pará and three for Brazil. The relatively high species can be explained for many factors, such as sampling at different times of the year, use of various collection methods and the fact that the study area is connected to an extensive forest matrix to the northeast, possibly allowing the dispersal of individuals between areas. Finally, the new records, the high species richness and the amount of undetermined species highlights the challenges of having an acceptable level of faunistic knowledge of Amazonia spiders.

Keywords: Amazon. Diversity. Faunistic inventory. Belém. Goeldi Museum.

Resumo: A ordem Araneae reúne mais de 52.000 espécies descritas de aranhas e, apesar da alta diversidade, ainda há muito o que estudar sobre a taxonomia e a biogeografia do grupo, especialmente em regiões tropicais. Neste trabalho, fornecemos uma lista de espécies/morfoespécies de aranhas do *Campus* de Pesquisa do Museu Paraense Emílio Goeldi, Belém, Pará, Brasil, com novos registros em diferentes escalas. As coletas ocorreram de forma esporádica entre 2011–2018, mediante diversos métodos de coleta. Foram amostrados 492 indivíduos de 172 morfoespécies, distribuídas em 103 gêneros e 25 famílias. Foi possível determinar 84 espécies (48,8%), com 16 novos registros para Belém, incluindo sete para o Pará e três para o Brasil. A riqueza de espécies relativamente alta pode ser explicada por diversos fatores, como amostragem em diferentes épocas do ano, uso de vários métodos de coleta e o fato de a área de estudo estar conectada com uma matriz florestal extensa ao nordeste, possivelmente permitindo a dispersão de indivíduos entre as áreas. Por fim, os registros novos, a alta riqueza de espécies e a quantidade de espécies não determinados destacam os desafios de se obter um nível aceitável do conhecimento faunístico de aranhas na Amazônia.

Palavras-chave: Amazônia. Diversidade. Inventário faunístico. Belém. Museu Goeldi.

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INTRODUCTION

Spiders are a group of chelicerates with great evolutionary success, having conquered most of the terrestrial environments (S. C. Dias et al., 2009; Foelix, 2011) and reaching more than 52,800 species described to date (World Spider Catalog, 2025). Currently, thanks to the numerous taxonomists working in highly diverse tropical regions, new spider species are being described at a rapid pace, an average of 834 species annually between 2012 and 2021 (World Spider Catalog, 2025). This accelerated rate of discovery corroborates estimates that the actual global spider richness ranges from 60,000 up to 170,000 species (Coddington & Levi, 1991; Platnick, 1999).

Although spiders are present in great richness and abundance in the tropics (A. Santos et al., 2007; Table 1), there are still several aspects about them that we know very little about. For example, taxonomic knowledge of spiders is quite uneven, with some taxa being much better known than others (Bonaldo et al., 2009a). Likewise, knowledge about the distribution of Neotropical spider species is fragmented (Bonaldo et al., 2009b) and, especially in Brazil, records are concentrated in easily accessible areas, such as the vicinity of large cities, highways, and riverside regions (Bonaldo et al., 2009b; Brescovit et al., 2011; U. Oliveira et al., 2017; Rodrigues et al., 2017). Furthermore, even areas that already have several species records may still be undersampled and present new records when resampled, given that the total species richness in a region is rarely achieved (Coddington et al., 2009).

The knowledge about distribution of spiders is quite incipient in Brazilian Amazon. U. Oliveira et al. (2017), when analyzing the taxonomic literature on spiders and inventories of the Brazilian araneofauna published between 1757 and 2009, recognized 1,036 species of spiders for the Brazilian Amazon, based on 2,516 records of spider species for the biome. However, these records come from samples taken in only 12% of the area occupied by the Amazon biome (U. Oliveira et al., 2017), indicating a strong sampling bias which generates large gaps in knowledge about the distribution of spider species in that region. These gaps are even present in fragments preserved in urban areas, which often harbor an unknown spider fauna. For example, Carvalho & Gasnier (2019) found 94 spider morphospecies in a fragment of Amazon rainforest in the center of Manaus (AM, Brazil; Table 3) and were also able to identify four new records in Central Amazon. This reveals that even small fragments with altered climate and landscape, under the strong influence of the city, maintain a significant diversity of spider communities (Taucare-Ríos et al., 2013).

In the State of Pará, in the Oriental Amazon, there are a few locations that can be considered intensively sampled and with extensive published lists of spider species/morphospecies (Table 1). One of those checklists was provided by Rodrigues et al. (2017), who analyzed records from the Belém Area of Endemism, including portions of eastern Pará and western Maranhão, and obtained 319 species, with 247 records for the municipality of Belém. In the present paper, we provide a checklist of spiders sampled at the Research *Campus* of the Museu Paraense Emílio Goeldi (RC-MPEG), Belém, Pará, an area composed by buildings, herbaceous vegetations and forest fragments, highlighting new local (Belém) or regional (Pará/Brazil) records.

MATERIAL AND METHODS

STUDY AREA

The Research *Campus* of the Museu Paraense Emílio Goeldi (01° 27' 04.44" S, 48° 26' 39.32" W; RC-MPEG) has approximately 0.11 km^2 and is located in the municipality of Belém, Pará, in an area that has been intensely anthropized, bordered to the west by an extensive urban matrix and to the east by cultivated areas and fragments of rainforest (Figure 1). The internal area of the RC-MPEG consists of buildings surrounded by areas of herbaceous and/or shrub vegetation, in addition to small fragments of secondary forest in its northwest and southeast portions (Figures 1–2), partially isolated from the biggest forest fragment by a brick wall of approximately 2 meter high. The study

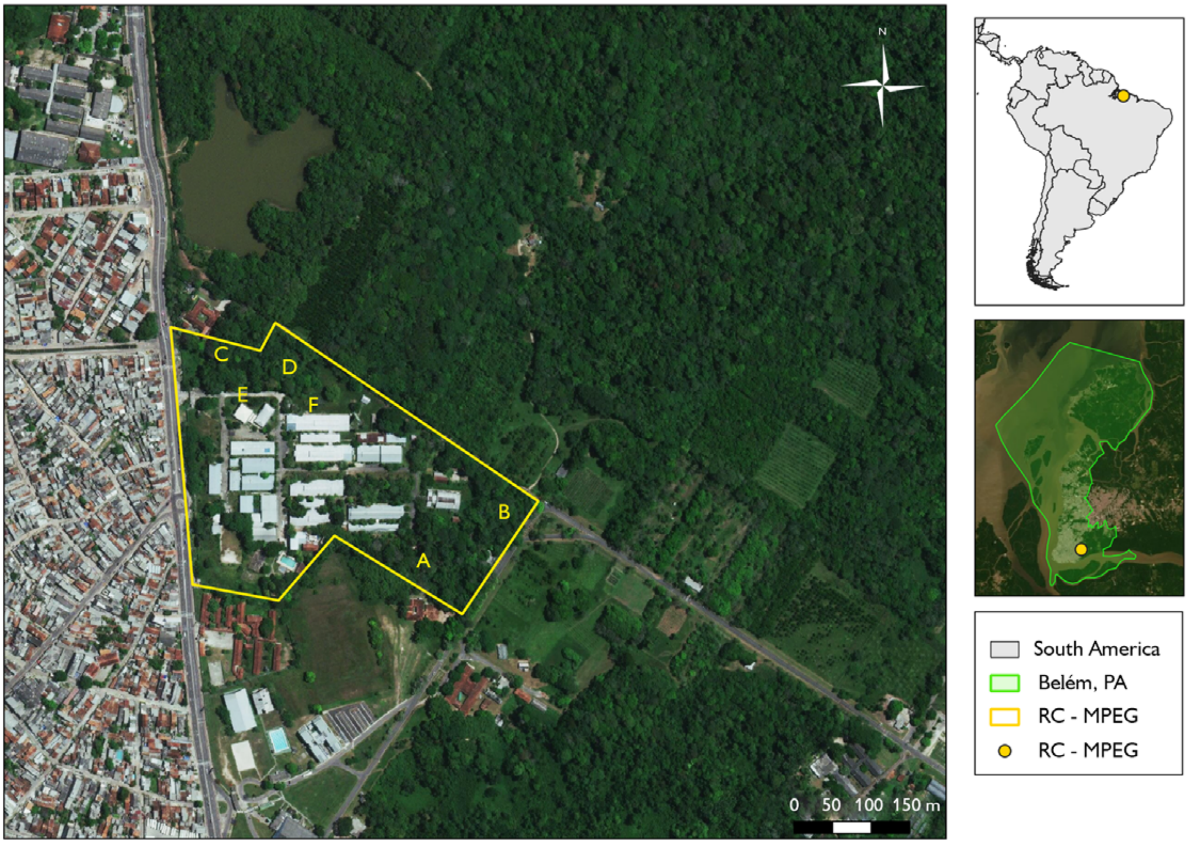

Figure 1. Map of the study area, Research *Campus* of the Museu Paraense Emílio Goeldi (in yellow), located in the city of Belém (in green), Pará, Brazil. The yellow letters (A–F) represent the images in Figure 2. Map: Paulo Pantoja (2017).

Table 1. Summary of inventories of spiders in regions of the State of Pará.

Reference	Locality	Species richness / Percentage of determined species
Ricetti and Bonaldo (2008)	Serra do Cachimbo, Novo Progresso	427 / 21%
Bonaldo et al. (2009b)	Caxiuanã National Forest, Melgaço	591 / 28%
Cafofo et al. (2013)	Caxiuanã National Forest, Melgaço	496 / 30%
Bonaldo et al. (2015)	Sustainable Industrial District of BR-163, Santarém – Castelo dos Sonhos	577 / 13%
Rodrigues et al. (2017)	Belém Area of Endemism, many municipalities	318 / 100%
Silva Junior and Saturnino (2016)	Reserva Extrativista Marinha de Soure, Soure	121 / 29%
Saturnino et al. (2017)	Bagre and Portel	493 / not provided

area is in the Afi climate zone, according to the Koppen classification, with a permanently humid climate and no cold season; the average annual precipitation reaches 2,834 mm (Belém, 2012).

DATA COLLECTION, IDENTIFICATION AND REGISTRATION

The sampling were conducted in several environments within the RC-MPEG, including the internal and external

Figure 2. Environments sampled at the RC-MPEG: A) forest area located to the southeast on the map; B) border area located to the southeast on the map; C-D) forest areas located to the northwest on the map; E-F) border areas at the entrance of the RC-MPEG, located to the northwest on the map. Photos: Paulo Pantoja (2016).

areas of the buildings, open areas dominated by grasses, and small forest fragments (Figure 2). Since the fragments were small and the sampling were intended to be qualitative, there was no demarcation of plots or control of the time spent on each method employed. Instead, sampling occurred across all possible environments within the *campus*, in sporadic periods between 2011 and 2018, with a considerably greater effort between 2014 and 2015, encompassing both rainy and dry seasons. During collections, at least one of the following methods were used: diurnal and nocturnal manual collections, beating tray, pitfall traps and Winkler extractors. All these methods were described by Bonaldo et al. (2009b).

The spiders were sorted and adult individuals were determined to the lowest possible taxonomic level based on literature available in the World Spider Catalog (2025). All adult individuals identified at the genus level were included, and when it was not possible to identify the species, the individuals were grouped into morphospecies based on genitalia characters. Adult individuals were fixed in 80% alcohol and deposited in the Arachnology Collection of the Museu Paraense Emílio Goeldi (MPEG; curator Alexandre B. Bonaldo). Some individuals were photographed in the field with a Canon 70D camera, Canon 100 mm 2.8 macro lens, external flash with homemade diffuser and collected for later identification. The map of the study area was created in the QGIS software v. 3.10 (QGIS Development Team, 2024), using the QuickMapServices plugin, v. 0.19, ESRI Satellite layer.

RESULTS

A total of 492 adult individuals belonging to 172 species/morphospecies, distributed in 113 genera and 25 families (Table 2; Figures 3–13) were obtained. Of this total, it was possible to identify 84 species (48.8%; Table 2), of which 16 species are new records from Belém, seven from Pará and three from Brazil. The most abundant species were *Micrathena aureola* (C. L. Koch, 1836) (n = 28; Figures 4A–4B), *Micrathena plana* (C. L. Koch, 1836) (n = 21; Figure 4E), Lycosidae sp. 1 (n = 16), *Scopocira tenella* Simon, 1900 (n = 15; Figure 9F), *Architis tenuis* Simon, 1898 (n = 13; Figure 7D), Oonopidae sp. 1 (n = 13), *Cotinusa dimidiata* Simon, 1900 (n = 12), *Philoponella opelli* Faleiro & Santos, 2014 (n = 11), *Eustala* sp. 1 (n = 11) and *Noegus coccineus* Simon, 1900 (n = 11), accounting for 22.8% of the total individuals collected. The remaining species/morphospecies were represented by 10 or fewer individuals, with 87 taxa represented by a single individual each (Table 2). Araneidae (38 spp.; n = 136) was the richest and most abundant family, followed by Salticidae (40 spp.; n = 101), which represented 45.3% of the species and 48.2% of the individuals collected. Eight families were represented by only one species/morphospecies (Table 2), namely: Gnaphosidae, Hahnnidae, Mimetidae, Ochyrocerathidae, Oecobiidae, Philodromidae, Sparassidae and Selenopidae.

Of the 84 species recorded for RC-MPEG, 56 species (67.4%) are widely distributed, among them: *Hasarius adansoni* (Audouin, 1826) is cosmopolitan, being found in several continents (World Spider Catalog, 2025); *Scytodes fusca* (Walckenaer, 1837) (Figure 12F) and *Zosis geniculata* (Olivier, 1789) (Figure 12F) have a pantropical distribution (World Spider Catalog, 2025); seven species are distributed throughout the Americas and another 46 species are distributed in the Neotropical region. On the other hand, 28 species have been recorded so far exclusively in the Amazon biome, among which *Capidava biuncata* Simon, 1902, *Lyssomanes tenuis* Peckham, Peckham & Wheeler, 1889 (Figure 9B), *Martella utingae* (Galiano, 1967), *Mesabolivar cambridgei* (Mello-Leitão, 1947), *Metazygia goeldii* Levi, 1995, *Myrmapana mocamboensis* (Galiano, 1974), *Rhyphelia muiratinga* (Ruiz, 2013) and *Tupirinna goeldi* Xavier & Bonaldo, 2021 are known only from the State of Pará, Brazil. Additionally, *Senoculus robustus* Chickering, 1941 (Figure 12C), *Eriophora nephiloides* (O. Pickard-Cambridge, 1889) and *Misumenoides rubrithorax* Caporiacco, 1947 (Figure 12B) are being recorded for the first time in Brazil and other 13 species are being recorded for the first time in the municipality of Belém, of which seven are new records for the State of Pará, totaling 16 new records (Table 2).

Table 2. List of spider species/morphospecies by family and number of individuals collected (N). Known distribution, type of new record (when applicable), and consulted bibliography in determining the species are provided by determined species. Synanthropic species are accompanied by '(S)'. (Continue)

Family / Species	N	Distribution	New record	Consulted bibliography
Anyphaenidae	5			
Anyphaenidae sp. 1	3			
Anyphaenidae sp. 2	1			
Anyphaenidae sp. 3	1			
Araneidae	136			
Alpaida truncata (Keyserling, 1865) (Figure 3A)	5	Neotropical		Levi (1988)
Alpaida veniliae (Keyserling, 1865)	2	Neotropical		Levi (1988)
Araneus guttatus (Keyserling, 1865)	1	Neotropical		Levi (1991a)
Argiope argentata (Fabricius, 1775) (S)	1	America		Levi (2004)
Bertrana striolata Keyserling, 1884	1	Neotropical		Levi (1989)
Cyclosa bifurcata (Walckenaer, 1841)	1	Neotropical		Levi (1999)
Cyclosa fililineata Hingston, 1932	2	Neotropical		Levi (1999)
Cyclosa tapetifaciens Hingston, 1932	1	Neotropical		Levi (1999)
Eriophora nephiloides (O. Pickard-Cambridge, 1889) (Figures 13A, 13B)	1	Neotropical	Brazil	Levi (1971)
Eustala sp. 1	11			
Eustala sp. 2	2			
Eustala sp. 3	4			
Eustala sp. 4	1			
Eustala sp. 5	3			
Eustala sp. 6	1			
Eustala sp. 7	1			
Eustala sp. 8	1			
Gasteracantha cancriformis (Linnaeus, 1758) (Figure 3E)	3	America		Levi (1996)
Mangora insperata Soares & Camargo, 1948	1	Amazon	Pará	Levi (2007)
Mangora melanocephala (Taczanowski, 1874)	2	Neotropical		Levi (2007)
Melychiopharis sp. 1	1			
Metazygia goeldii Levi, 1995	1	Amazon		Levi (1995a)
Metazygia yobena Levi, 1995	1	Amazon		Levi (1985)
Micrathena aureola (C. L. Koch, 1836) (Figures 4A-4B)	28	Neotropical		Levi (1985)
Micrathena evansi Chickering, 1960	7	Neotropical		Levi (1985)
Micrathena excavata (C. L. Koch, 1836)	1	Neotropical		Levi (1985)
Micrathena horrida (Taczanowski, 1873) (Figure 4D)	2	Neotropical		Levi (1985)
Micrathena patruelis (C. L. Koch, 1839)	3	Neotropical	Belém	Levi (1985)
Micrathena plana (C. L. Koch, 1836)	21	Neotropical		Levi (1985)
Micrathena schreibersi (Perty, 1833) (Figure 4C)	1	Neotropical		Levi (1985)
Micrathena spinosa (Linnaeus, 1758) (Figure 4E)	10	Amazon		Levi (1985)
Micrepeira hoeferi Levi, 1995	2	Neotropical	Pará	Levi (1995b)

Table 2. (Continue)

Family / Species	N	Distribution	New record	Consulted bibliography
Neoscona nautica (L. Koch, 1875)	2	Neotropical		Levi (1993)
Parawixia kochi (Taczanowski, 1873)	2	Neotropical		Levi (1992)
Scoloderus cf. *giber* (Figure 3D)	2			
Verrucosa sp. 1 (Figure 3F)	5			
Wagneriana neblina Levi, 1991 (Figure 4F)	1	Amazon	Belém	Levi (1991b)
Wagneriana transitoria (C. L. Koch, 1839)	1	Neotropical		Levi (1991b)
Corinnidae	13			
Corinna gr. *kochi* sp. n. 1	4			
Corinna gr. *kochi* sp. n. 2	2			
Corinna gr. *kochi* sp. n. 3	1			
Creugas sp. n. 1	3			
Falconina gracilis (Keyserling, 1891) (S)	1	America		Bonaldo (2000)
Myrmecotypus olympus Reiskind, 1969 (Figure 6D)	1	Neotropical		Reiskind (1969)
Simonestus sp. n. 1	1			
Tupirinna goeldi Xavier & Bonaldo, 2021	1	Amazon		Xavier and Bonaldo (2021)
Ctenidae	12			
Ancylometes rufus (Walckenaer, 1837) (S) (Figure 5A)	1	Neotropical		Höfer and Brescovit (2000)
Centroctenus ocelliventer (Strand, 1909) (Figure 5C)	1	Neotropical		Brescovit (1996)
Ctenus maculisternis Strand, 1909	5	Amazon		Höfer and Brescovit (1997)
Ctenus sp. 1	1			
Phoneutria reidyi (F. O. Pickard-Cambridge, 1897) (Figures 5E-5F)	1	Amazon		Eickstedt (1983)
Gnaphosidae	2			
Zimiromus aff. *tropicalis*	2			
Hahniidae	2			
Hahniidae sp.1	2			
Idiopidae	2			
Idiopis sp. 1 (Figure 6B)	1			
Idiopis sp. 2	1			
Ischnothelidae	4			
Ischnothele guianensis (Walckenaer, 1837) (S) (Figure 6A)	2	Amazon		Coyle (1995)
Ischnothele sp. 1	2			
Lycosidae	21			
Lycosidae sp. 1	16			
Lycosidae sp. 2	1			
Lycosa sp. 1	4			
Mimetidae	2			
Gelanor sp. 1 (Figure 6E)	2			
Ochyrocerathidae	5			
Ochyrocera hamadryas Brignoli, 1978	5	Amazon		Brignoli (1978)

Table 2. (Continue)

Family / Species	N	Distribution	New record	Consulted bibliography
Oecobiidae	7			
Oecobius concinnus Simon, 1893 (S)	7	America		A. Santos and Gonzaga (2003)
Oonopidae	26			
Amazonops sp. 1	2			
Aschnaoonops sp. 1	1			
Neoxyphinus barreirosi Abrahim & Bonaldo, 2012	3	Amazon	Belém	Abrahim et al. (2012)
Neoxyphinus termitophilus (Bristowe, 1938)	1	Neotropical		Abrahim et al. (2012)
Oonopidae sp. 1	13			
Oonopidae sp. 2	3			
Oonopidae sp. 3	1			
Oonopidae sp. 4	1			
Oonopidae sp. 5	1			
Oxyopidae	7			
Oxyopes sp. 1 (Figure 7C)	1			
Schaenicoscelis sp. 1 (Figure 7A)	4			
Tapinillus longipes (Taczanowski, 1872) (Figure 7B)	2	Neotropical	Belém	A. Santos (2004)
Philodromidae	3			
Cleocnemis querencia (Lise & Silva, 2011)	3	Amazon		Lise and Silva (2011)
Pholcidae	7			
Carapoia cambridgei (Mello-Leitão, 1947)	4	Amazon		Huber (2000)
Mesabolivar sp. 1 (Figure 6F)	3			
Pisauridae	20			
Architis tenuis Simon, 1898 (Figure 7D)	13	Neotropical		A. Santos (2007)
Thaumasia argenteonotata (Simon, 1898)	7	Neotropical		Silva and Carico (2012)
Salticidae	101			
Acragas aff. *falax*	1			
Acragas cf. *peckhami*	1			
Acragas sp. 1	1			
Acragas sp. 2	1			
aff. *Aphirape* sp. 1	1			
Bryantella sp. 1 (Figure 7F)	1			
Bryantella sp. 2	1			
Capidava biuncata Simon, 1902	4	Amazon		Edwards (2015)
cf. *Ilargus* sp. 1	1			
Chira trivittata (Taczanowski, 1871)	1	Neotropical		Galiano (1968)
Cotinusa dimidiata Simon, 1900	12	Amazon		Galiano (1968)
Freya decorata (C. L. Koch, 1846)	3	Amazon		Galiano (2001)
Frigga cf. *kessleri*	3			
Fritzia muelleri O. Pickard-Cambridge, 1879	2	Neotropical	Pará	Galiano (2001)
Gastromichans sp. 1	1			
Hasarius adansoni (Audouin, 1826) (S)	1	Cosmopolitan		Prószynski (2018)

Table 2. (Continue)

Family / Species	N	Distribution	New record	Consulted bibliography
Itata sp. 1	3			
Leptofreya aff. *ambigua*	4			
Lyssomanes aff. *robustus*	1			
Lyssomanes cf. *unicolor*	1			
Lyssomanes sp. 1	1			
Lyssomanes tenuis Peckham, Peckham & Wheeler, 1889	2	Amazon		Galiano (1962)
Maeota sp. 1	3			
Marma nigritarsis (Simon, 1900)	1	Neotropical		Zhang and Maddison (2015)
Martella utingae (Galiano, 1967)	1	Amazon		Galiano (1967)
Myrmapana mocamboensis (Galiano, 1974)	2	Amazon		Galiano (1974)
Noegus arator Simon, 1900	1	Amazon	Belém	J. Santos (2003)
Noegus cf. *franganilloi*	1			
Noegus coccineus Simon, 1900	10	Amazon	Pará	J. Santos (2003)
Nycerella cf. *neglecta*	2			
Parafluda banksi Chickering, 1946	2	Neotropical		Galiano (1971)
Philira sp. 1	4			
Rhyphaelia aff. *paxiuba*	1			
Rhyphelia muiratinga (Ruiz, 2013)	1	Amazon	Belém	Ruiz (2013)
Sarinda nigra Peckham & Peckham, 1892 (Figure 7A)	1	Neotropical		Galiano (1965)
Scopocira histrio Simon, 1900	2	Neotropical		Costa and Ruiz (2014)
Scopocira tenella Simon, 1900	15	Neotropical		Costa and Ruiz (2014)
Scopocira sp. 1	1			
Salticidae sp. 1	7			
Salticidae sp. 2	1			
Scytodidae	6			
Scytodes fusca Walckenaer, 1837 (S) (Figure 10B)	2	Pantropical		Šestáková et al. (2014)
Scytodes sp. 1	2			
Scytodes sp. 2	1			
Scytodes sp. 3	1			
Selenopidae	3			
Selenops maranhensis Mello-Leitão, 1918 (S) (Figure 10A)	3	Neotropical		Corronca (1995)
Senoculidae	3			
Senoculus robustus Chickering, 1941 (Figures 10C, 13E, 13F)	1	Neotropical	Brazil	Chickering (1941)
Senoculus sp. 1 (Figure 10D)	2			
Sparassidae	1			
Sparassidae sp. 1	1			
Tetragnathidae	5			
Azilia sp. 1 (Figure 10E)	3			
Leucauge sp. 1 (Figure 10F)	1			
Leucauge sp. 2	1			
Theraphosidae	4			
Acanthoscurria geniculata (C. L. Koch, 1841)	1	Amazon		Paula et al. (2014)

Table 2. (Continue)

Family / Species	N	Distribution	New record	Consulted bibliography
Avicularia avicularia (Linnaeus, 1758) (S) (Figures 11A, 11B)	3	Neotropical		Fukushima and Bertani (2017)
Theridiidae	41			
Achaearanea sp. 1	1			
Achaearanea sp. 2	1			
Achaearanea trapezoidalis (Taczanowski, 1873)	3	Neotropical		Levi (1955)
Anelosimus eximius (Keyserling, 1884)	10	America		Agnarsson (2006)
Ariamnes attenuatus O. Pickard-Cambridge, 1881	1	Neotropical		Exline and Levi (1962)
Dipoena cf. *hortoni*	2			
Janula salobrensis (Simon, 1895)	5	Neotropical		Levi (1964)
Spintharus flavidus Hentz, 1850	4	America		Levi (1963b)
Steatoda sp. 1	5			
Theridion cf. *archeri*	2			
Theridion soaresi Levi, 1963	1	Amazon		Levi (1963a)
Theridion sp. 1	2			
Thwaitesia bracteata (Exline, 1950)	2	Amazon		Levi (1963b)
Thymoites cf. *prolatus*	1			
Tidarren sisyphoides (Walckenaer, 1841) (S)	1	America		Levi (1957)
Thomisidae	28			
Bucranium taurifrons (O. Pickard-Cambridge, 1881)	1	Neotropical		Teixeira et al. (2014)
Epicadinus biocellatus Mello-Leitão, 1929 (Figure 11E)	2	Amazon		Prado et al. (2018)
Epicadus taczanowskii Roewer, 1951 (Figures 11C, 11D)	5	Neotropical		Machado et al. (2018)
Misumenoides rubrithorax Caporiacco, 1947 (Figures 12B, 13C, 13D)	2	Neotropical	Brazil	Lise et al. (in prep.)
Misumenops sp. 1	5			
Onocolus echinatus (Taczanowski, 1872)	1	Neotropical		Lise (1981)
Strophius cf. *albofasciatus*	1			
Strophius nigricans Keyserling, 1880 (Figure 12A)	2	Neotropical		Teixeira et al. (2014)
Synema sp. 1 (Figure 12C)	4			
Synema sp. 2 (Figure 12D)	1			
Tmarus sp. 1	1			
Tmarus sp. 2	1			
Tmarus sp. 3	1			
Tmarus sp. 4	1			
Tmarus sp. 5	1			
Trechaleidae	15			
Dossenus cf. *longipes* (Figure 12E)	7			
Neoctenus comosus Simon, 1897	7	Neotropical	Pará	Dávila (2003)
Syntrechalea adis Carico, 2008	1	Amazon	Pará	Carico (2008)
Uloboridae	12			

Table 2. (Conclusion)

Family / Species	N	Distribution	New record	Consulted bibliography
Philoponella opelli Faleiro & Santos, 2014	11	Neotropical	Pará	Faleiro and A. Santos (2014)
Zosis geniculata (Olivier, 1789) (S) (Figure 12F)	1	Pantropical		Opell (1979)
Individuals total	492			

Figure 3. Diversity of Araneidae at the RC-MPEG: A) *Alpaida truncata*, male; B) *Cyclosa* sp., female; C) *Eustala* sp., male; D) *Scoloderus* sp., female; E) *Gasteracantha cancriformes*, female; F) *Verrucosa* sp., female. Photos: César Favacho (2016).

Figure 4. Diversity of Araneidae at the RC-MPEG, genera *Micrathena* and *Wagneriana*: A-B) *Micrathena aureola*; A) female; B) male; C) *Micrathena schreibersi*, female; D) *Micrathena horrida*, subadult male; E) *Micrathena plana*, female; F) *Wagneriana neblina*, female. Photos: César Favacho (2016).

Figure 5. Diversity of Ctenidae at the RC-MPEG: A) *Ancylometes rufus*, male; B) *Ctenus* sp., female; C) *Centroctenus ocelliventer*, female; D) *Ctenus* sp., female; E-F) *Phoneutria reidyi*, male; E) dorsolateral view; F) frontal view. Photos: César Favacho (2016).

Figure 6. Diversity of spiders at the RC-MPEG: A) *Ischnothele guianensis*, Ischnothelidae, female; B) *Idiops* sp., Idiopidae, male; C) *Corinna* sp., Corinnidae, male; D) *Myrmecotypus niger*, Corinnidae, male; E) *Gelanor* sp., Mimetidae, female; F) *Carapoia fowleri*, Pholcidae, female. Photos: César Favacho (2016).

Figure 7. Diversity of Oxyopidae (A-D) and Salticidae (E-F) at the RC-MPEG: A) *Schaenicosceles* sp., subadult male; B) *Tapinillus longipes*, female; C) *Oxyopes* sp., female with egg sac; D) *Architis tenuis*, Pisauridae, female; E) *Sarinda* sp., female; F) *Bryantella* sp., female. Photos: César Favacho (2016).

Figure 8. Diversity of Salticidae at the RC-MPEG: A) *Acragas* sp., female; B) *Nycerella* sp., female; C) *Freya decorata*, female; D) *Philira* sp., female; E) *Freya rubiginosa*, male, preying on a dipteran; F) *Philira* sp., male. Photos: César Favacho (2016).

Figure 9. Diversity of Salticidae at the RC-MPEG: A) *Chira trivittata*, female; B) *Lyssomanes tenuis*, female; C) *Maeota* sp., male; D) *Noegus arator*, male; E) *Noegus* sp., female; F) *Scopocira tenella*, female. Photos: César Favacho (2016).

Figure 10. Diversity of spiders at the RC-MPEG: A) *Selenops maranhensis*, Selenopidae, female; B) *Scytodes fusca*, Scytodidae, female; C-D) Senoculidae – *Senoculus robustus*, female (C) and *Senolus* sp., male (D) –; E-F) Tetragnathidae – *Azilia* sp., female (E) and *Leucauge* sp., female (F). Photos: César Favacho (2016).

* * *

Figure 11. Diversity of Theraphosidae (A-B) and Thomisidae (C-F) at the RC-MPEG: A-B) *Avicularia avicularia*, Theraphosidae – female, dorsal view (A) and juvenile, dorsal view (B) –; C-D) *Epicadus taczanowskii*, Thomisidae – female, dorsanterior view (C) and male (smaller, brown spider) on the abdomen of the female (larger, yellow spider) (D) –; E) *Epicadinus biocelatus*, Thomisidae, female; F) *Tmarus* sp., Thomisidae, male. Photos: César Favacho (2016).

Figure 12. Diversity of spiders at the RC-MPEG: A-D) Thomisidae – *Strophius nigricans*, female preying on an ant (A); *Misumenoides rubrithorax*, female (B); *Synema* sp., female (C); *Synema* sp., male (D) –; E) *Dossenus* sp., Trechaleidae, male; F) *Zosis geniculata*, Uloboridae, female. Photos: César Favacho (2016).

Figure 13. New records for Brazil: A-B) *Eriophora nephiloides*, Araneidae, male – habitus dorsal (A) and palp, mesal view (B) –; C-D) *Misumenoides rubrithorax*, Thomisidae, female – habitus dorsal (C) and epigynum (D); E-F) *Senoculus robustus*, Senoculidae, female – habitus dorsal (E) and epigynum (F). Scale bars (mm): A: 2; B, D, F: 0.2; C: 1; E: 3. Photos: Paulo Pantoja (2024).

DISCUSSION

The number of determined species in this study represents almost half of the total of taxa sampled (48.8%), which can be considered high when we compare with other studies on spiders (Table 1) but demonstrate the challenges of having an acceptable level of faunistic knowledge of Amazonian spiders. Obtaining success in determining species depends, among several factors, on the availability of modern taxonomic revisions (Bonaldo et al., 2009a). In the case of spiders, the existence of an online worldwide taxonomic catalog (World Spider Catalog, 2025), which provides primary taxonomic data on the more than 52,800 described species, greatly facilitates the process of assigning a scientific name to the examined specimens. However, several groups still lack recent papers with informative illustrations and descriptions that allow a confident determination, resulting in lists of species with a taxonomic resolution below 50% (Table 1), with some families in which all individuals are grouped only into morphospecies. For example, S. C. Dias & Bonaldo (2012) provided the largest list of spider species/morphospecies for the Brazilian Amazon: 623 spp. in forest gaps and forest matrix in the Urucu River basin, Coari, Amazonas; however, only 23% of the taxa (144 spp.) were determined at the species level (Table 3). In this context, there is a scarcity of biogeographic knowledge of spiders due not only to sampling bias (U. Oliveira et al., 2017), but also to the difficulty in determining taxa at the specific level, which would provide reliably standards for the comparison of community structure across environments and biomes.

The species richness recorded for RC-MPEG is quite representative considering the small area of the *campus* and the obtained abundance. Additionally, the percentage of morphospecies represented by a single individual (49.7%) suggests that species richness is greater, since undersampling is the most likely reason to explain the record of a single individual for several species in a given area (Coddington et al., 2009). Increasing sampling effort would allow recording species abundance patterns more clearly and access new rare species (Coddington et al., 2009), increasing the number of local species.

Our study obtained a great species richness of spiders comparated to other studies carried out in forest fragments in the middle of the urban matrix (Table 3). However, that comparation must be made with reservations, since the sampling methods and periods largely vary between those studies (Table 3). For RC-MPEG, as mentioned previously, the spiders were collected over a long period (eight years) using various methods that allowed to explore different microhabitats (leaf litter, shrubs, tree trunks, grasses, and the interior of buildings) with the goal to obtain as many species as possible. Certainly, sampling in different times of the year and the diversity of sampling methods allowed such expressive richness to be achieved, especially of synanthropic spiders, reinforcing the importance of using different sampling methods in a faunistic inventory.

Another factor that may explain the great richness of spiders in RC-MPEG, is the fact that this site is connected to an extensive forest matrix to the northeast (Figure 1), encompassing the Mocambo Reserve and the Utinga State Park. Spiders have a great dispersal capacity (A. Santos et al., 2007) and it is likely that the spider assemblage disperses throughout this vegetation matrix, resulting in a constant influx of individuals from different species into the RC-MPEG area. Thus, we cannot consider RC-MPEG as an isolated fragment, as is the case of MB (S. C. Dias et al., 2006), BG (S. R. Dias et al., 2024) and UFAM (Carvalho & Gasnier, 2019), but rather as part of a set of forest patches, which are interconnected and contain significant spider diversity.

Regarding families, the greater number of individuals and species of Araneidae (Figures 3–4) can be explained by some reasons. Firstly, thanks to the tireless work of Herbert Levi, who reviewed several genera of Araneidae from Neotropics (see bibliography of Araneidae in Table 2), it was possible to determine at a specific level most of the collected individuals of that family. Furthermore, araneids can be easily sampled, since these spiders build conspicuous orb webs, and are easily seen in both nocturnal and diurnal

Table 3. Summary of some studies on spiders in urban fragments in Brazil.

Locality	Estação Ecológica da Universidade Federal de Minas Gerais, Belo Horizonte – MG	Mata do Buraquinho, João Pessoa – PB	*Campus* of the Federal University of Amazonas, Manaus – AM	Botanical Garden of Diadema City, Diadema – SP	Research *Campus* – Museu Paraense Emílio Goeldi, Belém – PA
Biome	Atlantic Forest	Atlantic Forest	Amazon	Atlantic Forest	Amazon
Reference	Álvares et al. (2004)	S. C. Dias et al. (2006)	Carvalho and Gasnier (2019)	S. R. Dias et al. (2024)	This study
Species richness	223	166	94	37	172
Abundance (only adults)	2,310	1,681	1,080	118	492
Sampling methods	Beating tray and pitfall trap	Nocturnal manual collection, beating tray and pitfall trap	Beating tray	Nocturnal manual collection and pitfall trap	Diurnal and nocturnal manual collections, beating tray, pitfall trap and Winkler extractor
Sampling period	2000-2001	2003-2004	2011-2012	2024	2011-2018
Study site area (in km^2)	1	5	7	0.026	0.11

collections. Additionally, many species build webs in easily accessible places, such as open environments and at the edges of forests (P. Pantoja, personal observation). Likewise, the high representation of Salticidae (Figures 7–9) in this study is largely because it is the most diverse family of spiders, with more than 6,800 described species, in addition to being very abundant in Neotropical region. Also, Neotropical salticids have been receiving attention from taxonomists for many years, with several species being described and redescribed with sufficient information to allow their determination (see bibliography of Salticidae in Table 2).

The 16 new records for the municipality of Belém, an addition to the 247 species already recorded (U. Oliveira et al., 2017) corroborate the idea that even areas in large cities, with easy access and close to research centers, may have previously unrecorded arachnid fauna, a reality also recognized for Manaus by Tourinho et al. (2011). Some factors related to sampling can explain that situation. At first, spiders occupy a multitude of microhabitats in tropical regions, from the litter to the canopy, and some species are found in cryptic environments, such as cracks between tree trunks and rocks. For this reason, it is necessary to use different collection methods when sampling an area to access the arachnid fauna of different vegetation strata (Coddington et al., 1991; Bonaldo et al., 2009b). In addition, the richness and abundance of spider species can vary according to seasonality (Mineo et al., 2010; Campuzano et al., 2019), and for this reason, some species are more easily collected at certain periods of the year. In this context, since the municipality of Belém does not have any published spider inventory, it is expected that new sampling using different methods and over several years will access a previously unknown fauna. Additionally, recent taxonomic publications have strong impact in the taxonomic resolution of the checklists and increase the number of new records. Therefore, even specimens collected a long time ago may represent new records in recent papers, since only after the publication of a recent taxonomic paper on that group it was possible to assign a scientific name to those specimens.

Some of the 83 records that were identified down to species in this paper deserve to be highlighted, due to their synanthropy, medical relevance and noteworthy aspects on natural history. Eleven species are considered synanthropic (Table 2), since they were collected inside buildings or have been recorded as such in other inventories (Rodrigues et al., 2017). All of them are harmless to humans. *Avicularia avicularia* (Linnaeus, 1758) (Theraphosidae; Figures 11A–11B) is a large synanthropic spider, a species of tarantula that was collected inside several buildings at RC-MPEG. Despite its large size, this species is not aggressive, and a curious fact is that juveniles have a color pattern that is distinct from adults: pink legs and red abdomen (Figure 11B). *Ancylometes rufus* (Walckenaer, 1837) (Ctenidae; Figure 5A) is common in homes, mainly in humid places such as bathrooms and backyards. *Selenops maranhensis* Mello-Leitão, 1918 (Selenopidae; Figure 10A) is also synanthropic, very common to be seen on residential walls, and has a wide and flat body; despite being adapted to the residential environment, specimens of *S. maranhensis* were collected on tree trunks at RC-MPEG. *Phoneutria reidyi* (F. O. Pickard-Cambridge, 1897) (Ctenidae; Figures 5E-5F), commonly known as the "aranha-armadeira" in Brazil, is the only species of medical importance recorded here for RC-MPEG. There are no reports in the literature of severe symptoms resulting from a bite by that species, the most common symptoms are local pain, erythema, edema and paresthesia (Bucaretchi et al., 2018; Salvatierra & Ramos, 2018). The specimen of *P. reidyi* was collected in one of the forest areas. *Anelosimus eximius* (Keyserling, 1884) (Theridiidae) is a social spider that can build community webs among vegetation (Agnarsson, 2006). A community web approximately 1.5 m high was sampled at RC-MPEG, where *Anelosimus* spiders coexisted with others of the species *Philoponella opelli* Faleiro & Santos, 2014 (Uloboridae). *Epicadus taczanowskii* Roewer, 1951 (Thomisidae; Figures 11C–11D) and *Misumenoides rubrithorax* are between the spiders with great sexual dimorphism; in the case of these species, males are distinctly smaller and darker than females. Finally, another Thomisidae that deserves to be highlighted is *Strophius nigricans* Keyserling, 1880 (Figure 12A), a species that feeds preferentially on ants (P. S. Oliveira & Sazima, 1985), in contrast to the generalist diet of most spiders (Foelix, 2011).

Although Belém has a relatively high number of records of spider species (U. Oliveira et al., 2017; Rodrigues et al., 2017), this number could be much higher, given the large extent of areas that remain unsampled (Rodrigues et al., 2017) and the number of taxa that remain unidentified at the species level. If the sampling of a small area, such as RC-MPEG, yielded 16 new records for Belém, we can expect that the sampling of larger and more continuous areas, will increase the list of species for the municipality. Finally, the 172 species recorded for RC-MPEG reinforce the importance of the study area in maintaining regional spider diversity.

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Adding a puzzle piece to the scorpion distribution: expanding the records of *Tityus* (*Tityus*) *confluens* Borelli, 1899 (Scorpiones, Buthidae) in southern Brazil

Adicionando uma peça do quebra cabeça da distribuição do escorpião: expansão dos registros dos *Tityus* (*Tityus*) *confluens* Borelli, 1899 (Scorpiones, Buthidae) no sul brasileiro

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Abstract: New records for the species *Tityus* (*Tityus*) *confluens* Borelli, 1899, previously known from the states of Ceará, Mato Grosso, Mato Grosso do Sul, Piauí, and Tocantins in Brazil, are made for the state of Paraná. In addition, an updated map with these new records from Brazil is provided.

Keywords: Neotropical. Paraná. South America. Scorpiofauna. Buthidae.

Resumo: Novos registros para a espécie *Tityus* (*Tityus*) *confluens* Borelli, 1899, anteriormente conhecida para os estados de Ceará, Mato Grosso, Mato Grosso do Sul, Piauí e Tocantins, no Brasil, são feitos para o estado do Paraná. Além disso, um mapa atualizado com esses novos registros para o Brasil é fornecido.

Palavras-chave: Neotropical. Paraná. América do Sul. Escorpiofauna. Buthidae.

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INTRODUCTION

The arachnids of the order Scorpiones C. L. Koch, 1837, are widely distributed on all continents, except Antarctica, with most species found in tropical and subtropical forests (Polis, 1990). They are found in various microhabitats, such as beneath the bark of dead logs, in cracks in stones, within leaf litter, and inside termite mounds, for instance (Polis, 1990). Currently, the order comprises approximately 2,800 species, but their phylogenetic relationships and taxonomy are still broadly discussed (Prendini & Wheeler, 2005; Sharma et al., 2015; Ojanguren-Affilastro et al., 2017; Santibanez-Lõpez et al., 2019, 2020, 2023).

In Brazil, approximately 180 species of scorpions are found, mostly belonging to the families Ananteridae, Bothriuridae, Buthidae, Chactidae, and Hormuridae (Porto et al., 2010; Bertani et al., 2024; Ythier, 2024). Within Buthidae, the genus *Tityus* Koch, 1836 is distributed in the West Indies, Central, and South America (Fet & Lowe, 2000; Lourenço, 2006). The genus stands out for having most of the species of medical interest across nearly all of South America (Borges et al., 2010, 2020). In this context, studies of its species have increased due to their medical importance, primarily involving research in toxinology, animal behavior, and public health services (Francke & Stockwell, 1987; Fet & Lowe, 2000; Souza et al., 2009; Lourenço, 2015; Borges et al., 2020). However, despite the genus' importance, its taxonomy is confusing and still needs to be reviewed, mainly with updates on the species distribution (Fet & Lowe, 2000; Borges et al., 2010; Lourenço, 2006, 2015).

Among this fauna, *Tityus* (*Tityus*) *confluens* Borelli, 1899 was firstly described as a subspecies of *Tityus trivittatus* Kraepelin, 1898 based on two female specimens from Bolivia (Borelli, 1899; Lourenço et al., 2004). Subsequently, Maury (1974, p. 86) elevated it to species rank. Nowadays, the species is divided into two subspecies: *T. confluens confluens* Borelli, 1899 and *T. confluens bodoquena* Lourenço, Cabral & Ramos 2004 (Lourenço et al., 2004). To date, *T. confluens* Borelli, 1899 has been the main point of disagreement and doubts surrounding its taxonomy and distribution with records in the Chaco region, particularly in Bolivia, Paraguay, Argentina, and Brazil (Lourenço et al., 2004; Bertani et al., 2005; Lourenço & Aparecida-da-Silva, 2006, 2007; Mattos et al., 2013, 2014; Carvalho et al., 2017). In Brazil, the species distribution has been debated, with some authors arguing in favor of its presence in states of Ceará, Mato Grosso, Mato Grosso do Sul, Paraná, Piauí, and Tocantins (see Bertani et al., 2005; Lourenço & Aparecida-da-Silva, 2006, 2007; Porto et al., 2014; Carvalho et al., 2017; Braga et al., 2022).

Particularly in Paraná, Mello-Leitão (1945) recorded the species in Foz do Iguaçu, and Bücherl (1959) recorded it in Rio Branco (= Rio Branco do Sul). Later, Maury (1974), Lourenço (1980), and Lourenço and Aparecida-da-Silva (2006) questioned the record in Foz do Iguaçu, suggesting it might actually be *T. trivittatus* rather than *T. confluens*, while Lourenço and Aparecida-da-Silva (2006) considered the record in Rio Branco do Sul as misidentification.

In this context, the occurrence of the species in Paraná has remained uncertain until now. To fill this gap in the distribution of *T. confluens* in Brazil, we confirmed the presence of adults and immatures in the state of Paraná. This finding confirms those of previous authors and significantly expands the geographic distribution of the species in the country. We also provide figures of adults and an updated map of the species' distribution in Brazil.

MATERIAL AND METHODS

The examined material is deposited in the following institutions (curators in parentheses): Instituto Butantan (IBSP), São Paulo, Brazil (A. D. Brescovit); Coleção Aracnólogica, Secretaria de Saúde do Estado do Paraná (SESA), Paraná, Brazil (J. C. Cequinel). The examined material was identified based on the descriptions provided by Maury (1974), Lourenço et al. (2004), and Bertani et al. (2005). A taxonomically conservative approach was employed in determining the examined material, considering the broad context regarding the "*Tityus confluens* complex" (see Mattos et al., 2013). All measurements and specimens examination were conducted in 70% ethanol using a Leica MZ16A stereomicroscope. The photographs were taken with a Leica DFC 500 digital camera mounted on a Leica MZ16A stereomicroscope, and the extended focal range images were composed with Leica Application Suite version 2.5.0 (Leica Microsystems, Canton de Saint-Gall, Switzerland). The geographical coordinates were obtained directly from the original label of the examined specimens. The distribution map was made using the free software DIVA-GIS ver. 7.5.0. (Hijmans et al., 2001), and the heatmap was made using the Flourish Studio (Seligman, 2013), with the values adjusted to minimum = 1, maximum = 150, and downsampling = 4x.

RESULTS

TAXONOMY

Family Buthidae C. L. Koch, 1837
Genus *Tityus* C. L. Koch, 1836
Tityus (*Tityus*) *confluens* Borelli 1899
(Figures 1–2)

Identification. Adapted from Bertani et al. (2005). Adults range from 52 to 53 mm. in total length (Figure 1). General coloration of prosoma and mesosomal tergites I–VI almost uniformly yellowish to blackish-brown; tergites VII yellowish, with a single median blackish spot, metasomal segments I to III light yellow to brownish, IV and V light brownish; pedipalps yellowish, with yellowish to brownish fingers; legs yellowish. The fixed and movable fingers of pedipalps with 17-16 rows of granules. Pectinal tooth count in females 23-24.

Descriptive notes. Females and immatures, see in Bertani et al. (2005, p. 2).

Material examined. BRAZIL. Paraná: Ivatuba [-23.620457, -52.219657], 07.xi.2022, Ademir coll., ♀ (IBSP 9905); 06.xi.2022, Vania leg., ♀ (IBSP 9908); 12.vii.2022, Antonina leg.; ♀ (IBSP 9910), 18.x.2022, Salim leg. ♀ (IBSP 9926); ♀ (IBSP 9931); 1.xi.2021, Vânia leg., ♀ (IBSP 9938); i.2023, Bruno leg., ♀ (IBSP 9664); 20.i.2023, Jaiton leg., ♀ (IBSP 9672); 23.i.2023, A. Requena leg., ♀ (SESA 9644); 26.viii.2022, ♀ (SESA 9314); 02.iv.2021, M. Bellun leg., ♀ (SESA 9110); 09.viii.2021, Adotino leg., ♀ (SESA 9109); 15.ix.2022, L. Dandoline leg., ♀ (SESA 9394); 06.iv.2022. H. Oliveira leg., ♀ (SESA 9240); 19.viii.2022, A. Pelissari leg., ♀ (SESA 9313); 11.viii.2020, D. Bortoti leg., ♀ (SESA 8171); 09.vi.2020, PMS leg., ♀ (SESA 8169); 25.ii.2021, O. Melo leg., ♀ (SESA 8488); 04.vi.2020, Lurdes leg., ♀ (SESA 8166); 02.ix.2020, A. Marques leg., ♀ (SESA 8450); 02.ii.2021, Prefeitura Municipal de Ivatuba leg., 1 immature (SESA 8491); 17.vii.2019, R. Sagrilo leg., ♀ (SESA 8054); 19.i.2021, E. Mattia leg., ♀ (SESA 8494); 14.x.2020, Nei leg., ♀ (SESA 8451); 23.v.2020, M.U. Silva leg., ♀ (SESA 8167); 30.xi.2020, S. Cardoso leg., ♀ (SESA 8493); 16.viii.2020, Prefeitura Municipal de Ivatuba leg., ♀, 1 immature (SESA 8453); 19.i.2021, E. Mattia leg., ♀ (SESA 8494); 14.iii.2019, A. Zola leg., ♀ (SESA 8001); 24.iv.2019, L. Dandolini leg., ♀ (SESA 7996); 10.xi.2017, ♀ (SESA 7615); 16.xi.2016, C. Parma leg., 1 immature (SESA 7217); 13.viii.2016, M. Tenedine leg., ♀ (SESA 7345); 09.ix.2016, S. Mattia leg., ♀ (SESA 7311); 09.v.2016, A. Valentini leg., ♀ (SESA 7198); 28.ii.2016, P. Mori leg., ♀ (SESA 7183); 04.v.2016, S. Mattia leg., ♀ (SESA 7200); 21.vi.2016, SISCRED leg., ♀, 1 immmature (SESA 7218); 29.iii.2016, J.E.R. Gimenes leg., ♀ (SESA 7186); 14.iv.2016, L.C. Santini leg., ♀ (SESA 7182); 13.iv.2016, J.E.R. Gimenes leg., ♀ (SESA 7187); 28.xi.2016, ♀ (SESA 7395); 24.xi.2018, P. Oliveira leg., ♀ (SESA 7942); 30.xi.2018, Prefeitura Municipal de Ivatuba leg., ♀ (SESA 7941); 05.ii.2019, Iva leg., ♀ (SESA 7943); 17.iii.2018, M. Semprebom leg., 1 immature (SESA 7729); 22.v.2017, I. Teodoro leg., ♀ (SESA 7535); 11.iv.2018, I. Duminelli leg., ♀ (SESA 7730); 28.vi.2018, V. Nazari leg., ♀ (SESA 7869); 28.i.2016, E.L. Ruiz leg., ♀ (SESA 7130); 15.vii.2015, S. Campanholo leg., ♀ (SESA 6924); 15.ix.2015, M.G. Araújo leg., ♀ (SESA 7013); 17.xii.2015, A. Zola leg., ♀ (SESA 7129); 23.vii.2015, V. Vercei leg., ♀ (SESA 6925); 04.vii.2015, M. Gomes leg., ♀ (SESA 6926); 25.vii.2015, H. Lavezo leg., ♀ (SESA 6929); 02.viii.2013, Romeu leg., ♀ (SESA 6005); 15.ii.2014; S. Celestino leg., ♀

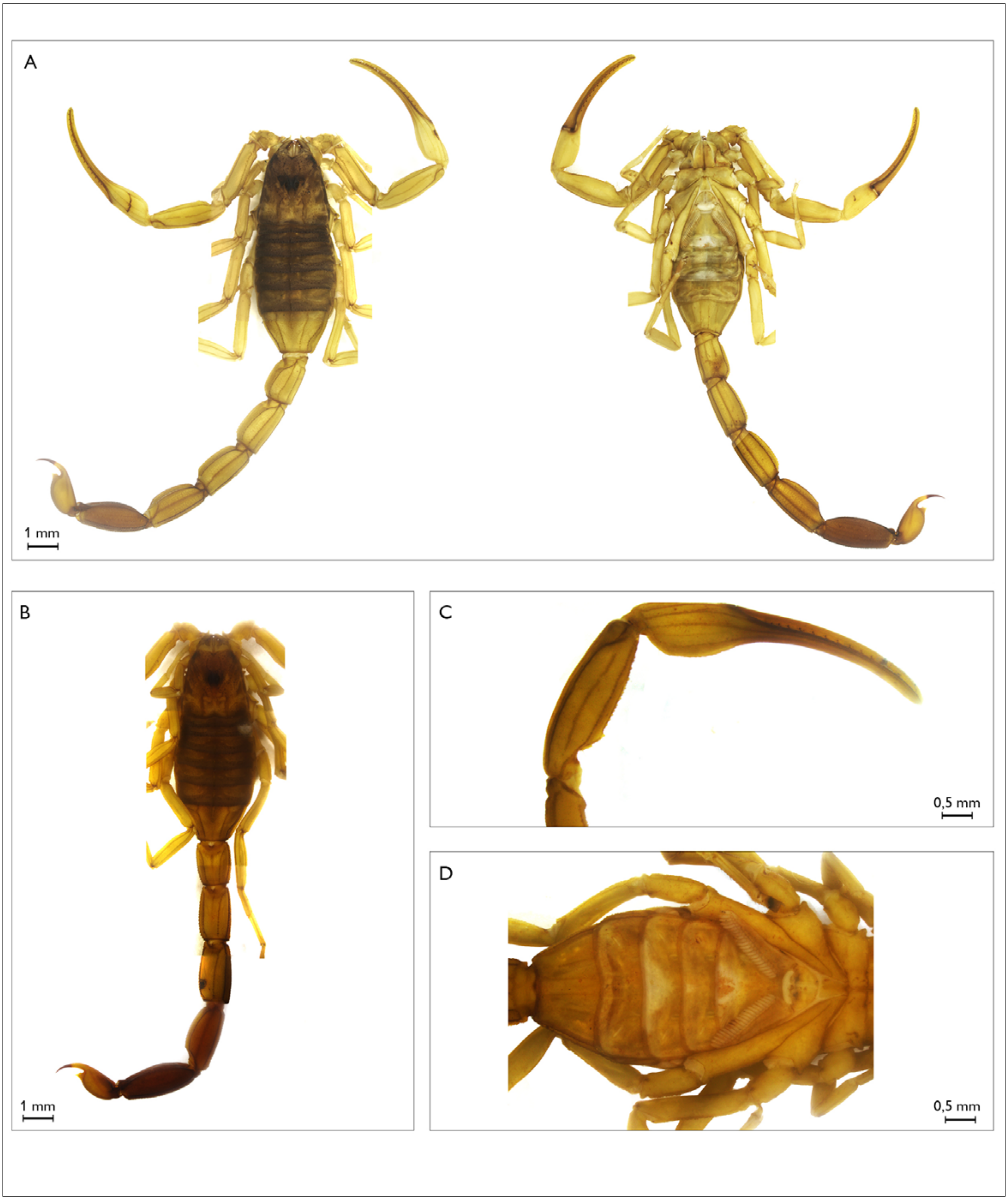

Figure 1. Habitus *of Tityus confluens* Borelli, 1899, from Foz do Iguaçu, Paraná, Brazil: A) dorsal and ventral view, female (IBSP 10182); B) dorsal view, male (IBSP 12544); C) detail of left pedipalp in dorsal view, male (IBSP 12544); D) detail of ventral view, male (IBSP 12544).

(SESA 6613); 26.iv.2014; S. Mattias leg., ♀ (SESA 6590); 13.xii.2013, M.A. Valentim leg., ♀ (SESA 6124); 29.xi.2013, E.L. Ruiz leg., ♀ (SESA 6114); Guaíra [-24.084028, -54.249948], 18.xi.2021, L.A. Miranda leg., ♀ (IBSP 9651); 08.iii.2023, M.C. Brum leg., ♀ (SESA 9089); 27.viii.2021, Reinaldo leg., ♀ (SESA 8781); 01.iv.2009, Wagner leg., ♀ (SESA 2056); 22.ii.2017, Correio leg., ♀ (SESA 7440); 21.v.2018, Barão do Rio Branco leg., ♀ (SESA 7717); 05.iii.2018; Ezequiel leg., ♀ (SESA 7680); 07.iv.2015, L.F. Fernandes leg., ♀ (SESA 6829); 04.xii.2014, E.P. Santos leg., ♀ (SESA 6741); Maripá [-24.417795, -53.829040], 24.viii.2023, M.A. Santos leg., ♀ (IBSP 10436); 17.iii.2023, G. Koch leg., 1 immature (SESA 9756); 22.iv.2021, G. Oenning leg., ♀ (SESA 8497); Santa Helena [-24.905643, -54.283102], 30.xi.2023, E.M. Marechal Deodoro da Fonseca leg., ♀ (IBSP 12493); 28.v.2022, J. Maldaner leg., 2 ♀♀ (SESA 9425); 28.v.2022, S.R.L. Ortiz leg., ♀ (SESA 9428); Ponta Grossa [-25.085080, -50.163495], 16.i.2024, Bianca leg., ♀ (IBSP 12180); Terra Roxa [-24.166232, -54.097836], 12.vi,2023, M.R. Oliveira leg., ♀ (IBSP 10492); 22.i.2023, A.L. Andrade leg., ♀ (SESA 8984); Foz do Iguaçu [-25.517890, -54.563184], 16.xii.2022, Lisete – CCZ 7743-22 leg., ♂ (IBSP 9271); 12.xi.2023, CCZ-77552-23 leg., ♂ (IBSP 12544); 3.xi.2022, Maria leg., ♀ (IBSP 8482); 3.x.2022, Eluzia leg., ♀ (IBSP 8569); Letícia leg., 06.xii.2022, ♀ (IBSP 9257); 06.xii.2022, Cláudia leg., ♀ (IBSP 9310); 08.xii.2022, M. Oliveira leg., ♀ (IBSP 9260); 10.xi.2022, ♀ (IBSP 9283); 11.x.2022, Sara leg., ♀ (IBSP 8483); 11.xi.2022, CCZ de Foz de Iguaçu leg.; 12.xi.2022, Edilene leg., ♀ (IBSP 9272); 14.xi.2022, 1 immature (IBSP 8754); ♀, 1 immature (IBSP 9256); 15.xii.2022, Nice leg., ♀ (IBSP 9039); 17.x.2022, José leg., ♀ (IBSP 8557); 17.xii.2017, Venerio leg., 1 immature (IBSP 9021); 18.x.2022, Cristiane leg., ♀ (IBSP 8810); 18.xi.2022, D. Camargo leg., ♀ (IBSP 9154); 19.xii.2022, Ketlin leg., ♀ (IBSP 9043); 19.xii.2022, José leg., ♀, 1 immature (IBSP 9053); 20.x.2022, Luana leg.♀ (IBSP 9275); 21.x.2022, Vanilda leg., ♀ (IBSP 9003); 21.xi.2022, Beatriz leg., ♀ (IBSP 8540); 21.xii.2022, Denise leg.,2 ♀♀ (IBSP 9011); 22.xi.2022, Joélcio leg., ♀ (IBSP 8936); 23.ix.2022, Juliana leg., ♀ (IBSP 8508); 23.xii.2022, Andressa Pita leg., ♀ (IBSP 10182); 24.xi.2022, Agnes leg., ♀ (IBSP 8594); 25.x.2022, Alan leg., ♀ (IBSP 10027); 26.x.2022, Lindamar leg., 5 ♀♀ (IBSP 8605); 26.xii.2022, David leg., ♀ (IBSP 9269); 27.x.2022, Inês Pereira leg., ♀ (IBSP 9073); 27.x.2022, Amanda leg., ♀ (IBSP 9136); 27.x.2022, João leg., ♀ (IBSP 9284); 27.x.2022, Aparecida leg. ♀ (IBSP 9311); 28.x.2022, Lucas leg., ♀ (IBSP 8895); 28.xii.2022, Dayane leg., ♀ (IBSP 9041); 28.xii.2022, Yasmin leg., ♀ (IBSP 9049); 28.xii.2022, Cláudio leg., ♀ (IBSP 9312); 29.ix.2022, Cláudio leg., ♀ (IBSP 8509); 29.ix.2022, Alexandra leg., ♀ (IBSP 8575); 30.xi.2022, Sueli leg., ♀ (IBSP 8989); 30.xi.2022, Francisco leg., ♀ (IBSP 9313); 30.xii.2022, Ione leg., ♀ (IBSP 9037); 30.xii.2022, Devanir leg., ♀ (IBSP 9259); 30.xii.2022, C. Silva leg., ♀ (IBSP 10060); 31.x.2022, Leonardo leg., ♀ (IBSP 8674); 01.iii.2023, José leg., ♀ (IBSP 9741); 01.iv.2023, Aparecida leg., 8 ♀♀ (IBSP 9825); 02.ii.2023, Fabieli leg., ♀ (IBSP 10156); 02.iii.2023, Conceição leg., ♀ (IBSP 9752); 03.ii.2023, Cecília leg., ♀ (IBSP 9871); 03.i.2023, Roselaine leg., ♀ (IBSP 9014); 03.iii.2023, Eva leg., ♀ (IBSP 9885); 03.iv.2023, Angélica leg., ♀ (IBSP 9748); 03.v.2023, Prefeitura Municipal de Foz de Iguaçu leg., ♀ (IBSP 9538); 03.iv.2023, ♀ (IBSP 9837); 03.iv.2023, Lucas leg., ♀ (IBSP 9853); 04.ix.2023, CMEI leg., ♀ (IBSP 10942); 04.vii.2023, M. Carvalho leg., ♀ (IBSP 10963); 05.i.2023, Sônia leg., ♀ (IBSP 9683); 05.v.2023, Karla leg., ♀ (IBSP 9518); 06.i.2023, José leg., 5 ♀♀ (IBSP 9918); 06.ii.2023, Terezinha leg., ♀ (IBSP 9663); 02.vi.2023, Roberto leg., ♀ (IBSP 10061); 02.vi.2023, Lucas leg., 3 ♀♀ (IBSP 10141); 03.vi.2023, Kelly leg., ♀ (IBSP 9870); 09.vi.2023, Rafaela leg., ♀ (IBSP 10955); 02.vii.2023, Cleia Lima leg., ♀ (IBSP 10165); 02.vii.2023, Carlos leg., ♀ (IBSP 10177); 02.vii.2023, Ana Luiza leg., ♀ (IBSP 10204); 03.vii.2023, Evandro leg., ♀ (IBSP 9762); 08.vii.2023, L. Multilog leg., ♀ (IBSP 10967); 02.viii.2023, Cristiane leg., ♀ (IBSP 10154); 02.viii.2023, M. Maia leg., ♀ (IBSP 10208); 08.iii..2023, Lilian leg., ♀ (IBSP 9738); 03.viii.2023, Cleonice leg., ♀ (IBSP 9849); 04.viii.2023, Jennifer leg., ♀ (IBSP 10961); 01.ix.2023, Sofia leg., ♀ (IBSP 9659); 05.ix.2023, Jocélia leg., ♀ (IBSP 9515); 05.ix.2023, Edwin leg., ♀ (IBSP 9526);

05.ix.2023, Jocélia leg., ♀ (IBSP 9546); 05.ix.2023, Edwin leg., ♀ (IBSP 9572); 01.x.2023, Dedé leg., ♀ (IBSP 10058); 02.x.2023, S. Halem leg., ♀ (IBSP 10168); 03.x.2023, Aline leg., ♀ (IBSP 9829); 09.x.2023, Aline leg., ♀ (IBSP 10953); 01.xi.2023, Eliane leg., ♀ (IBSP 9682); 01.xi.2023, R. Draga leg., ♀ (IBSP 10025); 09.xi.2023, Lilian leg., ♀ (IBSP 10970); 05.xi.2023, Luciane leg., ♀ (IBSP 9540); 01.xii.2023, Helena leg., ♀ (IBSP 9913); 01.xii.2023, Isadora leg., ♀ (IBSP 10055); 07.xii.2023, Wilma leg., ♀ (IBSP 10951); 07.xii.2023, L. Multilog leg., ♀ (IBSP 10957); 13.iv.2023, Isabela leg., ♀ (IBSP 9881); 13.v.2023, Giovana leg., ♀ (IBSP 9517); 14.ii.2023, Beatriz leg., ♀ (IBSP 10017); 14.ii.2023, Douglas leg., ♀ (IBSP 10170); 14.ii.2023, Mariana leg., ♀ (IBSP 10174); 14.iii.2023, Clarice leg., ♀ (IBSP 9758); 14.iii.2023, Francieli leg., ♀ (IBSP 9835); 14.iii.2023, Gedimar leg., ♀ (IBSP 9847); 14.vii.2023, Ricardo leg., ♀ (IBSP 10959); 15.iii.2023, Sandra leg., ♀ (IBSP 9830); 15.iii.2023, P. Sérgio leg., ♀ (IBSP 9832); 15.v.2023, Lilian leg., ♀ (IBSP 9520); 16.i.2023, Elieri leg., ♀ (IBSP 9642); 16.i.2023, Marcos leg., ♀ (IBSP 9955); 16.iii.2023, Juliana leg., ♀ (IBSP 9875); 16.ix.2023, Asenat leg., ♀ (IBSP 10971); 17.i.2023, Lucineide leg., ♀ (IBSP 9669); 17.iv.2023, José leg., ♀ (IBSP 9575); 18.ii.2023, A. Cristina leg., 2 ♀♀ (IBSP 9709); 18.iii.2023, Edivaldo leg., ♀ (IBSP 9756); 18.iii.2023, Rogério leg., ♀ (IBSP 9854); 18.ix.2023, Fernando leg., ♀ (IBSP 10962); 18.ix.2023, Giane leg., ♀ (IBSP 10966); 19.iv.2023, B.C. Mouro leg., 5 ♀♀ (IBSP 9510); 19.iv.2023, Luana leg., ♀ (IBSP 9626); 19.ix.2023, Juliano leg., ♀ (IBSP 10960); 19.viii.2023, Ana Paula leg., ♀ (IBSP 10965); 20.ii.2023, Ana Paula leg., ♀ (IBSP 9693); 21.viii.2023, Kamila leg., ♀ (IBSP 10946); 22.iii.2023, M. Alves leg., ♀ (IBSP 9759); 22.iii.2023, Márcia leg., ♀ (IBSP 9844); 22.v.2023, Kary leg., ♀ (IBSP 10956); 23.v.2023, V. Lúcia leg., ♀ (IBSP 10952); 23.v.2023, Geisse leg., ♀ (IBSP 10958); 24.vii.2023, Felipe leg., ♀ (IBSP 10941); 25.iv.2023, Cibele leg., ♀ (IBSP 9610); 26.vi.2023, Cláudia leg., ♀ (IBSP 10950); 26.vii.2023, Nicolle leg., ♀ (IBSP 10969); 27.ii.2023, ♀ (IBSP 9843); 28.ii.2023, W.F. Cardoso leg., ♀ (IBSP 9704); 28.iii.2023, Luana leg., ♀ (IBSP 9694); 28.iii.2023, ♀ (IBSP 9732); 28.iii.2023, ♀ (IBSP 9890); 01.iv.2023, João leg., ♀ (IBSP 9607); 28.vi.2023, Jean leg., ♀ (IBSP 10949); 29.iii.2023, Aderbal leg., ♀ (IBSP 9833); 29.v.2023, Arnete leg., ♀ (IBSP 10945); 30.iii.2023, Jussara leg., ♀ (IBSP 9828); 30.iii.2023, Gesira leg., ♀ (IBSP 9840); 01.iii.2023, Paulo leg., 1 immature (IBSP 9851); 02.iii.2023, Bruno leg., 1 immature (IBSP 9751); 24.vii.2023, CCZ6257-23 leg., 2 ♀♀, 3 immatures (IBSP 10964); 07.xii.2006, L. Gonçalves leg., ♀ (SESA 1387); 11.xii.2006, Juliana leg., ♀, 1 immature (SESA 1388); 29.i.2009, A. Marcos leg., ♀ (SESA 1929); 18.ii.2009, William leg., ♀ (SESA 1981); 27.ii.2009, João leg., ♀ (SESA 2040); 28.iii.2009, Marcos leg., 3 ♀♀ (SESA 2053); 01.iv.2009, Rafael/Simone leg., ♀, 1 immature (SESA 2054); 02.iv.2009, 2 ♀♀, 4 immatures (SESA 2055); 01.iv.2009, Wagner leg., ♀ (SESA 2056); 21.v.2009, J. Gilberto leg., ♀ (SESA 2117); Joelcil leg., ♀ (SESA 2118); 05.viii.2009, Ozilia leg., 4 ♀♀, 3 immatures (SESA 2217); 20.viii.2009, Rafael leg., 1 immature (SESA 2219); 17.xii.2009, Silvana leg., ♀ (SESA 2463); 10.xii.2009, Marcos leg., ♀ (SESA 2464); 20.i.2010, Edwin leg., ♀ (SESA 2485); 11.i.2010, Rafael leg., ♀ (SESA 2486); 21.i.2010, Jussara leg., ♀ (SESA 2489); 03.iii.2010, ♀ (SESA 2553); 08.iii.2010, ♀ (SESA 2554); 08.iii.2010, 1 immature (SESA 2555); 16.iv.2010, Edwin leg., ♀ (SESA 2596); 21.vii.2010, Alessandro leg., 1 immature (SESA 2646); 09.vi.2010, Carolina leg., ♀ (SESA 2648); 07.xii.2010, Dorival leg., ♀ (SESA 3020); 26.iv.2011, Guarda Municipal leg., ♀ (SESA 3259); Apucarana [-23.555617, -51.431445], 13.xi.2020, Dirce leg., ♀ (SESA 8143); Cambará [-23.041876, -50.070898], 02.iv.2020, P. Massataro leg., ♀ (SESA 8150); 03.iii.2021, M.C. Lima leg., ♀ (SESA 8396); 11.ii.2020, Wagner leg., ♀ (SESA 8125); 25.ii.2021, M. Fonseca leg., ♀ (SESA 8414); 21.i.2020, E.G. Costa leg., ♀ (SESA 8126); 30.x.2019, H.C. Caetano leg., ♀ (SESA 8087); 20.v.2019, M.A. Almeida leg., ♀ (SESA 7968); 04.iv.2019, S.G. Justo leg., ♀ (SESA 7958); 24.iii.2022, D. Lopes leg., ♀ (SESA 9242); 04.iv.2016, L.C. Pereira leg., ♀ (SESA 7194); 27.xi.2018, CEMEI Caminho do Sabor leg., ♀ (SESA 7904); 22.xi.2015, M. Santana leg., ♀ (SESA 7113); 02.viii.2015, I.A. Rafagnin leg., ♀ (SESA 6928); 05.ii.2016, D.C. Nogueira leg., ♀ (SESA

7147); 28.vii.2015, S.P. Santos leg., ♀ (SESA 6927); 05.ii.2016, C. Lorenção leg., ♀ (SESA 7148); 16.v.2014, Pires leg., 1 immature (SESA 6624); 03.xi.2014, N.N. Diniz leg., ♀ (SESA 6727); 28.v.2014, E.G. Silva leg., 1 immature (SESA 6626); 06.i.2015, C. Freitas leg., ♀ (SESA 6771); Iporã [-24.002437, -53.709094], 08.iii.2023, Escola Dom Pedro leg., 1 immature (SESA 8350); Santa Terezinha do Itaipú [-25.438490, -54.404598], 13.ii.2023, J.A. Gonçalvez leg., ♀ (SESA 9692); 09.v.2022, P. Damiani leg., ♀ (SESA 9134); 07.iii.2023, Thalize leg., ♀ (SESA 9758); 03.vi.2021, A. Manente leg., 1 immature (SESA 8602); 11.xi.2019, C.A. Oliveira leg., ♀ (SESA 8076); Doutor Camargo [-23.557794, -52.2193617], 15.x.2020, C.L. Eleutério leg., 1 immature (SESA 8252); Japurá [-23.470137, -52.553501], 16.i.2023, R.R. Vale leg., ♀ (SESA 9605); Palmeira [-25.417400, -50.003198], 25.ii.2015, L.E. Wonsttret leg., ♀ (SESA 6784); Umuarama [-23.762125, -53.312704], 20.v.2019, Douglas leg., ♀ (SESA 7986); 10.xi.2020, V. Santos leg., ♀ (SESA 8284).

Distribution. Records of the species in Brazil have so far been reported in the states of Ceará, Mato Grosso, Mato Grosso do Sul, Piauí, and Tocantins, although some of these have been questioned and still require reanalysis for confirmation. New records are now reported for the state of Paraná based on the examined material (municipalities of Apucarana, Cambará, Doutor Camargo, Foz do Iguaçu, Guaíra, Iporã, Ivatuba, Japurá, Maripá, Palmeira, Ponta Grossa, Santa Helena, Santa Terezinha do Itaipú, Sertaneja, Terra Roxa, and Umuarama) (Figure 2).

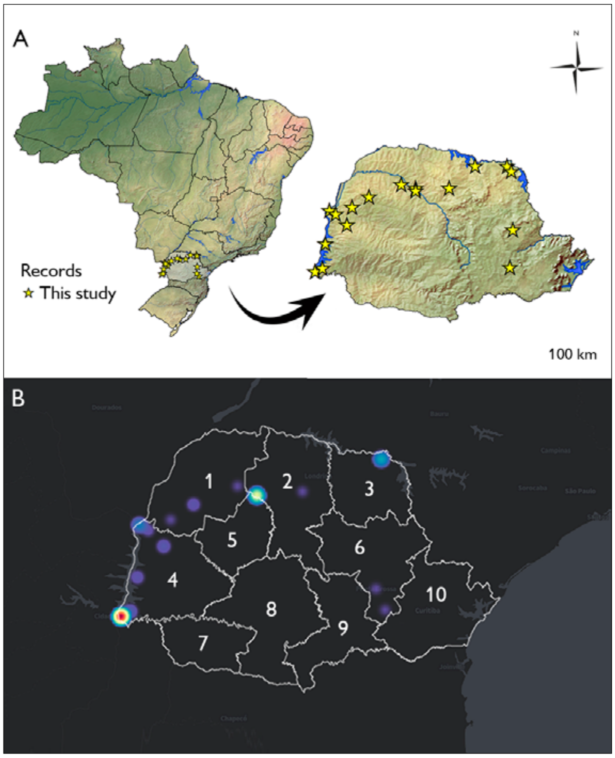

Figure 2. Distribution map of *Tityus confluens* Borelli, 1899, in Paraná based on the examined material from IBSP and SESA: A) occurrence points; B) heatmap of occurrences of *T. confluens*. The scheme of colors refers to the density of records of the species, with blue indicating low density and red high density. The numbers refer to the mesoregions of Paraná: 1) Northwest; 2) North-Central; 3) North Pioneer; 4) West; 5) Central-West; 6) Central-East; 7) Southwest; 8) Central-South; 9) Southeast; 10) Metropolitan Curitiba. Map: elaborated by the authors (2024).

DISCUSSION

The genus *Tityus* comprises approximately 220 species described in five subgenera (Lourenço, 2006, 2015), with 66 of these species with occurrence in Brazil (Bertani et al., 2024). To date, among these species, in Brazil only four are recognized by their medical importance: *Tityus serrulatus* Lutz & Mello, 1922; *Tityus bahiensis* Perty, 1833; *Tityus obscurus* Gervais, 1843; and *Tityus stigmurus* (Thorell, 1876). The species *Tityus confluens*, although not considered as medically significant in Brazil as the species mentioned above, has been involved in some human accidents over the last few decades (Roodt et al., 2009). In Argentina, for instance, there have been reports of accidents involving this species, including the record of children's deaths (Roodt et al., 2009; Ojanguren-Affilastro et al., 2019; López, 2021). In Brazil, there is no record of death involving directly accidents by *T. confluens*, although the species has been identified as a potential medical concern (Guerra-Duarte et al., 2023). Additionally, due to the superficial similarity of the species with other congenerics, particularly *T. serrulatus* and *T. trivittatus*, it is likely that in some cases the animal might have been misidentified, leading to an underreporting number of accidents in the country.

Considering the wide distribution of *T. confluens* in the Chaco region (Lourenço, 2006), it is not surprising its occurrence in other western and southern regions of Brazil. Based on a total of 2 males, 310 females, and 31 immatures of examined specimens of the species *T. confluens*, this study confirms its occurrence in Paraná, expanding its distribution to cover most of the state. The oldest record from Paraná dates back to 1954, suggesting that the species has occurred in the state for a long time. A high density of records is evident in both western and central regions of the state, particularly in the municipalities of Foz do Iguaçu (which borders both Argentina and Paraguay) and Ivatuba (located in the metropolitan region of Maringá) (Figure 2B). Although these reports are not standardized in sampling methods, including biases in sampling as a consequence of greater attention given by local health services, the number of occurrences of specimens in these areas warrants attention. In this context, as with other parthenogenetic species of *Tityus* (Seiter, 2012), it is highly recommended to monitor the distribution of *T. confluens*, not only within Brazil, but also in neighboring countries such as Bolivia, Paraguay, and Argentina, with a focus on public health policies related to the number of accidents and medical assistance.

It is important to highlight that most records of *T. confluens* in Brazil, particularly those from Ceará, Piauí, and Tocantins, still require reanalysis to confirm its occurrence. In this context, some authors have argued for a more conservative approach to species identification within the so-called "*Tityus confluens* complex" (see Mattos et al., 2013, 2014; Porto et al., 2014; Carvalho et al., 2017). This approach has proven to be the most appropriate, given the medical importance of *T. confluens* and the need for a taxonomic review of most *Tityus* species.

Despite the significant urban influence on the data in this work, the results reveal a broad distribution and notable abundance of the species in Paraná (Figure 2). These new records contribute to expanding our understanding of the scorpiofauna encountered by the population around their houses or in surrounding areas. Further studies focusing on medical reports involving scorpions and synanthropic surveys are important for enriching zoological collections and providing reliable data on species identification and distribution. Additionally, many specimens deposited in collections have been misidentified and still need further study to correct these errors, which has led to delays in improving public health and environmental preservation policies in many Brazilian states.

CONCLUSION

This study confirms the occurrence of *Tityus confluens* in the state of Paraná, with a high density of species records in the western and central regions of the state. It also highlights potential accidents caused by the species in Paraná and encourages the scientific community to collaborate with policymakers and the public to mitigate risks and raise awareness.

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AUTHORS' CONTRIBUTIONS

P. A. M. Goldoni contributed to the conceptualization, data curation, species identification, project administration, writing (original draft), and formal analysis; L. F. M. Iniesta contributed to the writing (review and editing), software, and supervision; E. Marques-da-Silva contributed to the data curation and writing (review and editing); and A. D. Brescovit contributed to the project administration, supervision, and acquisition of financing.

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Natural history of *Loxosceles chapadensis* Bertani, Fukushima & Nagahama, 2010 (Araneae, Sicariidae)

História natural de *Loxosceles chapadensis* Bertani, Fukushima & Nagahama, 2010 (Araneae, Sicariidae)

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Abstract: Brown recluse-spiders of the genus *Loxosceles* comprise 147 species and it is responsible for the most significant araneism in South America. Gaps in knowledge exist for various species, such as *Loxosceles chapadensis*, whose biological information is scarce and limited to its description in 2010 and a few publications that mentioned it in some way. We aim to characterize the natural history of *L. chapadensis* and expand its knowledge and distribution. We captured 457 specimens through active search between 2022-2024 in seven locations (six caves) in Bahia, Brazil. We marked sampling areas according to microclimatic variables. Temperature and humidity were considered environmentally homogeneous, but the spatial distribution of spiders was heterogeneous, determined by luminosity. We conclude that *L. chapadensis* is a spider with cave-dwelling habits, endemic to the Brazilian *Caatinga* environments with high-altitude xeric geomorphological and vegetational characteristics, until then, with records in the States of Bahia and Piauí. Its occurrence at places with a large tourist flow requires care in the management plan of the caves where it occurs.

Keywords: Brown recluse-spider. Caves. Chapada Diamantina. *Caatinga*.

Resumo: Aranhas-marrons do gênero *Loxosceles* compreendem 147 espécies e são responsáveis pelo araneísmo mais significativo na América do Sul. Existem lacunas de conhecimento para várias espécies, como *Loxosceles chapadensis*, cuja informação biológica é escassa, limitada à sua descrição em 2010 e a poucas publicações que a mencionam de alguma forma. Objetivamos contribuir com a caracterização da história natural de *L. chapadensis*, bem como com a expansão sobre seu conhecimento e sua distribuição. Foram coletados 457 espécimes por meio de busca ativa entre 2022-2024 em sete localidades (seis grutas) da Bahia, Brasil. As áreas de amostragem nas grutas foram marcadas de acordo com variáveis microclimáticas. Temperatura e umidade foram consideradas ambientalmente homogêneas, mas a distribuição espacial das aranhas foi heterogênea, determinada pela luminosidade. Concluímos que *L. chapadensis* é uma aranha de hábitos cavernícolas, endêmica dos ambientes de Caatinga brasileira com características geomorfológicas e vegetacionais xéricas de altitude, até então com registros nos estados da Bahia e do Piauí. Sua ocorrência em locais de grande fluxo turístico demanda cuidados no plano de manejo das cavernas onde ocorre.

Palavras-chave: Aranha-marrom. Grutas. Chapada Diamantina. Caatinga.

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INTRODUCTION

Loxosceles is one of the three genera of medically important spiders in Brazil (Ministério da Saúde, 2001) and it is responsible for the most important form of araneism in South America (Sampaio et al., 2016). Currently, 147 species are recognized with a global and cosmopolitan distribution. Of these, 22 are recorded in different regions of Brazil (World Spider Catalog, 2024), but only 3 are recognized as etiological agents according to the Ministry of Health in Brazil: *L. intermedia* Mello-Leitão, 1934, *L. laeta* (Nicolet, 1849), and *L. gaucho* Gertsch, 1967 (Ministério da Saúde, 2001), which occur in the southern region of the country. The contribution of other *Loxosceles* species occurring in Brazil to human accidents remains unknown, as case reports almost never identify the causative agent. Furthermore, there is limited data on the venoms of these other species, but available evidence suggests that these less-studied venoms exhibit relevant toxicity (Silva-Magalhães et al., 2024). Most confirmed cases with the identified species are in the South and Southeast regions, reflecting the proximity of institutions that house taxonomists and health-qualified teams. The Brazilian Ministry of Health has recorded approximately 38,000 accidents caused by these spiders in the period from 2019 to 2023, the majority in the Southeast and South regions, particularly in the state of Paraná, where the largest case series of loxoscelism in the country is concentrated (Brasil, 2024a). However, these recorded numbers probably do not reflect the real number of accidents caused by *Loxosceles*. As noticed in other countries, cases can be underreported, as there is often no development of symptoms and no reference to spider bites by the victim, or overreported, as many of the differential symptomatic characteristics of loxoscelism are confused with several other diseases (Vetter, 2015).

It has been shown in review studies that spider bites remain a controversial issue globally. The harmful effects of spider bites are often mistakenly attributed to harmless spider groups. This attribution of clinical effects to various spiders is problematic due to vague case definitions and a lack of clinical evidence (Isbister & White, 2004; Vetter, 2015). Isbister et al. (2005) reinforced that to avoid perpetuating misinformation and in the interest of advancing the clinical understanding of spider bites, future publications must focus on witnessed and definitive bites, with expert identification of the spider involved. However, in Brazil there are significant challenges in training the hospital emergency teams, who typically handle accident cases, to identify spiders accurately at any taxonomic level. Consequently, during the period from 2019 to 2023, the majority of cases (63.9%) were simply reported as "spiders" (Brasil, 2024a).

A recent study shows eight species identified in the state of Bahia (Northeast region) *L. amazonica* Gertsch, 1967, *L. boqueirao* Bertani & Gallão, 2024, *L. cardosoi* Bertani, von Schimonsky & Gallão, 2018, *L. carinhanha* Bertani, von Schimonsky & Gallão, 2018, *L. chapadensis* Bertani, Fukushima & Nagahama, 2010, *L. karstica* Bertani, von Schimonsky & Gallão, 2018, *L. similis* Moenkhaus, 1898, and *L. troglobia* Souza & Ferreira, 2018 (Andrade-de-Sá et al., 2024). None of them are recognized as being of medical interest or related to any reported accident in this state, which does not mean they can't be. This probably occurs for at least two reasons: because some are recently described species and have not been evaluated for their risk to human health yet, and because of the lack of taxonomic identification by the health team providing care. Of the 995 spider accidents reported in 2023 in Bahia, only 80 (8%) were diagnosed as loxoscelism, the vast majority through the clinical effects of the patients, while 670 (67.3%) were undiagnosed (Brasil, 2024a).

Despite the volume of research surrounding these cosmopolitan spiders, the main focus has been on aspects of poisoning and accidents, so there are still many gaps in knowledge about the biology and distribution of the species in different regions of the country. The taxonomy of the genus was the subject of numerous debates, most intensely in the 1960s, regarding the number and overlap of *Loxosceles* species found in South America (Marques-da-Silva & Fischer, 2005). The last taxonomic revision was conducted by Willis John Gertsch in 1967, when he divided them into four groups according to the characteristics of the male and female genitalia: *gaucho*, *laeta*, *spadicea*, and *amazonica* (Gertsch, 1967). Taking into account the Gertsch criteria, the gaucho group includes six species in Brazil, currently: *L. gaucho*; *L. adelaida* Gertsch, 1967; *L. similis*; *L. chapadensis*; *L. niedeguidonae* Gonçalves-de-Andrade, Bertani, Nagahama & Barbosa, 2012; *L. troglobia*.

Loxosceles chapadensis is a small spider, measuring approximately 5 to 8 cm. The male can be distinguished from other species by a palpal tibia more than two times longer than the cymbium, and by a thickened embolus. The female can be recognized by its broad transversal plate, straight, apically enlarged seminal receptacles, and dorsal part of the bursa copulatrix strongly sclerotized for half of its length (Bertani et al., 2010).

Little is known beyond its morphological characteristics, which included it in the Gaucho group (Bertani et al., 2010). Its type material (holotype and paratype) was destroyed in the fire that ravaged the National Museum of Rio de Janeiro (Brazil) in 2018 (World Spider Catalog, 2024), and its taxonomic *status* remained unchanged until then.

After its description, only six publications mentioned *L. chapadensis* in some way, revealing a restricted distribution in *Caatinga* regions of the States of Bahia (Gonçalves-de-Andrade et al., 2012; Almeida et al., 2017; Carvalho et al., 2014; Bertani et al., 2018; Andrade-de-Sá et al., 2024) and Piauí (Carvalho et al., 2020). The scarcity of recent publications on *L. chapadensis*, which are limited to specific occurrence records, highlights the need to fill gaps in our understanding of its natural history. This is particularly important given that the species has only been documented in a specific region characterized by unique environmental features and located within a designated environmental protection areas like Chapada Diamantina National Park (Bahia) and Serra das Confusões National Park (Piauí). Herein we aim to identify and analyze the environmental variables influencing its distribution, examine its coexistence with other species, and characterize its biological and behavioral aspects within its natural habitat.

MATERIAL AND METHODS

This is a participant observational study focusing exclusively on *Loxosceles chapadensis* spiders found in caves (except for Serra das Paridas). Observations were conducted *in situ*, and the study involved specimen collection and field observations (Permanent License for Collection of Zoological Material SISBIO/ICMBio [Sistema de Autorização e Informação em Biodiversidade/Instituto Chico Mendes de Conservação da Biodiversidade] No. 73871, and Licenses No. 10751-6; 10751-7).

To confirm the occurrence of *L. chapadensis* in the various municipalities of the state of Bahia, we consulted the data from the following scientific collections: Arachnological Collection (Order Araneae) of the Natural History Museum of Bahia, Federal University of Bahia [UFBA-ARA, T. K. Brazil]; Arachnida Collection of the Federal University of Minas Gerais [UFMG-ARA, A. J. Santos]; Zoological Collections Laboratory, Butantan Institute [IBSP, A. D. Brescovit]; Myriapoda and Arachnida Collection of the National Museum of Rio de Janeiro, Federal University of Rio de Janeiro [MNRJ, A. B. Kury]. All records from MHNBA and UFMG were consulted on the SpeciesLink platform (SpeciesLink, n. d.). All the MHNBA specimens were analyzed by the authors. Data from the IBSP and MNRJ collections were kindly provided by their respective curators.

The primary data were obtained in the localities of the Chapada Diamantina ecoregion, in the municipalities of Iraquara, Lençóis, and Seabra, Bahia, Brazil. The captured specimens are deposited in the arachnology collection of the Natural History Museum of the University of Bahia (curator T. K. Brazil, acronym UFBA-ARA). Live specimens are still being kept in the arachnidarium of the Nucleus of Ophidiology and Venomous Animals (NOAP).

RESEARCH AREA

The study was conducted at seven locations, six of which were caves in the municipalities of Lençóis, Iraquara, and Seabra, in the state of Bahia, Brazil. All sites are situated within Chapada Diamantina *Caatinga* ecoregion.

The Chapada Diamantina, part of the Serra do Espinhaço Plateau, covers an area of 41,751km^2 and comprises 33 municipalities. Endemism is a defining characteristic of this region, due to its semi-arid climate, high potential evapotranspiration throughout the year, and low, erratic rainfall. Average precipitation is significantly lower than in other regions of Brazil, with prolongated drought periods. Rainfall tends to occur almost entirely in the summer months between November and April, ranging from 300 to 2,000 mm per year (Barreto, 2010). In the Iraquara region, where a transition to higher altitudes occurs, average annual rainfall exceeds 750 mm (Laureano, 1998). The entire area lies within the *Caatinga* biome (Velloso et al., 2002), but exhibits a mix of rocky countryside vegetation, Brazilian *Cerrado*, and varying degrees of humid forest remnants. It is the highest ecoregion within the *Caatinga* biome, with altitudes ranging from 200 to 1,800 meters, forming a natural watershed where rivers flow into the São Francisco basin. The soils are generally poor, with shallow, rocky soils prevalent in the massifs and high mountains, while deeper soils are found in the plains (Velloso et al., 2002).

The Chapada Diamantina National Park (PARNA_CD) is part of this ecoregion as a Conservation Unit with 'full protection' *status*, spanning 1,520 km^2 across six municipalities: Andaraí, Ibicoara, Itaetê, Lençóis, Mucugê, and Palmeiras (ISA, 2024) and it is considered the main ecotourism hub in the State of Bahia (Santos, 2006). It became economically important in the early 1990s, due to diamond mining, and more recently, ecotourism. Both activities have significantly impacted the environment, especially considering that this region is the source of nearly all the rivers in the Paraguaçu, Jacuípe, and Rio de Contas basins (Bahia, 2004).

It is important to note that all caves in Brazil are property of the Union (Brazilian government) (Brasil, 1988). In Bahia, they are designated as areas of permanent protection (Bahia, 1989). As inalienable assets, their sustainable use by private individuals, such as for tourism, is permitted; however, this use is regulated by public law rather than private law norms (Ribas & Carvalho, 2009).

The studied caves have distinct formations and characteristics, despite being in the same ecoregion:

- Lapão Cave (Figure 1A): Recognized by the Brazilian Speleological Society (SBE) under number BA-41, it is located at the northernmost point of the Chapada Diamantina National Park (12° 32' 25" S, 41° 24' 09" W), about 2 km from the center of the city of Lençóis. It is part of the São José River basin, a tributary of the Paraguaçu River, at an approximate altitude of 600 meters, and consists mainly of sandstones interspersed with conglomerates. It has two known entrances: the North entrance, which measures 50 x 10 m (width and height), and the East entrance, which measures 80 x 40 m (width and height). The cave extends for about 800 meters (tourist section), is predominantly straight, with some meandering sections and contains all zones: photic, dysphotic, and aphotic. The cave features several large chambers with ceilings close to 20 meters high and sections with low-ceilinged galleries (1.5 meters). Its uneven floors consist of blocks or sandy sediment. The Lapão Cave receives constant visitors, mainly due to its proximity to the city of Lençóis, a tourist city with significant national and international traffic (Linhares, 2007). It is not exploited by private initiative;
- Torrinha Cave (Figure 1B): Recognized by the SBE under number BA-37, it is located in the municipality of Iraquara (12° 19' 4" S, 41° 36' 13" W). The Torrinha Cave is rich in speleothems, concentrating some of the rarest formations in the world, which is its distinguishing feature (Brunelli, 2001). The cave entrance is an elliptical horizontal opening

approximately 15 meters high and 20 meters wide. Its total linear development reaches 14 km. The photic zoning is characterized by all zones: photic, dysphotic, and aphotic (Loureiro, 2017). The vault spans sometimes reach a hundred meters. In the 1990s, 8,300 meters were mapped by the French speleological group "Meandres," positioning Torrinha Cave as one of the largest caves in Brazil (Brunelli, 2001). It has exploited by private initiative and receives around 7,000 to 9,000 visitors annually (Loureiro, 2017);

- Lapa Doce I Cave (Figure 1C): Recognized by the SBE under numbers BA-72 (Doce I) and BA-200 (Doce II), this cave is part of a complex, located in the municipality of Iraquara (12° 19' 59" S, 41° 36' 14" W). The cave has several entrances, with the tourist entrance being an elliptical horizontal opening 60 meters high and 50 meters wide. The tourist section is only 950 meters long (Loureiro, 2017) and contains all zones: photic, dysphotic, and aphotic. This is considered one of the most extensive known cave systems. It has larger galleries, many of which have widths and heights of more than 50 and 15 meters, respectively (Cruz Jr., 1998). The emergent galleries mostly contain a rich collection of speleothems, predominantly calcite deposits, which occur as stalactites, stalagmites, columns, flowstones, and travertines (Laureano & Cruz Jr., 2002). The farm where the Lapa Doce cave is located has been owned by the same family for more than 150 years (Loureiro, 2017). It is exploited by private initiative;
- Fumaça Cave (Figure 1D): Recognized by the SBE under number BA-125, it is located in the municipality of Iraquara (12° 19' 57" S, 41° 35' 48" W). The Fumaça Cave is notable for its richness in speleothems. Information in the National Cave Registry (CNC) only contains information relating to its linear development: 246 meters (Loureiro, 2017). All zones can be distinguished in this cave: photic, dysphotic, and aphotic. Despite no further published information being found, large spaces and galleries less than two meters in height, which required the team to crouch, were observed. It is exploited by private initiatives, with installations such as wooden stairs to facilitate tourist access. Heavy truck traffic passing over it has caused internal damage to the cave (Sbragia & Cardoso, 2008);
- Lapa do Sol Cave (Figure 1E): Recognized by the SBE under number BA-74, it is located in the municipality of Iraquara (12° 19' 51" S, 41° 36' 23" W). Lapa do Sol Cave only presents horizontal projection data, with no further topographical information in the National Cave Registry (CNC). This cave also features panels of rock paintings, constituting yet poorly investigated evidence of the prehistoric civilizations that inhabited the region (Laureano & Cruz Jr., 2002). During the expedition, it was observed that the cave entrance was below ground level, requiring descent with the aid of equipment. Besides, it contains all zones: photic, dysphotic, and aphotic. The cave is part of the same property as Lapa Doce I but currently does not have organized visits;
- Lapa da Santa Cave (Figure 1F): This cave is not registered in the SBE. It is located near the Bolo-de-Noiva cave (formerly Buraco do Cão), in the municipality of Seabra (12° 23' S, 41° 35' W). Although no further published information was found, it is visible that this cave is heavily degraded. It contains only the photic and dysphotic zones. The cave's name comes from a rock formation resembling a Saint, which attracted many visitors over the years, leaving permanent marks of human alteration on the site. Currently, there are no signs of commercial exploration;
- Serra das Paridas (Figure 2): Serra das Paridas is the only locality that is not a cave, despite having cliffs and rock projections that resemble cave entrances. Therefore, there is no aphotic zone. It is located between the

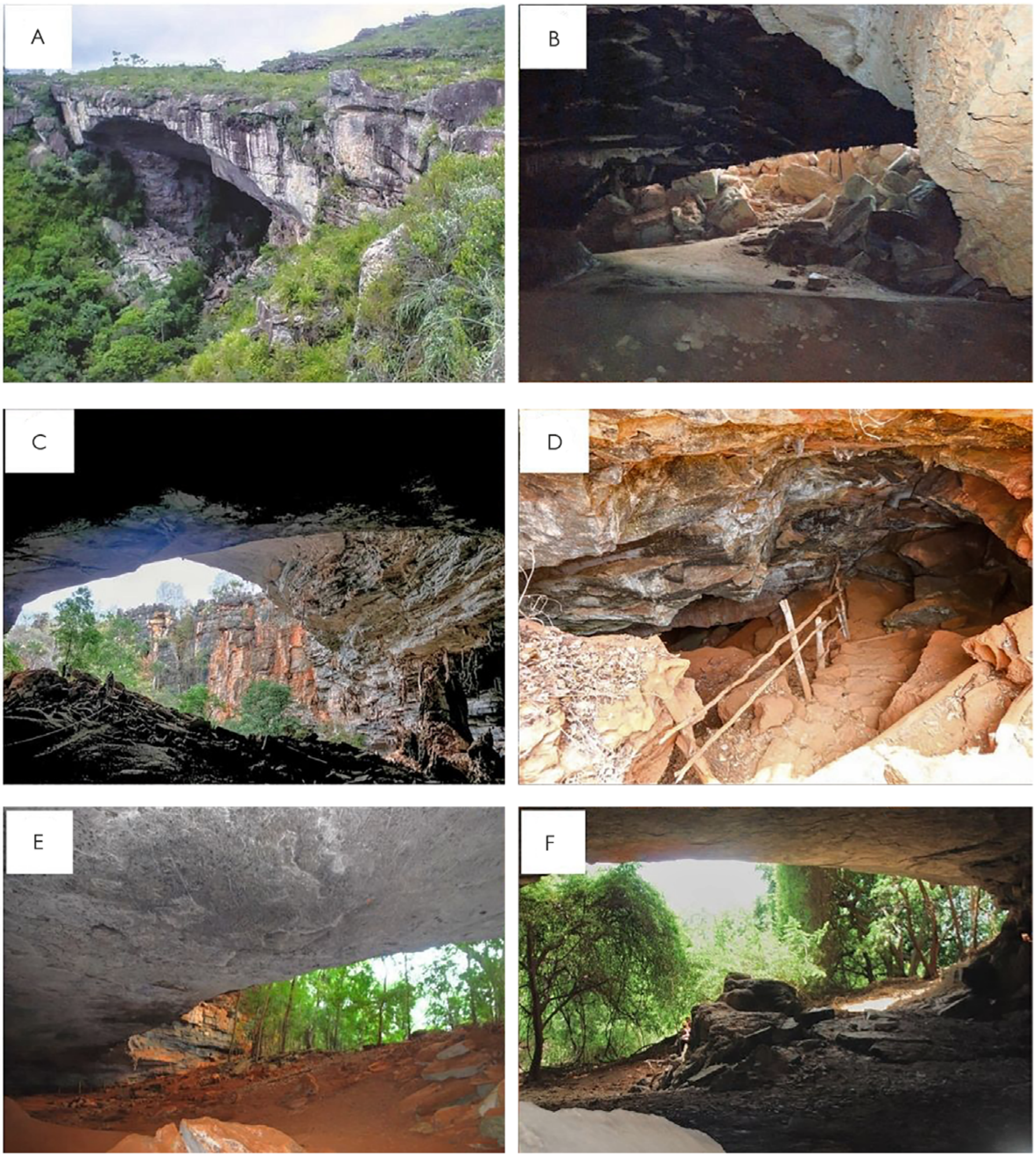


Figure 1. Caves sampled in this study: A) Lapão Cave, Lençóis; B) Torrinha Cave, Iraquara; C) Lapa Doce Cave, Iraquara; D) Fumaça Cave, Iraquara; E) Lapa do Sol Cave, Iraquara; F) Lapa da Santa Cave, Seabra. Photos: Gruta Lapão – Lençóis (n. d.) (A); Gruta da Fumaça (n. d.) (C); images by the authors (2024) (B, D, E, F).

Figure 2. Serra das Paridas, Lençóis, Bahia. Photo: image by the authors (2024).

municipalities of Lençóis and Wagner (12° 20' 48" S, 41° 14' 44" W). The area consists of 18 archaeological sites forming an important complex where the daily life of prehistoric Brazilian man is recorded in rock paintings (Silva Jr., 2008). It comprises shelters and cliffs in sandstone outcrops. The rocky blocks emerge in a landscape characterized by a flat strip with mangabeira (*Hancornia speciosa* Gomes) fields and a wide hilly zone with denser and more varied vegetation. The shelters are mostly located at the base of the outcrops. The complex has four concentrations of outcrops: Serra das Paridas I, II, III, and IV, with the first and last having the highest number of graphic representations (Etchevarne, 2023).

SPIDER SAMPLING

Five expeditions were carried out from November 2022 to March 2024, with an average stay of 4 days in different climatic periods (autumn, summer, and spring) throughout the year. The team, composed of five to nine people, spent approximately two hours each day collecting, with at least one session in the morning and/or another in the afternoon or night. The total sampling effort (SE) for all the expeditions was around 230 hours. The spiders captured were categorized according to these segments: photic zone (above 002 lux) and aphotic zone (less than or equal to 002 lux) (Figure 3). The light intensity values were obtained using a luxmeter, temperature and humidity with a thermohygrometer. The variables were measured at the beginning and end of each sampling effort. A total of 457 spiders were collected from the seven caves, with Gruta do Lapão (212 specimens collected) and Gruta da Torrinha (176 specimens collected) standing out. This was associated with the sampling effort in these locations, which were visited during more than one expedition and over a longer period than the other sites.

DATA ANALYSIS

The variables analyzed aimed to evaluate the spiders' conditions of permanence in their natural environment:

- Qualitative variables were estimated in absolute and relative frequency measures: coexistence with other arthropods, spatial distribution inside of caves, behavior (spatial distribution, aggregation, cannibalism), and types of prey on feeding;
- Quantitative variables were summarized using measures of central tendency (arithmetic mean) and dispersion (standard deviation): temperature (°C), humidity (%), and luminosity (lux). Quantitative and qualitative data were arranged in tables, with quantitative variables depicted in scatter plots and boxplots. We used SPSS (Statistical Package for the Social Sciences) version 26 to process, tabulate, and analyze all data.

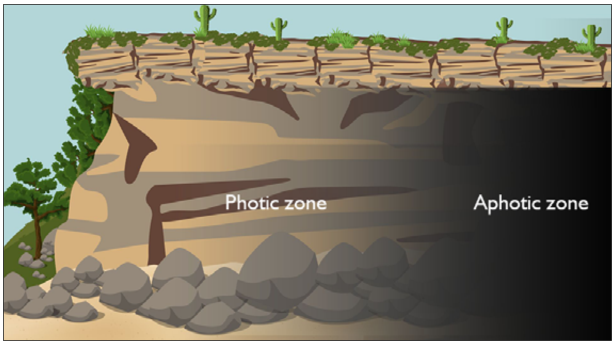


Figure 3. Schematic drawing in a vertical section of the caves' inside where the spiders were captured. Photic zone: cave entrance in contact with the outside, with direct and indirect light influence. Aphotic zone: cave zone without light influence. Illustration by the authors (2024).

MAP

The map was produced using the Geographic Information System (GIS) software QGIS versions 3.36.3-Maidenhead and 3.38.0-Grenoble (QGIS Development Team, 2024). The ESRI Satellite topographic map (ArcGIS/World_Imagery) was obtained from the QuickMapServices plugin of the QGIS GIS software versions 3.36.3-Maidenhead and 3.38.0-Grenoble (QGIS Development Team, 2024). The São Francisco River shapefile was obtained from the 50K Hydrographic Ottocoded Base – drainage section of the database from the National Water and Basic Sanitation Agency (ANA, 2017). The shapefiles for the *Caatinga*, *Cerrado*, and Atlantic Forest biomes were obtained from the Brazilian Institute of Geography and Statistics and delimited only for the state of Bahia (IBGE, 2019). The South America shapefiles and the shapefile for Bahia were obtained from the Brazilian Institute of Geography and Statistics (IBGE, 2021, 2022, 2023). The Chapada Diamantina National Park (PARNA-CD) boundaries were obtained from the National Register of Conservation Units (CNUC) (Brasil, 2024b).

The geographic coordinates were obtained from the scientific literature and the previously cited scientific collections. Occurrences without any information on geographic coordinates were georeferenced using the SpeciesLink geoLoc geoprocessing tool of the Environmental Information Reference Center (CRIA, n. d.), and the Brazilian National Registry of Caves (SBE, n. d.).

RESULTS AND DISCUSSION

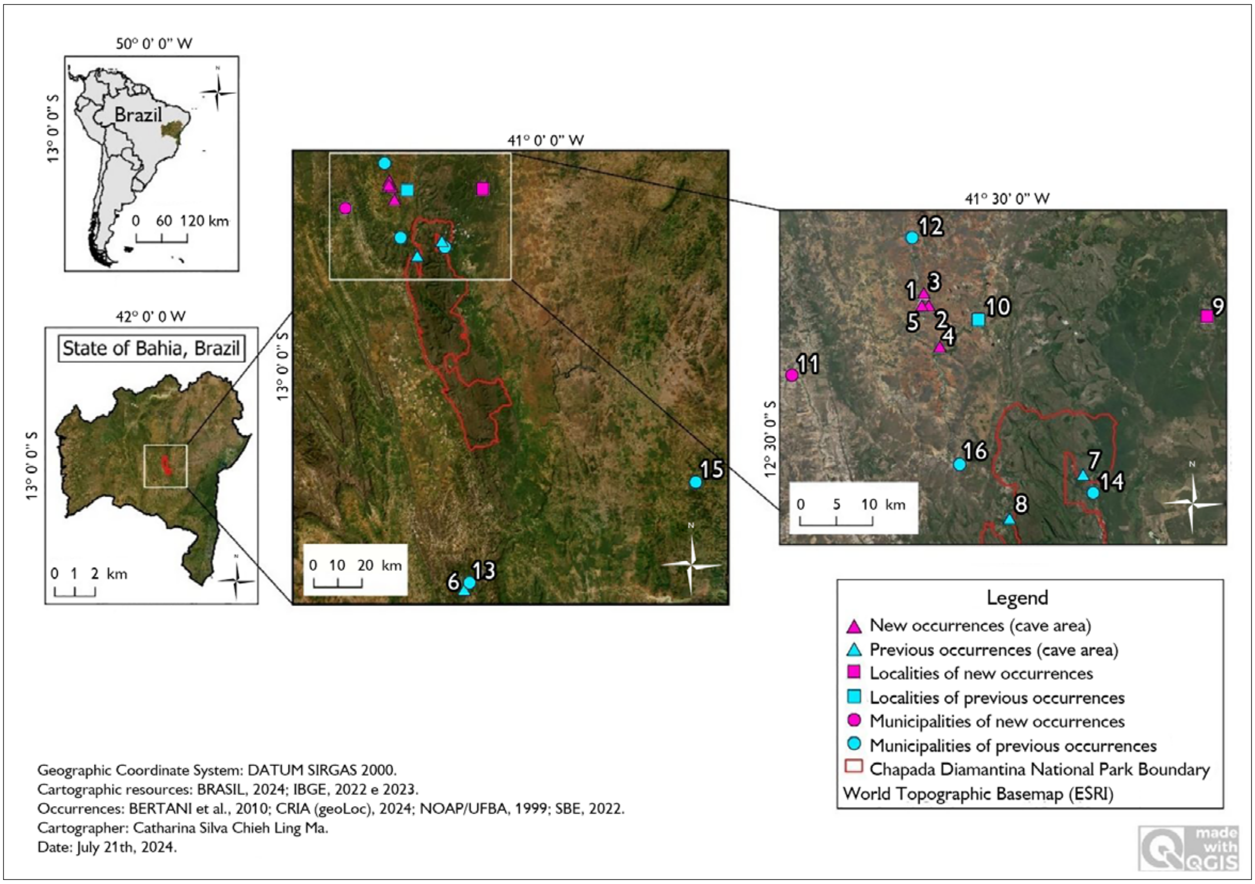
OCCURRENCE IN THE CHAPADA DIAMANTINA

We confirmed the presence of *Loxosceles chapadensis* in 10 locations (Table 1) spanning 6 municipalities in Bahia, all in the Chapada Diamantina ecoregion (Figure 4). So far, the species has only been registered in Iraquara, Lençóis, Palmeiras (Bertani et al., 2010), Ituaçu, and Maracás

Table 1. Distribution of *Loxosceles chapadensis* by municipalities, related to environmental data (biome, phytophysiognomy/environment, altitude, temperature, rainfall).

Municipalities	Location	Biome	Environment/ Phytophysiognomy	Altitude (m)	Average annual temperature (°C)	Average annual rainfall (mm)
Iraquara	Pratinha Farm	*Caatinga*	Indeterminated	655	22.2	687
Iraquara	Lapa Doce I	*Caatinga*	Cave	655	22.2	687
Iraquara	Torrinha Cave 🕷	*Caatinga*	Cave	655	22.2	687
Iraquara	Fumaça Cave 🕷	*Caatinga*	Cave	655	22.2	687
Iraquara	Lapa do Sol 🕷	*Caatinga*	Cave	655	22.2	687
Ituaçu	Mangabeira Cave	*Caatinga*	Cave	522	21.5	967
Lençóis	Lapão Cave	*Caatinga*	Cave	394	21.8	637
Lençóis	Serra das Paridas 🕷	*Caatinga*	Rocky fields	394	21.8	637
Lençóis	Indeterminated	*Caatinga*	Indeterminated	394	21.8	637
Maracás	Indeterminated	*Caatinga*; Atlantic Forest	Indeterminated	964	21.0	750
Palmeiras	Indeterminated	*Caatinga*	Cave	870	21.0	637
Palmeiras	Riachinho Cave	*Caatinga*	Cave	870	21.0	637
Seabra 🕷	Lapa da Santa 🕷	*Caatinga*	Cave	812	20,5	609

🕷 = new record



Geographic Coordinate System: DATUM SIRGAS 2000.
Cartographic resources: BRASIL, 2024; IBGE, 2022 e 2023.
Occurrences: BERTANI et al., 2010; CRIA (geoLoc), 2024; NOAP/UFBA, 1999; SBE, 2022.
Cartographer: Catharina Silva Chieh Ling Ma.
Date: July 21th, 2024.

Figure 4. Occurrence map of *L. chapadensis* in the municipalities and localities of Chapada Diamantina ecoregion. Legends: 1 = Lapa do Sol cave, Iraquara; 2 = Fumaça cave, Iraquara; 3 = Torrinha cave, Iraquara; 4 = Lapa da Santa Cave, Seabra; 5 = Lapa Doce cave, Iraquara; 6 = Mangabeira cave, Itaetê; 7 = Lapão cave, Lençóis; 8 = Riachinho Cave, Palmeiras; 9 = Serra das Paridas, Lençóis; 10 = Pratinha Farm, Iraquara; 11 = Seabra; 12 = Iraquara; 13 = Ituaçu; 14 = Lençóis; 15 = Maracás; 16 = Palmeiras. Map: Catharina Ma (2024).

(Andrade-de-Sá et al., 2024). Herein we have expanded its distribution to include Seabra municipality.

All these records shown in Table 1 and in the map (Figure 4) indicate that *L. chapadensis* is found in a climatic scenario typical of the ecoregion, with an altitude reaching 964 meters, an average temperature of 22 °C, and 967 millimeters/year of rainfall (Andrade-de-Sá et al., 2024). The ecoregion of Chapada Diamantina has more than 30,000 km^2 and many other caves, so we consider the possibility that *L. chapadensis* could be dispersed and distributed in different locations within this region. Passive transport contributes to the dispersal of spiders of this genus (Gertsch, 1967), mainly through the movement of goods transported between cities. Additionally, the record of its occurrence in the Serra das Confusões National Park (Piauí) in 2020, expands its distribution within the Northeast region (Carvalho et al., 2020), but maintains its occurrence in similar Brazilian *Caatinga* environments with high-altitude xeric geomorphological and vegetational characteristics.

Although this study focuses on caves, we also found *L. chapadensis* in Serra das Paridas (Lençóis) which is not a cave but has rock projections similar to cave entrances. It is already known that these spiders can occur in other environments as already found in rock crevices, under rocks in Palmeiras and Lençois in the natural environment, and under construction materials (stones, bricks, and tiles) near human dwellings in Iraquara (Bertani et al., 2010). Records outside the cave refuge and close to human habitations may indicate that the species can acclimatize to the urban environment. This is the case of *L. gaucho*, frequently found in the north of Paraná state, adapted to the specific climatic characteristics. It is often found in cracks between the ground, under roof tiles, and leftover construction debris, where temperatures are likely milder and humidity is higher, as intra-domiciliary occurrences are rarely recorded (Marques-da-Silva & Fischer, 2005).

OCCURRENCE IN CAVES

Of the 10 confirmed locations of *L. chapadensis* occurrence, nine are caves. Of these, four are new records: Torrinha, Fumaça, Lapa do Sol, and Lapa da Santa Caves (Table 1).

Studies on *Loxosceles* species in Brazilian caves have focused only on their presence in different caves (Dessen et al., 1980; Trajano & Gnaspini-Neto, 1990; Trajano & Moreira, 1991; Gnaspini & Trajano, 1994; Gnaspini et al., 1994; Gonçalves-de-Andrade et al., 2001). Of the 22 species of *Loxosceles* already described in Brazil, ten were recorded in caves: *L. adelaida* Gertsch, 1967, *L. boqueirao*, *L. bodoquena* Bertani & Gallão, 2024, *L. similis*, *L. willianilsoni* Fukushima, de Andrade & Bertani, 2017, *L. karstica*, *L. carinhanha*, *L. cardosoi*, *L. planetaria* Bertani & Gallão, 2024 and *L. troglobia* (Bertani et al., 2024), six of them from the Gaucho group. We can now include *L. chapadensis* in this group and consider it as one of the 11 species with cave-dwelling habits.

Most *Loxosceles* spiders found in caves are troglophiles (facultative cave dwellers) as they can complete their life cycle inside and outside caves, with source populations in epigeal and hypogeal habitats, with gene flow between habitats (Trajano & Carvalho, 2017; Bertani et al., 2024). Until now, *L. troglobia* and *L. boqueirao* are the only troglobite species (restricted and exclusive cave dwellers) recorded in Brazil (Bertani et al., 2024). Since *L. chapadensis* has been found both inside and outside the caves, it is suggested that there are troglophilic populations. However, this only means that some populations of species live above ground and do not show clear evidence of living in an isolated underground environment. To confirm this suggestion, it is important to carry out long-term studies using chronobiological methods to detect any recurring patterns of movement between surface and underground habitats (Trajano & Carvalho, 2017).

SPATIAL DISTRIBUTION INSIDE THE CAVES

Caves are unique environments: extremely stable, with high humidity, constant temperatures, and absence of light, which favor the colonization and persistence of these spiders if there is sufficient food (Ferreira et al., 2005). Although all the caves in this study were in the same range of humidity (median between 75 and 85%) (Figure 5A) and temperature (median between 22 and 25 °C) (Figure 5B), we draw attention to the fact that their little variation between the photic and aphotic zones for each cave, could also interfere with the distribution of the spiders. *L. chapadensis* was observed in high humidity values of 58.5 and 89%, and temperature values of 20.7 and 29.2 °C.

It was observed that *L. chapadensis* is distributed heterogeneously according to the level of luminosity throughout the interior of the caves. So, we can understand that light intensity was a crucial factor in the spiders' distribution. Almost 90% of the spiders were collected in photic zones, with direct or indirect light influence (Figure 6). Despite being photophobic (Bücherl, 1961), these spiders occurred predominantly in the photic zone. This could suggest that the spiders are feeding in areas where there are more arthropods, naturally oriented towards light. However, defensively, the spiders do not remain exposed to light, preferring locations with low light intensity. Therefore, it is common to find *L. chapadensis* in crevices, sheltered areas, and places with lower light intensity. The presence of *L. chapadensis* in diverse environments, including caves already heavily influenced by human activity, indicates its adaptation to environmental variations.

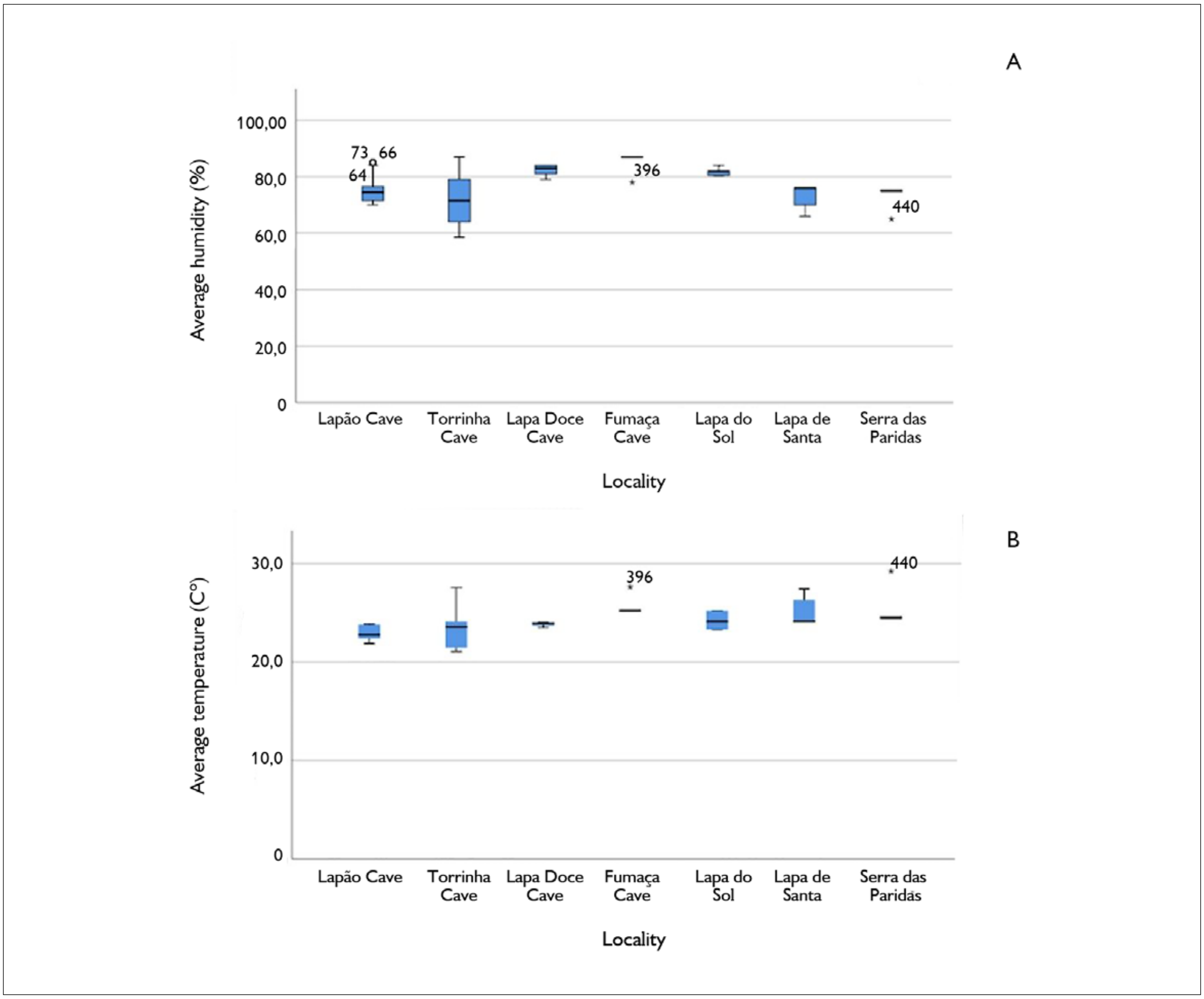


Figure 5. A) Graph of humidity values (%) in different collection localities; B) graph of temperature values (°C) in different collection localities.

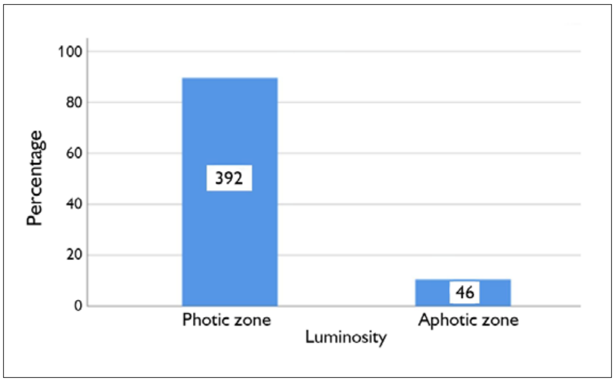


Figure 6. Percentage of spiders collected by luminous zone (photic and aphotic).

Abundance variation regarding *L. similis* within caves was discussed in Ferreira et al. (2005). In their work, the decrease in abundance in inner zones can be explained in two ways: first, if spiders colonize caves through entrances, the distance may act as a barrier to colonizing deeper areas; second, the reduction in prey in the deeper zone. The authors indicate that the presence or absence of food resources can influence spider concentration in certain areas. So, the reduced availability of potential prey inside the cave may lead to a decrease in *Loxosceles* abundance in these zones (Ferreira et al., 2005).

Despite the difficulty in finding *L. chapadensis* in aphotic zones, which was consistent across all sampled locations, molts of these spiders were often found in these environments. In the same study by Ferreira et al. (2005), it is mentioned that the lack or irregular distribution of prey in a cave may lead spiders to travel longer distances in search of food, with movements of up to 40 meters recorded in *L. similis*. Thus, the hypothesis raised is that spiders may frequent aphotic environments especially when more vulnerable during molting, but they would preferentially inhabit photic zones for foraging, reproduction, and other activities.

According to Vetter (2015), *Loxosceles* spiders prefer vertical to horizontal distribution, which probably does not apply to cave-dwelling spiders of this genus, as we observed for *L. chapadensis*. Despite we found the spiders up to about six meters in height (Figure 7) (which varies depending on the reference point, given the irregular structure of the environments) they generally are located close to the ground. That is similar to the described behavior of *Loxosceles boqueirao*: generally solitary in their webs on cave walls very close to the ground, with one specimen found approximately 2 meters above ground (Bertani et al., 2024).

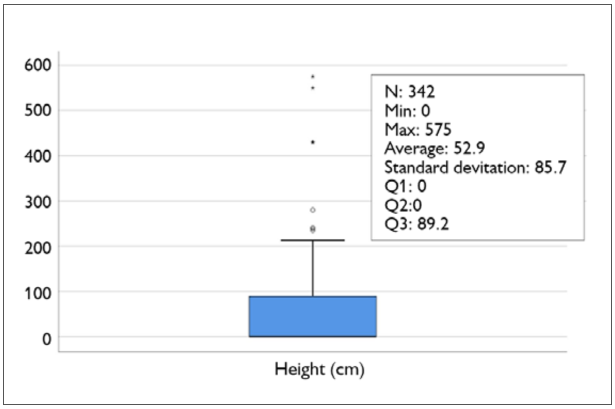


Figure 7. Boxplot of substrate height to collected *Loxosceles.*

COEXISTENCE WITH OTHER TAXA

Twenty-six taxa were recorded coexisting with *L. chapadensis* in this study (Table 2; Figure 8). The majority had already been reported as cave fauna, including non-identified *Loxosceles* species (Trajano, 1986). A diversity of 25 taxa was found in the photic zones, while only 12 were observed in the aphotic zones (Table 2). The discrepancy in the number of observed taxa reinforces the argument that abundance is associated with prey presence.

No predation of *L. chapadensis* was observed by any of the taxa mentioned. However, amphibians and reptiles have been reported as important predators of spiders, regardless of the taxonomic level (Foelix, 1996). And, for some species of *Loxosceles* predators such as bats (Chiroptera) (Fischer et al., 2006) and Pholcidae spiders - *Pholcus phalangioides* (Fuesslin, 1775) (Sandidge, 2004; Fischer & Krechemer, 2007) this has already been observed. Both bats, frogs, and Pholcidae spiders were found in the cave fauna of the explored environments, thus considered potential predators of *L. chapadensis*

Table 2. Taxa recorded coexisting with *L. chapadensis* by zone. Legends: amb = Amblypygi; anu = Anura; aran = Araneae; araneid = Araneidae; blatt = Blattaria; chirop = Chiroptera; coleop = Coleoptera; cten = Ctenidae; dermap = Dermaptera; dip = Diptera; diplop = Diplopoda; hemip = Hemiptera; hymenop = Hymenoptera; kerodon = *Kerodon rupestris*; lepdop = Lepdoptera; lycosid = Lycosidae; opili = Opiliones; ortop = Ortoptera; pholc = Pholcidae; pseudo = Pseudoscorpiones; sau = Sauris; scutig = Scutigera; *tityus*_m = *Tityus martinpaechi*; therap = Theraphosidae; ulob = Uloboridae; zygent = Zygentoma; X = presence; 0 = absence.

Zone	amb	anu	aran	araneid	blatt	chirop	coleop	cten	dermap	dip	diplop	hemip	hymenop
Fotic	X	X	X	X	X	X	X	X	X	X	X	X	X
Aphotic	X	0	X	X	X	X	0	0	0	0	X	0	0
	kerodon	lepdop	lycosid	opili	ortop	pholc	pseudo	sau	scutig	*tityus*_m	therap	ulob	zygent
Fotic	X	X	X	X	X	X	0	X	X	X	X	X	X
Aphotic	0	0	X	X	X	0	X	0	0	0	X	0	X

(Figure 9). The identification of Pholcidae individuals remains at the family level, but it is a common taxa observed among caves.

AGGREGATION AND BEHAVIOR

Regarding horizontal distribution, the distance between the closest *Loxosceles* was measured (Figure 10). According to Bücherl (1961), these animals tend to keep themselves separate from each other, strictly respecting the habitat of their neighbors and not invading each other's domicile while living. However, it was not uncommon to find adult *L. chapadensis* separated by only a few centimeters without displaying hostile behavior (Figure 11).

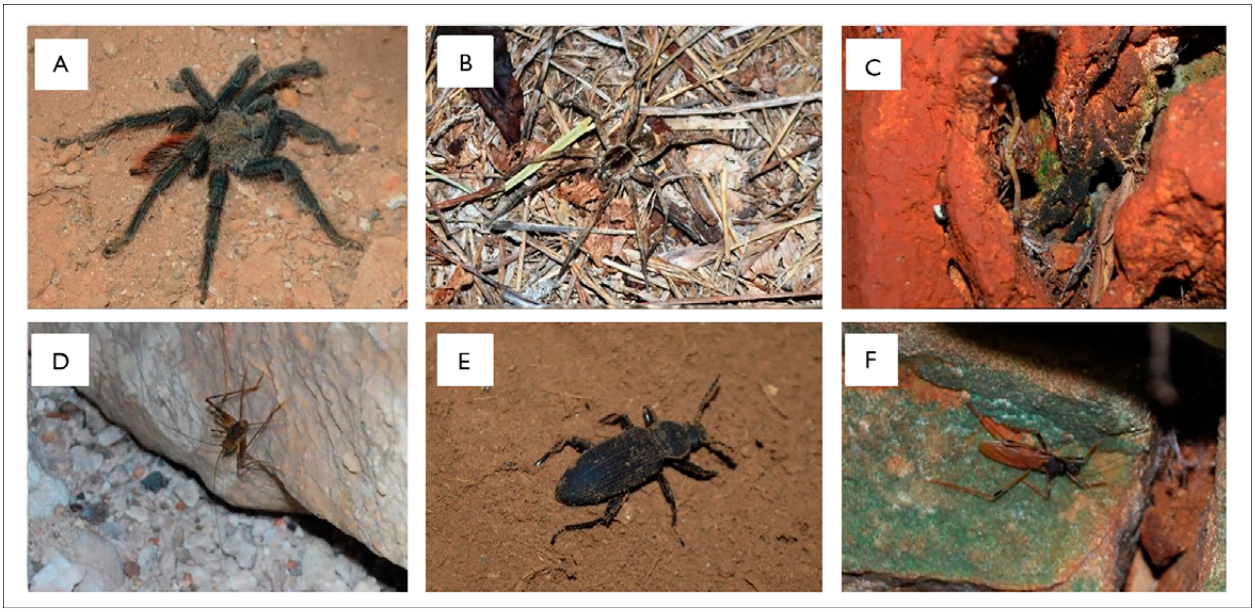


Figure 8. Cave fauna of the Lapão (Lençóis), Torrinha, Lapa Doce, and Fumaça caves, (Iraquara): A) Theraphosidae (tarantula); B) Lycosidae (wolf spider); C) *Tityus martinpaechi* (scorpion); D) Gryllidae (cricket); E) Coleoptera (beetles); F) Hemiptera (true bugs). Photos: images by the authors (2023/2024).

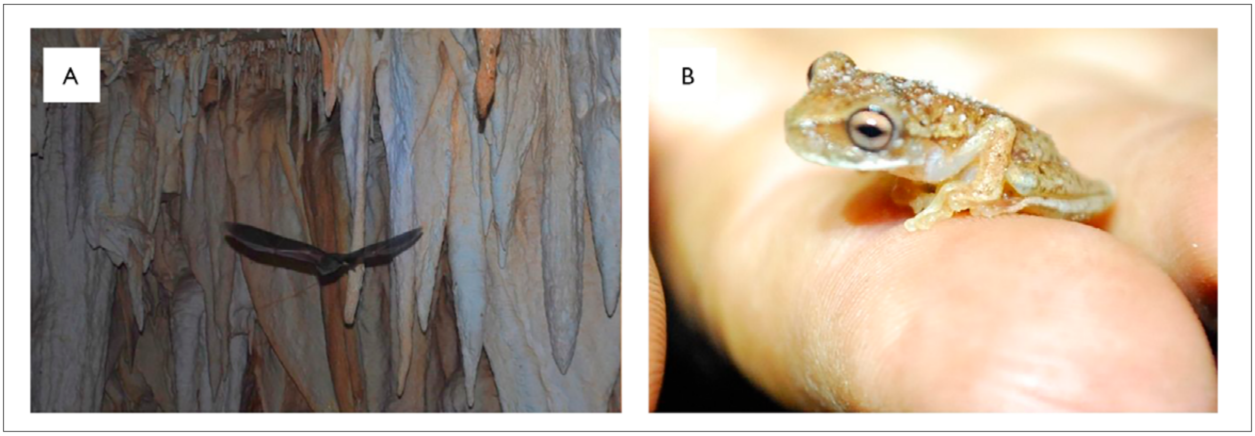


Figure 9. Possible predators of *L. chapadensis*, found in the studied caves: A) Chiroptera in Fumaça Cave, Iraquara; B) Amphibia in Lapão Cave, Lençois. Photos: images by the authors (2024).

A discrepant ratio between females and males was observed (Table 3), which can be explained by the evasive behavior of males in the field. This male behavior was already observed by Rinaldi et al. (1997), showing they are more evasive than females when promptly hiding to any slight disturbance occurs. Additionally, females (total length 8.76 mm) are larger than males (total length 5.60 mm), making them possibly easier to spot and capture. These values refer to the holotype and paratype measure (Bertani et al., 2010).

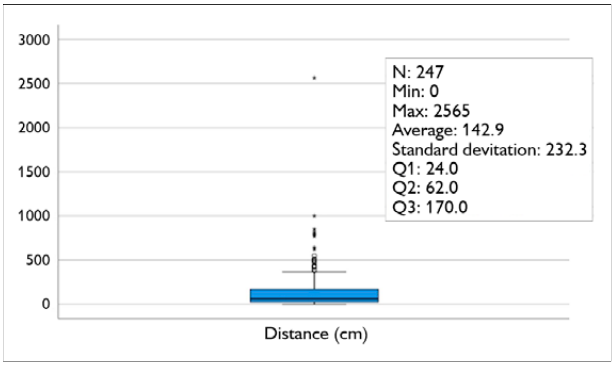


Figure 10. Distance (cm) between the nearest *Loxosceles*.

Specimens of *L. chapadensis* are often found resting on the substrate in their web sheets, as is well-known for the genus (Bücherl, 1961). Among the categorized behaviors, 'Inactive' stood out among those observed during the expeditions (Figure 12). This behavior includes the classic position where the animal rests its ventral side on the substrate and retracts its legs in a slanted way (Figure 13C), characterized by other authors, such as Vetter (2015). They were found on a variety of substrates, including sand, rock, and soil (Figure 13).

A behavior not systematically recorded but frequently observed among *L. chapadensis* was site fidelity, as expected. According to Vetter (2015), the recluse-spiders show site fidelity: it is not uncommon to find multiple shed

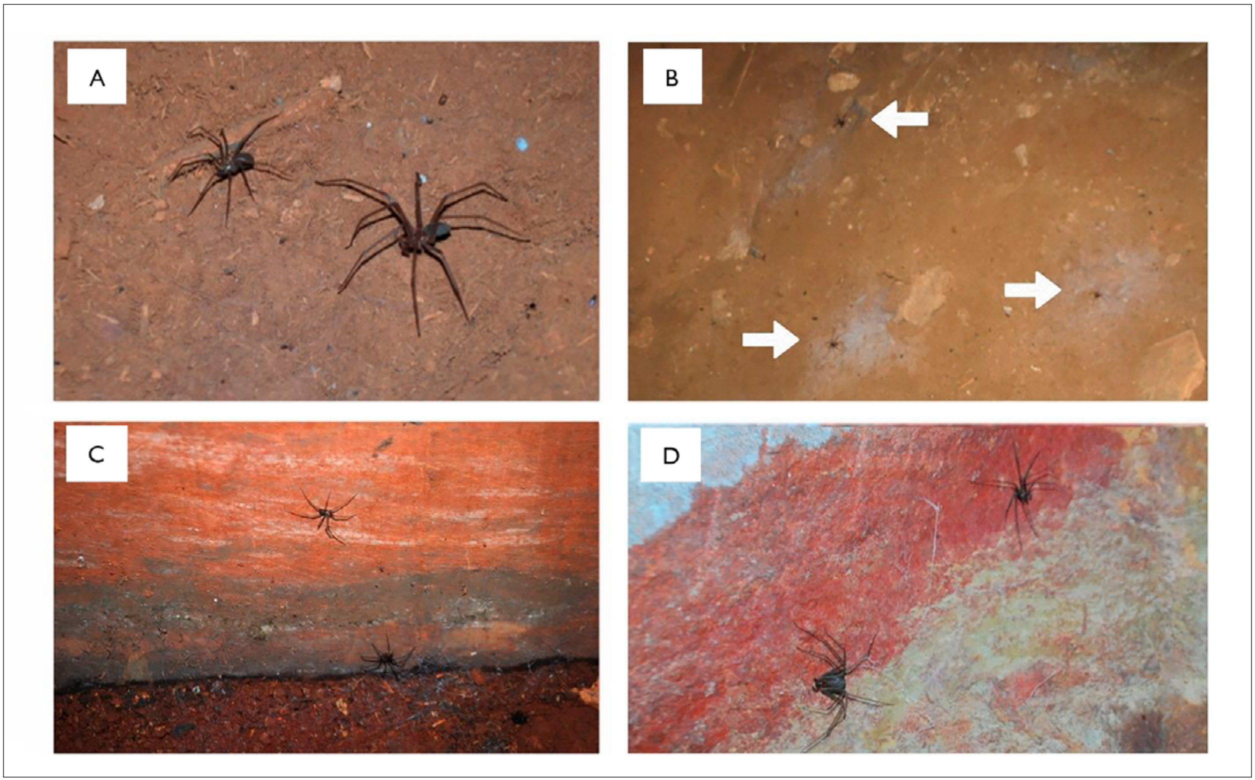


Figure 11. *L. chapadensis* coexisting just a few centimeters apart: A, B) *L. chapadensis* in Torrinha Cave, Iraquara; C) Fumaça Cave, Iraquara; D) Lapão Cave, Lençóis. Photos: images by the authors (2023/2024).

Table 3. Percentage of animals collected by sex. Legend: * = omission cases relate to occasions where the information was either not provided or not identified for some reason that made it impossible to determine. This could happen due to limitations in the observation process.

		Frequency	Percentage	Valid percentage
Valid	Female	258	56.5	65.0
	Male	63	13.8	15.9
	Indeterminate	76	16.6	19.1
	Total	397	86.9	100.0
Omission*	Ignored/White	60	13.1	
Total		457	100.0	

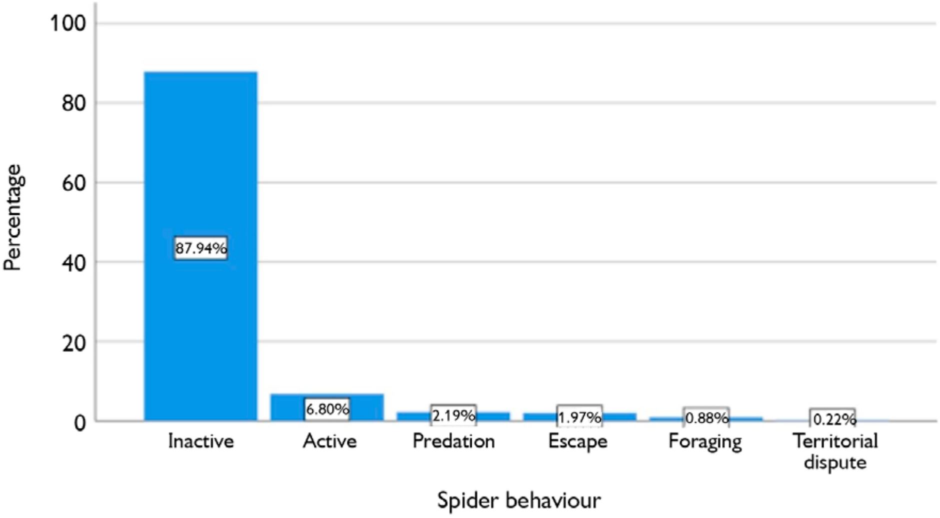


Figure 12. Percentage of *Loxosceles chapadensis* observed behavior.

skins of increasing size in one spot, indicating the repeated return of the spider to the same retreat as it was growing. Some of them hide during the day in a retreat such as a slot in a sliding window or a hole at the base of a staircase and then emerge at night and wait in their same retreat for a prey item to land nearby (Vetter, 2015).

Regarding feeding, *Loxosceles* species are reported as troglophile predators (Ferreira et al., 2005), but little is known about their foraging habits (Souza-Silva & Ferreira, 2014). They generally capture live invertebrates as food (Fischer et al., 2006), but *Loxosceles* can also use necrophagous strategies and cannibalism (Sandidge, 2003; Fischer et al., 2006; Cramer, 2008; Vetter, 2011). In Brazilian caves, *Loxosceles* are often observed with their webs placed over or near food resources or within invertebrate breeding sites, thereby obtaining their prey opportunistically (Ferreira & Martins, 1998, 1999; Ferreira et al., 2000, 2007; Gnaspini & Trajano, 2000). According to Souza-Silva and Ferreira (2014), out of thirty predation events of *Loxosceles* species observed in caves, all the prey were arthropods: most of the prey captures were insects (80%), with the remainder being Pseudoscorpiones, Araneae, and Diplopoda. Diptera was the most representative order, with 23.3% occurrence. The body sizes of some prey were larger than those of *Loxosceles* species. In this work, all the *L. chapadensis* recorded prey were also arthropods, with Coleoptera being the most representative taxa (Figure 14).

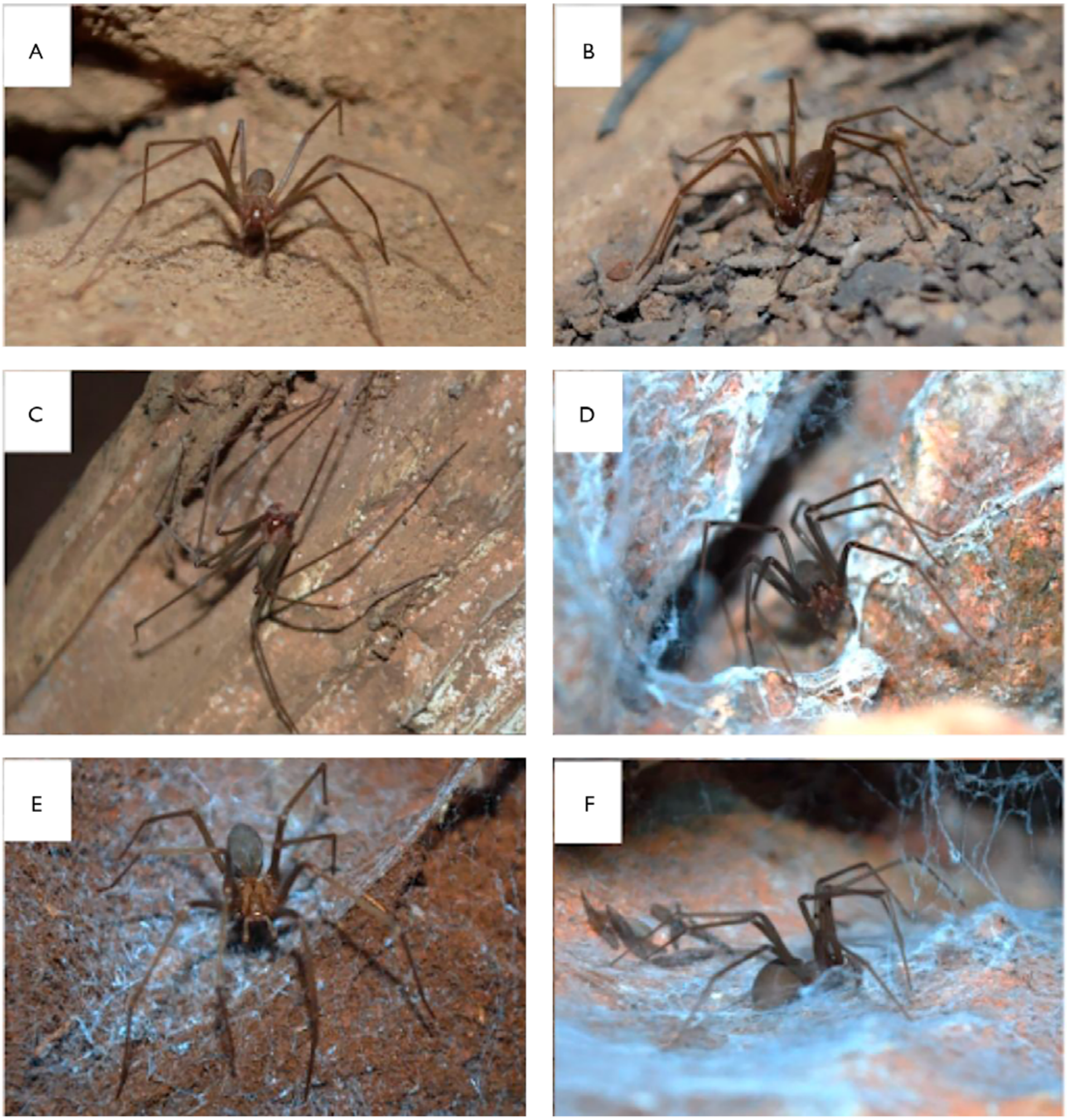


Figure 13. Behavior of *L. chapadensis* inside of caves: A) *L. chapadensis* inactive on sand; B) inactive on rock; C) resting on rock; D-F) inactive on rock, in a sheet web. Photos: images by the authors (2023/2024).

In most cases, it was not possible to observe *L. chapadensis* approaching prey to feed, but it was possible to photograph them in the act of feeding (Figure 15).

Cannibalism has been evidenced on at least two occasions (Figure 14). This event is considered common in spiders of this genus, especially when the caves are extremely dry and oligotrophic; additionally, cannibalism was also observed when population densities were high (Souza-Silva & Ferreira, 2014). In some caves, several spiders were observed preying on smaller individuals (Souza-Silva & Ferreira, 2014). According to Fischer et al. (2006), the generalist habits and cannibalism observed in some caves are likely due to the scarcity of food resources within the caves, and it may be rare in areas with much potential prey. In the case of *L. chapadensis*, it was not possible to associate cannibalism with a reduction in prey or other factors. However, given the diversity of taxa found in this work, it is believed that cannibalism was more related to population density than to resource scarcity.

CONCLUSION

We conclude that *Loxosceles chapadensis* is a spider that has populations with cave-dwelling habits, endemic to the Brazilian *Caatinga* environments with high-altitude xeric geomorphological and vegetational characteristics, until then, with records in the states of Bahia and Piauí.

Their strong presence in caves indicates an adaptation to this environment. Also, it is possible that this spider occurs in other caves in the same region, or even could acclimatize to the human environment. Due to the presence of individuals in both hypogean and epigean habitats, we can suggest that troglophile populations of *L. chapadensis* do exist.

The distribution of *L. chapadensis* inside the caves is directly related to the luminosity, associated with the presence of invertebrate fauna as part of the spiders' foraging availability. In the photic zone, *L. chapadensis* are distributed horizontally among varied substrates, not far from each other (aggregation). Vertically, they can reach approximately 6 meters on the cave walls.

The presence of *L. chapadensis* in areas with high tourist traffic demands careful consideration in the management plans for the caves where it has been found. Despite its restricted occurrence in a region with unique environmental characteristics, current data are still insufficient to determine the species' threat *status*.

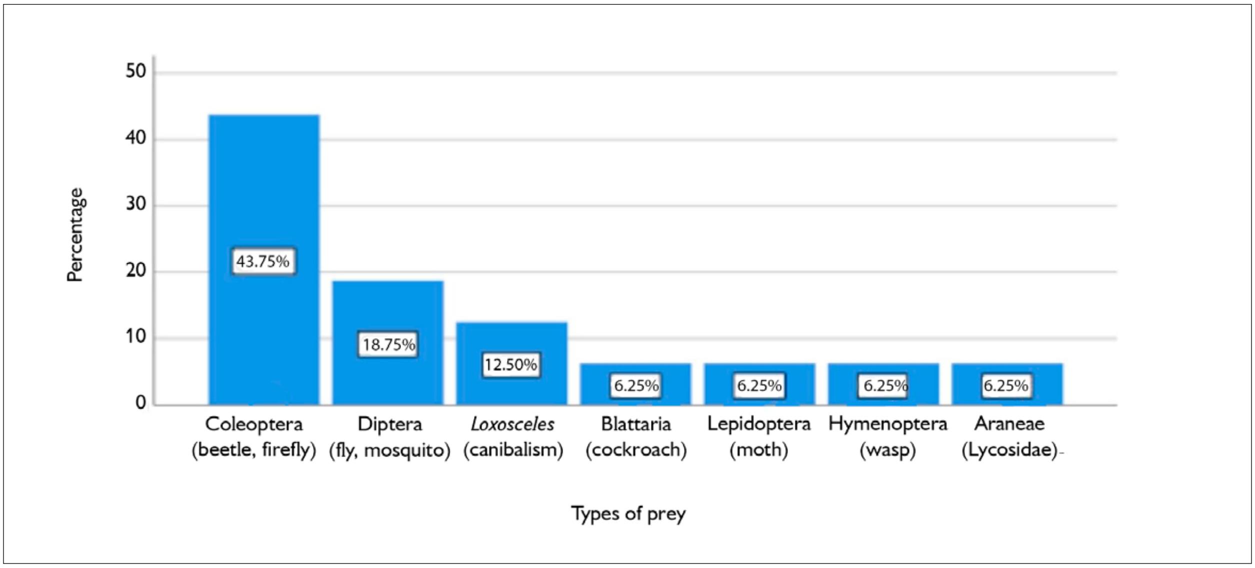


Figure 14. Percentage of *Loxosceles chapadensis* types of prey.

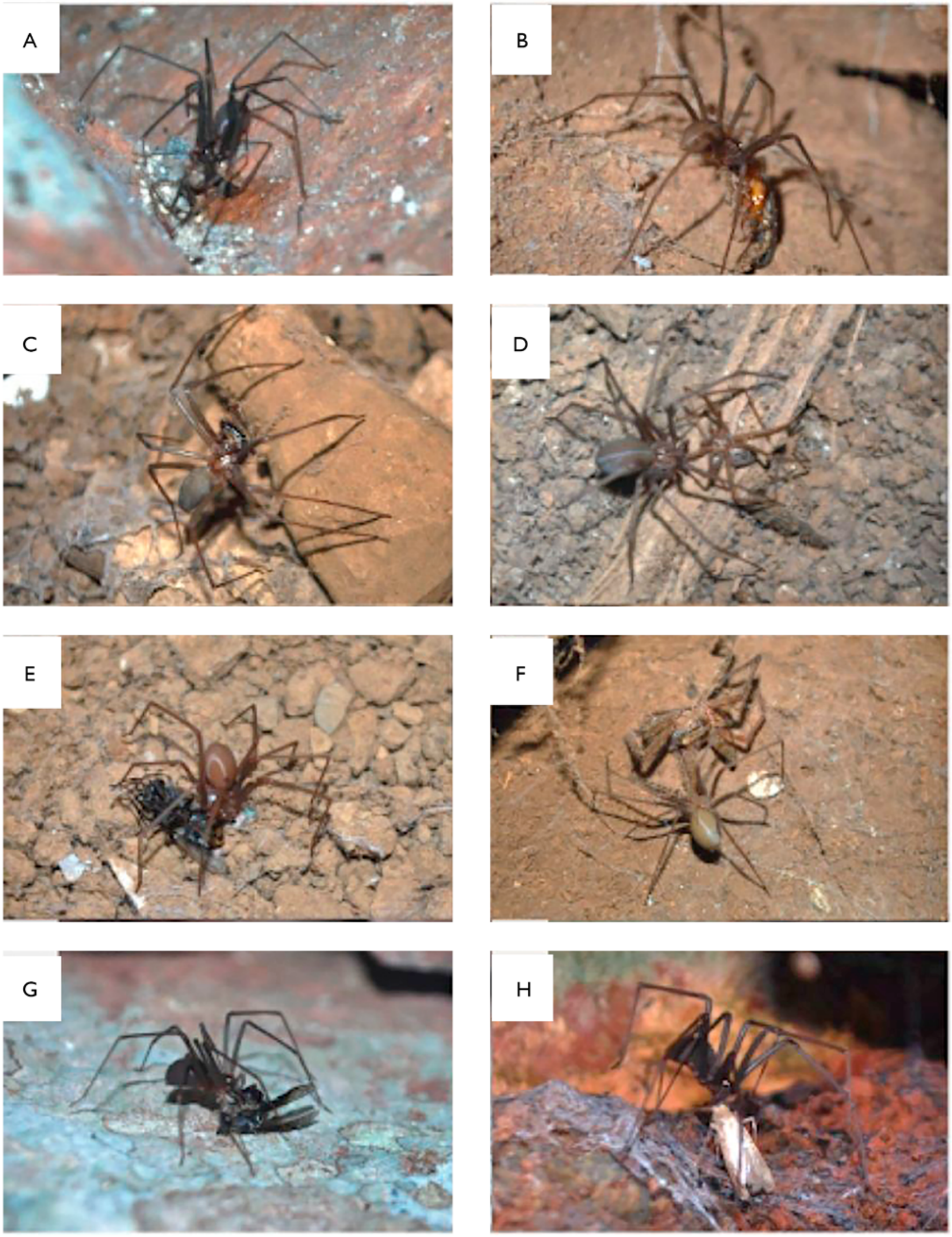


Figure 15. Observations on *L. chapadensis* feeding: A, B) on Blattaria; C, H) on Lepidoptera; D) cannibalism; E) on Diptera; F) on Lycosidae; G) feeding on Hymenoptera. Photos: images by the authors (2023/2024).

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AUTHORS' CONTRIBUTIONS

J. Andrade-de-Sácontributed to the application of statistical techniques (formal analysis), conducting a research and investigation process (investigation) and writing (original draft); T. K. Brazil contributed to the conceptualization and writing (original draft, review & editing); Y. F.Mise contributed to the application of statistical techniques (formal analysis) and development or design of methods (methodology); R. M. Lira-da-Silva contributed to the ideas (conceptualization), management and coordination responsibility for the research activity, planning and execution (project administration), supervision and writing (review & editing).

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2.	Dígitos geralmente sem unhas, dorsais lisas	*Bachia flavescens*
	Dígitos com unhas, dorsais quilhadas	*Bachia panoplia*
3.	Mãos com apenas 4 dedos	4
	Mãos com 5 dedos	5
4.	Escamas dorsais lisas	*Gymnophthalmus underwoodii*
	Escamas dorsais quilhadas	*Amapasaurus tetradactylus*
5.	Cabeça com grandes placas	6
	Cabeça com escamas pequenas	7
6.	Placas posteriores da cabeça formam uma linha redonda	*Alopoglossus angulatus*
	Placas posteriores da cabeça formam uma linha reta	*Arthrosaura kockii*
7.	Etc.	
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Artigo de periódico: Gans, C. (1974). New records of small amphisbaenians from northern South America. *Journal of Herpetology, 8*(3), 273-276. http://dx.doi.org/10.2307/1563187.

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   Dorsal scales keeled..........*Amapasaurus tetradactylus*
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   Head with small scales..........7
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