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Richness, diversity and faunal similarity estimators of soil spiders (Arachnida: Araneae) in two vegetation formations of the Cerrado biome

Estimativas de riqueza, diversidade e similaridade faunística de aranhas (Arachnida: Araneae) de solo em duas formações vegetais do bioma Cerrado

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Abstract: Studies on soil araneofauna in the Cerrado biome are still scarce in northeastern Brazil, especially in Maranhão. This study aimed to conduct an inventory of richness, diversity, and faunal similarity estimators of soil spiders in two vegetation formations of the Cerrado biome, namely gallery forest and Cerrado sensu stricto, in the Inhamum Municipal Environmental Protection Area (EPA), Caxias, Maranhão, Brazil. Collections were carried out during dry and rainy periods using Provid-type traps. For faunal analysis, species richness, diversity and equitability tests were used in the Anafau program and faunal similarity tests in the R program. In the present inventory, 23 families, 37 genera, and 43 species were identified. Richness estimators and species accumulation curves generated for both sites (gallery forest and Cerrado sensu stricto) revealed that the sampling effort was not sufficient to fully quantify soil araneofaunal species; therefore, the richness of soil spiders at the two analyzed sites of the Inhamum EPA is underestimated, suggesting that it might be possible to record even higher richness values in the two studied vegetation formations of the Cerrado biome. The Shannon–Wiener diversity index (H′) and Pielou's evenness index (J′) were similar and indicated a moderate diversity of soil spiders in both gallery forest and Cerrado sensu stricto sites. Similarity dendrogram analysis showed that the soil spider communities analyzed were substantially similar, with most species occurring at both sites.
Keywords: Spiders; Phytophysiognomies; Maranhão.

Resumo: Estudos sobre a araneofauna de solo no bioma Cerrado ainda são escassos na região Nordeste do Brasil, especialmente no Maranhão. O objetivo do presente estudo foi realizar um inventário sobre as estimativas de riqueza, diversidade e similaridade faunística de aranhas de solo em duas formações vegetais do bioma Cerrado (Mata de Galeria e Cerrado sensu stricto) presente na Área de Proteção Ambiental Municipal do Inhamum (APA do Inhamum), em Caxias, Maranhão. As coletas foram realizadas durante os períodos secos e chuvosos utilizando armadilhas do tipo Provid. Para as análises faunísticas foram utilizados os testes de riqueza de espécies, diversidade e equitabilidade no programa Anafau e de similaridade faunística no programa R. Neste inventário foram identificadas 23 famílias, 37 gêneros e 43 espécies. Os estimadores de riqueza e as curvas de acumulação obtidas para ambas as áreas (Mata de Galeria e Cerrado sensu stricto) revelaram que o esforço não foi suficiente para quantificar totalmente as espécies e que, portanto, a riqueza de aranhas de solo nas duas áreas analisadas da APA do Inhamum encontra-se subamostrada, sendo possível encontrar riqueza ainda maior nas duas formações vegetais estudadas do bioma Cerrado. Os índices de diversidade de Shannon-Weaver (H') e de Equitabilidade de Pielou (e) foram similares e os valores obtidos apontam para uma diversidade moderada tanto na Mata de Galeria como no Cerrado stricto sensu. A análise do dendrograma de similaridade mostrou que as comunidades de aranhas analisadas são bastante semelhantes entre si, com a maioria das espécies ocorrendo em ambas as áreas.
Palavras-chave: Aranhas; Fitofisionomias; Maranhão.

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1. Introduction

As the second largest Brazilian biome, the Cerrado is notable for its great geographical extension and vast diversity of lithologies, landforms, and soils. Given this high heterogeneity, the vegetation of the Cerrado biome is one of the most diverse in Brazil (PEREIRA et al., 2011). In northeastern Brazil, the highest concentrations of Cerrado vegetation are found in Piauí and Maranhão States, with approximately 10,000,000 hectares distributed throughout more than 38 municipalities (NERES; CONCEIÇÃO, 2010).

The Cerrado is one of the world's biodiversity hotspots, and also one of the richest and most threatened biomes worldwide (MMA, 2002). Cerrado areas have been subject to intense degradation (LEITE et al., 2010; FERNANDES; PESSOA, 2011; SOUZA et al., 2020), and the loss of native vegetation is occurring at an alarming rate. A major environmental problem of the modern world is the increasing fragmentation of forest ecosystems, which affects species richness and diversity (LAURANCE et al., 2002). For this reason, new studies on the species composition and richness of the Cerrado biome should be encouraged (CARVALHO; AVELINO, 2010).

Structured inventories have been increasingly used in faunal studies to assess patterns of species richness and diversity, mainly because they allow drawing comparisons between environments (CODDINGTON et al., 1996; MARTINS, et al., 2022; RODRIGUES, et al., 2021; FORMIGA, et al. 2020; SOARES, et al., 2020). Studies on soil araneofauna in the Cerrado biome are still scarce, limited to a few records of taxonomic and geographical nature (CARVALHO; AVELINO, 2010; MORAES, 2014; SANTANA, 2015; OLIVEIRA et al., 2017). Spiders are recognized as bioindicators of environmental quality, owing to their extreme sensitivity to natural and anthropic disturbances (ROCHA, 2017).

Brazil has one of the greatest diversity of spiders in the world (BRESCOVIT et al., 2011). A total of 625 species were recorded in the Cerrado alone, 169 of which are endemic to this biome (OLIVEIRA et al., 2017). Because of their high species richness, easy sampling, and sensitivity to environmental factors, spiders can be used to assess differences in environmental conditions between habitats (RODRIGUES, 2020).

In view of these considerations, this study aimed to conduct an inventory of richness, diversity, and faunal similarity estimators of soil spiders in two vegetation formations of the Cerrado biome in the Inhamum Municipal Environmental Protection Area (APA of Inhamum), Caxias, Maranhão, Brazil. This study contributes to expanding our knowledge of spider biodiversity in the region and may provide some insight as to how this diversity is maintained in the two vegetation formations analyzed. This is the first standardized survey of soil spiders carried out in the area.

2. Metodology

2.1 Study sites

Collections were carried out at two experimental sites in the Inhamum EPA, representing two typical vegetation formations of the Cerrado biome, namely gallery forest (Site 1) and Cerrado sensu stricto (Site 2) (Figure 1). The Inhamum EPA is characterized by dry subhumid climate with two well-defined periods, a rainy season from January to June and a dry season from July to December (ALBUQUERQUE, 2012).

In the Cerrado biome, gallery forests are characterized by large amounts of grasses and leaf litter, arboreal species, and dispersed trees, forming a continuous canopy (da SILVA et al., 2016). Cerrado sensu stricto also has a typical vegetation, characterized by well-defined arboreal and shrubby-herbaceous strata and small to medium-sized trees without a continuous canopy (CONCEIÇÃO et al., 2014).

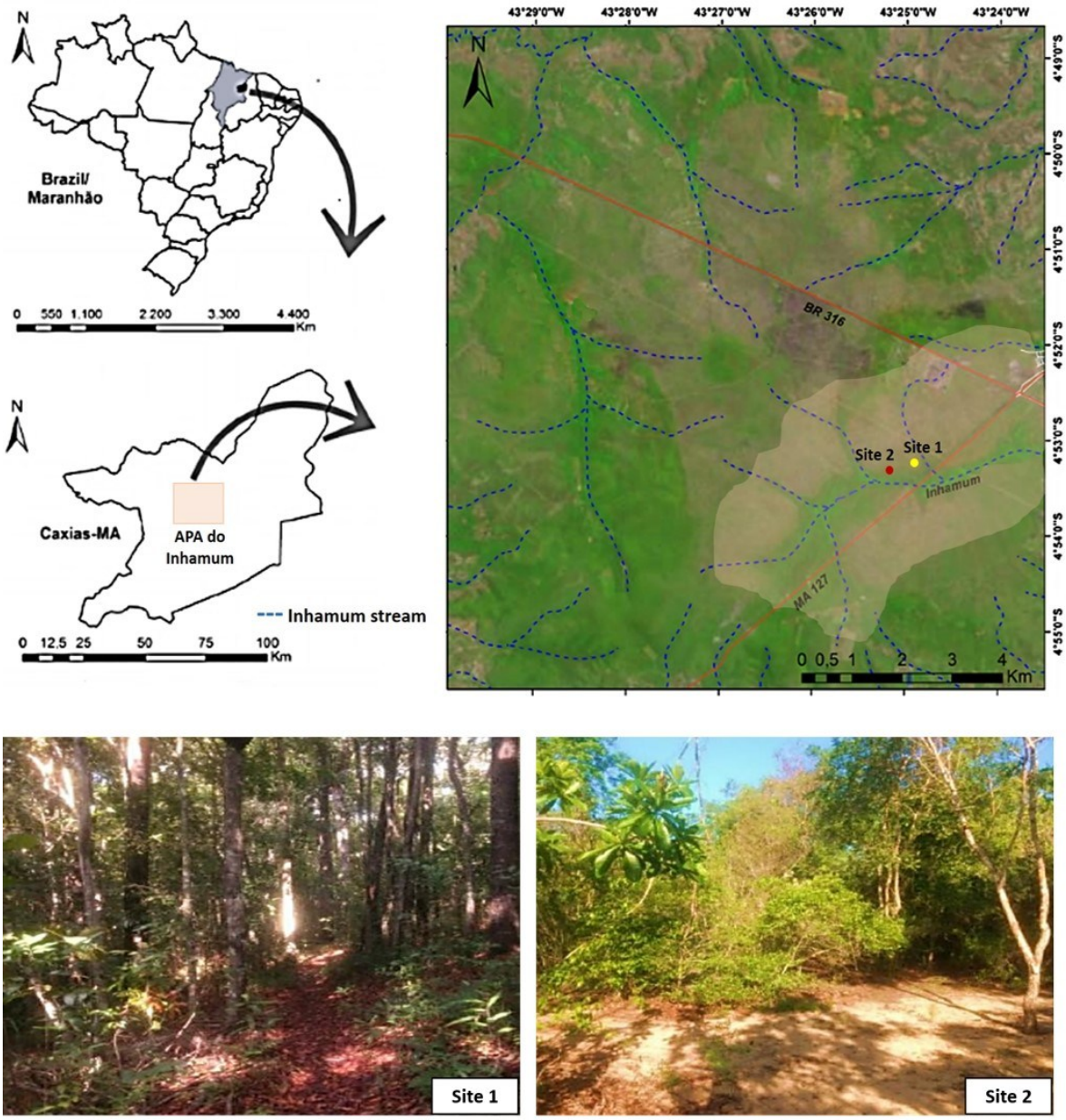

Figure 1 – Location map of the Inhamum Municipal Environmental Protection Area, Caxias, Maranhão, Brazil, showing the vegetation formations of the Cerrado biome sampled in the study. Site 1= Gallery forest; Site 2= Cerrado sensu stricto.
Source: Authors (2020).

2.2 Sampling design and spider identification

Specimen collection was carried out during the dry (October, November, and December 2017) and rainy (January, February, March, and April 2018) seasons by using Provid traps (FORNAZIER et al., 2007; GIRACCA et al., 2003). The traps were distributed in the gallery forest (Site 1) and Cerrado sensu stricto (Site 2). At each site, six parallel transects (10 × 10 m) and 30 sampling points were demarcated, totaling 60 sampling points (SOARES et al., 2020).

The collected spiders were fixed in 70% ethanol and sent for identification at the Butantan Institute. Adult individuals were identified at the species or morphospecies level, whereas immature individuals were counted and discarded. The material was deposited in the collection of the Zoological Collections Laboratory of the Butantan Institute (curator: A. D. Brescovit). Specimen collections were authorized by ICMBio/IBAMA (License nº. 583781).

2.3 Faunal analysis

Species richness was estimated using ANAFAU software (MORAES et al., 2003) based on 100 permutations. The relationship between species richness and sampling effort was analyzed by constructing two species accumulation curves (one for each sampling site) using R software version 3.3 (R Core Team, 2017), with 95% confidence intervals ($\alpha < 0.05$) (EFRON; STEIN, 1981).

Species diversity at each site was evaluated using the Shannon–Wiener diversity index (H′) (Begon et al., 1996). Comparisons between diversity indices (H′) were performed using the t-test proposed by Hutcheson (1970) apud Magurran (1988). Multiple pairwise comparisons were performed using Bonferroni correction (ZAR, 1984) with a 95% confidence interval ($\alpha = 0.05$). Pielou's evenness index (J′) was also determined (MAGURRAN, 1988). Diversity and evenness indices were calculated using ANAFAU software (MORAES et al., 2003).

Araneofaunal compositions at Sites 1 and 2 were compared by month of collection (from October 2017 to April 2018). The comparison was made using the Jaccard similarity index (SJ′) (MUELLER-DOMBOIS; ELLENBERG, 1974). The resulting faunal similarity indices were used for cluster analysis by the unweighted pair group method with arithmetic mean (UPGMA) and generation of a dendrogram (SNEATH; SOKAL, 1973). These analyses were performed in the R environment (version 3.3, R Core Team, 2017).

3. Results and Discussion

3.1 Composition of soil araneofauna

In this inventory, 23 families, 37 genera, and 43 species were identified from 543 specimens of soil spiders, including 253 adult individuals and 290 juveniles. Of the total number of adult specimens, 111 were collected in gallery forest (Site 1) and 142 in Cerrado sensu stricto (Site 2). Of the 43 species identified, 18 were singletons and 8 were doubletons. Most of the species collected in this study (70% of the identified species) are recorded for the first time in Maranhão State (see SOARES et al., 2020).

3.2 Richness estimators and species accumulation curves

Richness estimators ranged from 38 (Bootstrap) to 57 (Jackknife 2) species for Site 1 and from 40 (Bootstrap) to 67 (Chao) species for Site 2 (Table 1). All estimators were higher than the observed richness (Site 1 = 31 species and Site 2 = 32 species), indicating that the sampling effort was insufficient. Therefore, the richness of soil spiders at the two analyzed sites of the Inhamum EPA is underestimated, and it might be possible to find even higher species richness in the two vegetation formations of the Cerrado biome. These results may explain the large proportion (41.9%) of species represented by one individual only (singletons).

None of the species accumulation curves (Sites 1 and 2) showed a tendency to reach an asymptote (Figure 2), thus, the curves were not stabilized, suggesting that the sampling effort was not satisfactory to comprehend the total number of species at each site. Such a finding corroborates richness estimators, which differed considerably from the observed richness. According to Santos (2003), this situation is common in inventories of tropical regions, where stabilized curves of species accumulation are unlikely to be obtained.

Similar results were observed by Azevedo et al. (2017) in an inventory study of epigeal spiders from a forest fragment in an urban area in Fortaleza, Ceará State. The analyses indicated a considerable percentage of rare species (17.33% of the total species were singletons), and, according to the authors, the non-stabilization of richness estimators and species accumulation curves indicated that the area requires greater sampling efforts.

In the study of Coddington et al. (2009), who carried out large inventories of tropical arthropods, singletons corresponded on average to 32% of the sampled species, a number considered high and indicative of undersampling. According to Silva (2012), species accumulation curves, as well as richness estimators, provide subsidies for decision-

making in relation to taxonomic richness and biodiversity conservation and are important tools for determining the adequacy of the sampling effort.

Table 1 – Richness estimators of soil spider species collected from two vegetation formations of the Cerrado biome in the Inhamum Environmental Protection Area, Caxias, Maranhão, Brazil, between October 2017 and April 2018.

Estimator	Site 1	Site 2
Observed richness	31	32
Chao	53	67
Jackknife 1	47	50
Jackknife 2	57	61
Bootstrap	38	40

Site 1= Gallery forest; Site 2= Cerrado sensu stricto.
Source: Authors (2020).

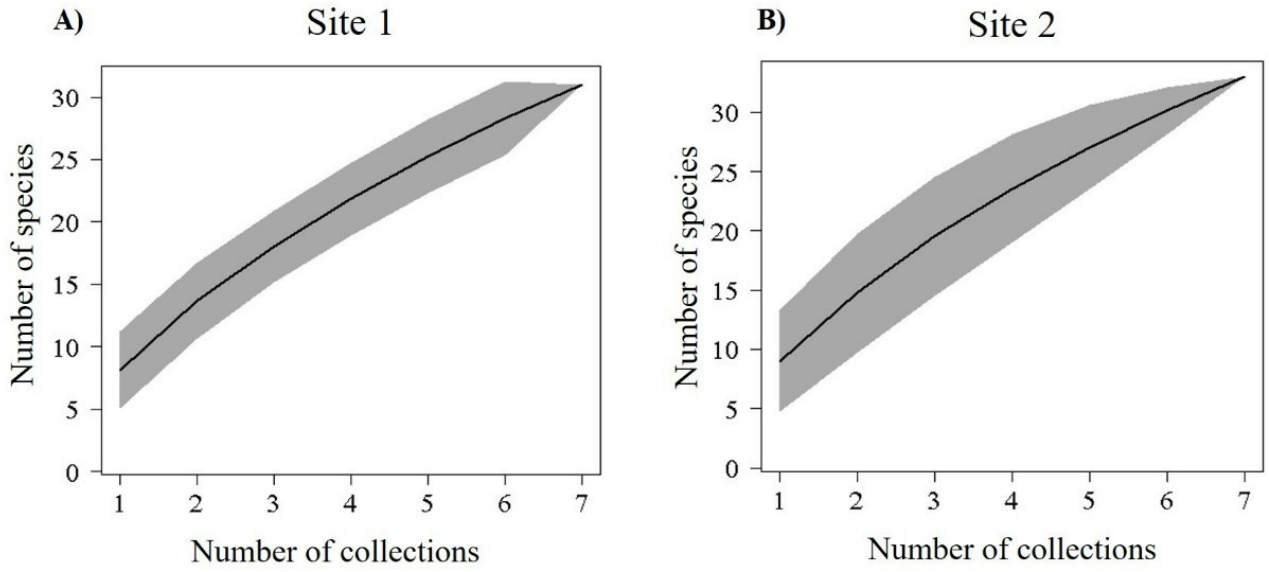

Figure 2 – Species accumulation curves (number of species × number of collections) of soil spiders sampled at two vegetation formations of the Cerrado biome in the Inhamum Environmental Protection Area, Caxias, Maranhão, Brazil, between October 2017 and April 2018. Site 1= Gallery forest; Site 2= Cerrado sensu stricto. Shaded areas represent 95% confidence intervals.
Source: Authors (2020).

3.3 Diversity and evenness indices

The study sites had similar Shannon–Wiener diversity indices (Site 1, H′ = 2.7; Site 2, H′ = 2.6) (Table 2). The values indicate moderate diversity in both gallery forest and Cerrado sensu stricto. These results were confirmed by Pielou's evenness indices (Site 1, J′ = 0.78; Site 2, J′ = 0.77) (Table 2). In theory, a 23% increase in the number of collected species would result in maximum diversity of the spider faunal community of these areas, according to Brower et al. (1998). This parameter represents the proportion of species that are equally distributed in the community. Therefore, both gallery forest and Cerrado sensu stricto sites showed moderate uniformity in the distribution of individuals among species, given that evenness is directly proportional to diversity.

Cunha et al. (2012), in analyzing the diversity values of soil araneofauna in the municipalities of Tutóia and Paulino Neves, Piauí, Brazil, observed that, although Tutóia had higher absolute plant density, higher number of plant species, and greater botanical diversity, spider diversity was greater in Paulino Neves (1.74 versus 1.85). Azevedo et al. (2017) observed

that the Shannon–Wiener index differed significantly according to sampling month, ranging from 1.0 to 2.5 between the analyzed sites.

Table 2 – Shannon–Wiener diversity (H') and Pielou's evenness (J') indices of soil spiders collected from two vegetation formations of the Cerrado biome in the Inhamum Environmental Protection Area, Caxias, Maranhão, Brazil, between October 2017 and April 2018.

Index	Site 1	Site 2
Shannon–Wiener diversity index (*H*′)	2.7	2.6
Confidence interval for *H*′ (*P* = 0.005)	2.66–2.70	2.66–2.69
Pielou's evenness index (*J*′)	0.78	0.77

Site 1= Gallery forest; Site 2= Cerrado sensu stricto.
Source: Authors (2020).

3.4 Faunal similarity dendrograma

Cluster analysis, which was based on the faunal similarity index of each sampling month (October 2017 to April 2018), showed that the araneofaunal composition of gallery forest and Cerrado sensu stricto sites were quite similar. Most species occurred at both sites (80–95% similarity). Only 35% of species occurring in the gallery forest were unique to this environment, and 37% of species recorded in Cerrado sensu stricto were exclusive to the site (SOARES et al., 2020). The analysis also revealed four functional groups. The first group showed similarity between species collected in March 2018 at Site 1 and February and March 2018 at Site 2, during the rainy season (Figure 3).

The second group revealed similarities between species collected in December 2017 and January to February 2018 at Site 1 and species obtained in January 2018 at Site 2, during transition from the dry to the rainy season. The third group was formed by similarities between species recorded from October to November 2017 at Site 1 and October to December 2017 at Site 2, during the dry period. The last cluster comprised species collected in April 2018 at Sites 1 and 2, during the rainy season (Figure 3).

In contrast to our findings, Carvalho & Avelino (2010) observed low similarity between four phytophysiognomies of the Cerrado biome in Piauí State. Only two fragments of dry semideciduous forests (primary and secondary) showed similarities of at least 20%, indicating the occurrence of species turnover among the sampled plant formations.

Dias et al. (2005) generated a similarity dendrogram for six forest environments in southern Bahia. Four groups were identified (95% similarity): (i) capoeira (secondary vegetation), (ii) cabruca (agroforestry system), (iii) continuous forest center, and (iv) forest fragment center, continuous forest edge, and forest fragment edge. The last three forest environments showed high similarity between each other.

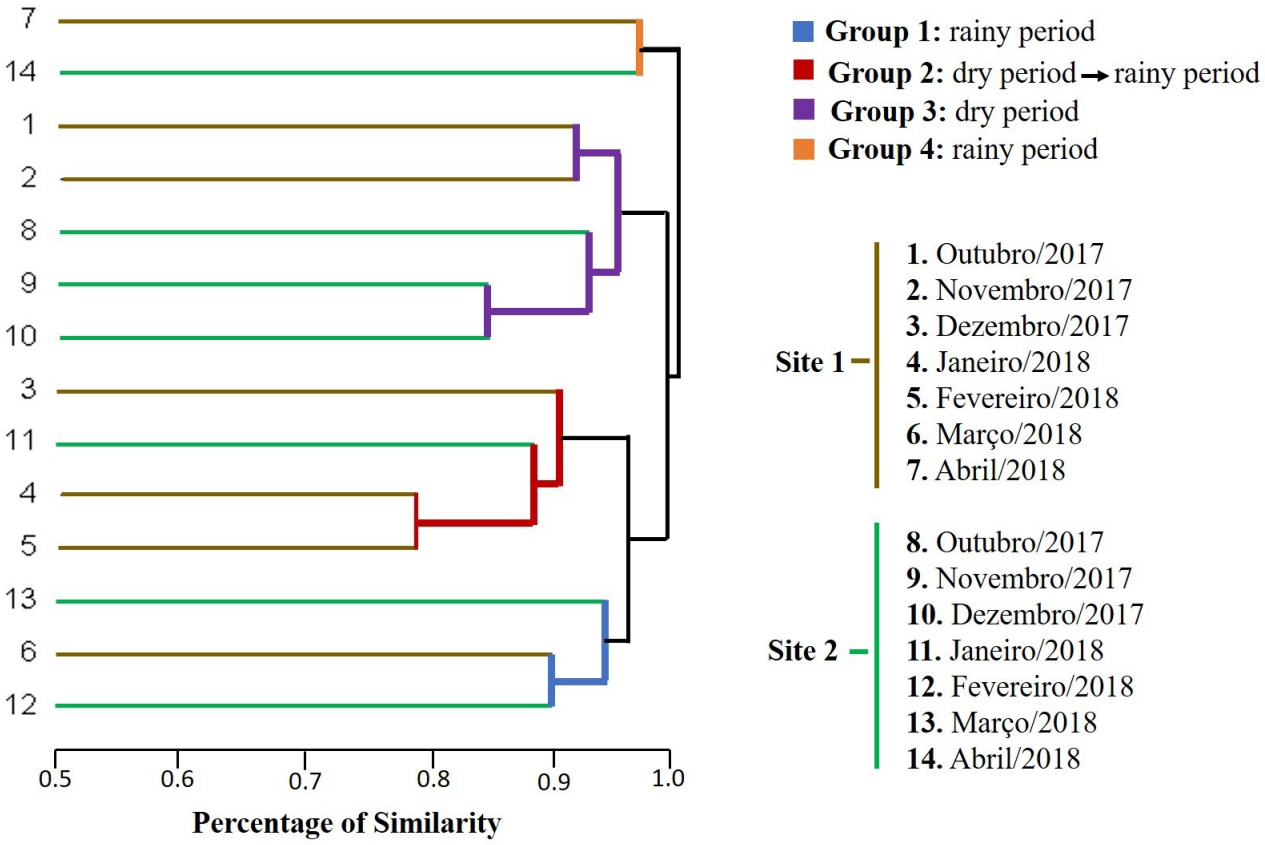

Figure 3 – Dendrogram constructed using Jaccard similarity indices between monthly araneofaunal compositions of Sites 1 (Gallery forest) and 2 (Cerrado sensu stricto) sampled in the Inhamum Environmental Protection Area, Caxias, Maranhão, Brazil, between October 2017 and April 2018.
Source: Authors (2020).

4. Final considerations

The results allowed us to infer that the two vegetation formations of the Cerrado biome (gallery forest and Cerrado sensu stricto) in the Inhamum EPA had moderate species diversity. More species can be sampled, which would result in an even higher richness. Spider communities were similar, with most species occurring at both sites.

Although richness estimators showed that the sampling effort was insufficient, we underscore the importance of the information obtained in this study, as a considerable species diversity was identified at both sites. Further research on the composition of soil spiders in these areas may contribute more effectively to the development of conservation strategies for araneofauna of the Cerrado biome in the Inhamum EPA, as well as in other localities of Maranhão State and northeastern Brazil, where studies on the dynamics and diversity of spiders, especially in the Cerrado biome, are still incipient.

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References

ALBUQUERQUE, A. Riacho Pontes e a Área de Proteção Ambiental Municipal do Inhamum, Caxias/MA. In: Barros, M.C. et al. (Org.). *Biodiversidade na Área de Proteção Ambiental do Inhamum*. São Luís: UEMA, 2012. p. 22-25.

AZEVEDO, R.; MENEZES, K. G.; BARBOSA, R. A.; MATOS, J. D. R.; MONTEIRO, J. O. N.; COUTINHO, A. G.; SALES, L. G. Aranhas epígeas de um fragmento de mata em área urbana em Fortaleza, Ceará, Brasil. *Research and Teaching in Exact and Natural Sciences*, v. 1 n. 2, 104-114, 2017.

BEGON, M.; HARPER, J. L.; TOWSEND, C. R. *Ecology individuals, populations and communities*. Oxford, Blackwell Science, 1996. 1068p.

BRESCOVIT, A. D.; OLIVEIRA, U.; Santos, A. J. Aranhas (Araneae, Arachnida) do Estado de São Paulo, Brasil: diversidade, esforço amostral e estado do conhecimento. *Biota Neotropica*, v. 11, n. 1, 717-747, 2011.

BROWER, J. E.; ZAR, J. H.; VAN ENDE, C. N. *Field and laboratory methods for general ecology*. 4 th New York, WCB/McGraw, 1998. 273p.

CARVALHO, L. S.; AVELINO, M. T. L. Composição e diversidade da fauna de aranhas (Arachnida, Araneae) da Fazenda Nazareth, Município de José de Freitas, Piauí, Brasil. *Biota Neotropica*, v. 10, n. 3, 1-11, 2010.

CODDINGTON, J. A.; YOUNG, L. H.; COYLE, F. A. Estimating spider species richness in a southern appalachian cove hardwood forest. *The Journal of Arachnology*, v. 24, n. 2, 111-128, 1996.

CODDINGTON, J. A.; AGNARSSON, I.; MILLER, J. A.; KUNTNER, M.; HORMIGA, G. Undersampling bias: the null hypothesis for singleton species in tropical arthropod surveys. *Journal of Animal Ecology*, v. 78, n. 3, 573-84, 2009.

CONCEIÇÃO, G. M.; da SILVA, D. S.; RODRIGUES, M. S. Aspectos florísticos e ecológicos da família convolvulaceae da área de proteção ambiental municipal do Inhamum, Caxias, Maranhão, Brasil. *Brazilian Geographical Journal*: Geosciences and Humanities research medium, v. 5, n. 2, 595-613, 2014.

CUNHA, J. A. S.; ARZABE, C.; CASTRO, A. A. J. F; BRESCOVIT, A. D. Diversidade preliminar de aranhas de solo em áreas de Cerrado Litorâneo com diferentes níveis de conservação, Maranhão, Brasil. *Revista Biociências*, v. 18, n., 5-13, 2012.

DIAS, M. F. R.; BRESCOVIT, A. D.; MENEZES, M. Aranhas de solo (Arachnida: Araneae) em diferentes fragmentos florestais no sul da Bahia, Brasil. *Biota Neotropical*, v. 5, n. 1, 1-10, 2005.

DRESCHER, M. S.; ELTZ, F. L. F.; ROVEDDER, A. P. M.; DORNELES, F. O. Mesofauna como bioindicador para avaliar a eficiência da revegetação com Lupinus albescens em solo arenizado do sudoeste do Rio Grande do Sul. *Anais*. In: XXXI Congresso Brasileiro de Ciência do Solo - SBCS, Gramado, 2007.

EFRON, B.; STEIN, C. The Jackknife estimate of variance. *The Annals of Statistics*, v. 9, n. 3, 586-596, 1981.

FERNANDES, P. A.; PESSÔA, V. L. S. O cerrado e suas atividades impactantes: uma leitura sobre o garimpo, a mineração e a agricultura mecanizada. Revista Eletrônica de Geografia, v. 3, n. 7, 19-37, 2011.

FORMIGA, L. D. A. da S.; OLIVEIRA, J.dos S.; GONÇALVES, M. V. P.; LIMA, F. O.; MARTINS, A. E. de S.; RODRIGUES, J. C.; SOARES, F. I. L; MOREIRA, J. O. Estudo da entomofauna de diptera em área de proteção ambiental no Maranhão, Brasil. *Revista de Geociências do Nordeste*, v. 6, n. 2, 258–265, 2022.

FORNAZIER, R.; GATIBONI, L. C.; WILDNER, L. P.; BIANZI, D.; TODERO, C. Modificações na fauna edáfica durante a decomposição da fitomassa de *Crotalariajuncea* L. *Anais*. In: XXXI Congresso Brasileiro de Ciência do Solo - SBCS, Gramado, 2007. p. 1-5.

GIRACCA, E. M. N.; ANTONIOLLI, Z. I.; ELTZ, F. L. F.; BENEDETTI, E.; LASTA, E.; VENTURINI, S. F.; VENTURINI, E. F.; BENEDETTI, T. Levantamento da meso e macrofauna do solo na microbacia do Arroio Lino, Agudo, RS. *Revista Brasileira Agrociência*, v. 9, n. 3, 257-261, 2003.

HUTCHESON, K. Um Teste para Comparar Diversidades Baseado na Fórmula de Shannon. *Journal of Theoretical Biology*, v. 29, n. 1, 151-154, 1970.

LAURANCE, W. F.; LOVEJOY, T. E.; VASCONCELOS, H. L.; BRUNA, E. M.; DIDHAM, R. K.; STOUFFER, P. C.; GASCON, C.; BIERREGAARD, R. O.; LAURANCE, S. G.; SAMPAIO, E. Ecosystem decay of Amazonian forest fragments: a 22-year investigation. *Conservation Biology*, v. 13, n. 3, 605-618, 2002.

LEITE, L. F. C.; FREITAS, R. C. A.; SAGRILO, E.; GALVÃO, S. R. S. Decomposição e liberação de nutrientes de resíduos vegetais depositados sobre Latossolo Amarelo no Cerrado Maranhense. *Revista Ciência Agronômica*, v. 41, n. 1, 29-35, 2010.

MAGURRAN, A. E. *Ecological diversity and its measurement*. New Jersey, Princeton University Press, 1988. 179p.

MARTINS, A. E. de S.; da SILVA, M. J. R.; RODRIGUES, J. C.; SILVA, M. R. de A. C.; GONÇALVES, M. V. P.; FORMIGA, L. D. A. da S.; FRANCO, C. L. Levantamento da Mirmecofauna em Fragmentos de uma Área de Proteção Ambiental em Caxias, Maranhão- Brasil. *Revista de Geociências do Nordeste*, v. 8, n. 1, 188–197, 2022.

MINISTÉRIO DO MEIO AMBIENTE (MMA). 2002. *Bioma Cerrado*. Disponível: https://www.gov.br/mma/pt-br/search?SearchableText=biomo%20cerrado%20hotspots. Acesso: 15/07/2022.

MORAES, V. S. 2014. *Efeitos da estrutura da vegetação na composição da assembleia de aranhas (Arachnida: Araneae) em estrato arbóreo de diferentes fitofisionomias do Cerrado*. Brasília, 2014. 58f. Dissertação (Mestrado em Ecologia). Programa de Pós-Graduação em Ecologia, Universidade de Brasília, Brasília-DF, 2014.

MORAES, R. C. B.; HADDAD, M. L.; SILVEIRA NETO, S.; REYES, A. E. L. *Software para análise faunística* - ANAFAU. Livros de resumos. In: Simpósio de Controle Biológico, 8, São Pedro - SP. Piracicaba: ESALQ/USP, 2003. p. 195.

MUELLER-DOMBOIS, D.; ELLEMBERG, H. *Aims and methods of vegetation ecology*. New York, Jonh Wiley Sons, 1974. 547p.

NERES, L. P.; CONCEIÇÃO, G. M. Florística e fitossociologia da área de proteção ambiental municipal do Inhamum, Caxias, Maranhão, Brasil. *Cadernos de Geociências*, v. 7, n. 2, 122-130, 2010.

OLIVEIRA, U. *Diversidade e biogeografia de aranhas do Brasil*: esforço amostral, riqueza potencial e áreas de endemismo. Belo Horizonte, 2011. 105f. Dissertação (Mestrado em Ecologia). Programa de Pós-Graduação em Ecologia, Conservação e Manejo da Vida Silvestre, Universidade Federal de Minas Gerais, Belo Horizonte – MG, 2011.

OLIVEIRA, U.; BRESCOVIT, A. D.; SANTOS, A. J. Sampling effort and species richness assessment: a case study on Brazilian spiders. *Biodiversity and Conservation*, v. 26, n. 6, 1481-1493, 2017.

PEREIRA, A. B. S.; VENTUROLI, F.; CARVALHO, F. A. Florestas estacionais no cerrado: uma visão geral. *Pesquisa Agropecuária Tropical*, v. 41, n. 3; 446-455, 2011.

RODRIGUES, V. E. O. *Riqueza e composição de aranhas (Arachnida: Araneae) em fragmentos florestais urbanos de Salvador*. Salvador, 2020. 35f. Graduação (Bacharel em Ciências Biológicas). Curso de Ciências Biológicas (Bacharelado), Universidade Católica do Salvador, Salvador – BA, 2017.

R CORE TEAM. 2017. *A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna. Disponível: https://www.R-project.org. Acesso: 22/05/2019.

ROCHA, L. M. *Fauna de aranhas edáficas (Arachnida: Araneae) em um fragmento periurbano em ambiente de Mata Atlântica no Sul do Brasil*. Criciúma, 2017. 28f. Graduação (Bacharel em Ciências Biológicas). Universidade do Extremo Sul Catarinense - UNESC, Criciúma – SC, 2017.

RODRIGUES, J. C.; MARTINS, A. E. de S.; LIMA, F. O.; SOUZA, M. T. A.; SILVA, M. R. de A. C.; SOARES, F. I. L.; FORMIGA, L. D. A. da S. Levantamento da mesofauna edáfica em áreas de proteção do Maranhão. *Revista de Geociências do Nordeste*, v. 7, n. 2, 230–238, 2022.

SANTANA, R. C. Community structure and composition of litter spiders (Arachnida: Araneae) and influence of macro-climatic factors on Parque Ecológico Jatobá Centenário, Morrinhos, Goiás, Brazil. *Journal of Threatened Taxa*, v. 7, n. 10, 7612-7624, 2015.

SANTOS, A. J. Estimativas de Riqueza em Espécies. In: Cullen Jr., L.; Rudran R. & Valladares-Pádua, C. (orgs.). *Métodos de Estudos em Biologia da Conservação e Manejo da Vida Silvestre*. Curitiba, Editora da UFPR - Fundação O Boticário de Proteção à Natureza, 2003. p. 19-41.

SILVA, D. R. de O. *Estimativa de riqueza de macroinvertebrados bentônicos e a relação da composição de comunidades com componentes de meso-habitat em riachos de cabeceira no cerrado*. Belo Horizonte, 2012. 65f. Dissertação (Mestrado em Ecologia). Programa de Pós-Graduação em Ecologia, Conservação e Manejo da Vida Silvestre, Universidade Federal de Minas Gerais, Belo Horizonte – MG, 2012.

SILVA, G.; SILVA, D. L.; SILVA, M. L.; SILVA, W. F.; CONCEIÇÃO, G. Trilhas ecológicas da área de proteção ambiental municipal do Inhamum e seus aspectos florísticos, Maranhão, Brasil. *Revista Agrária Acadêmica*, v. 3, n. 6, 86-98, 2016.

SNEATH, P. H.; SOKAL, R. R. *Numerical taxonomy the principles and practice of numerical classification*. San Francisco: W.H. Freeman, 1973. 573p.

SOARES, F. I. L.; SOARES, L. A. da L.; REIS, L. da L. dos; MARTINS, A. E. de S.; RODRIGUES, J. C.; BRESCOVIT, A. D.; FORMIGA, L. D. A. da S. Estudo da composição e abundância de aranhas (Arachnida: Araneae) de solo em duas fitofisionomias do Cerrado, Maranhão, Brasil. *Revista de Geociências do Nordeste*, v. 6, n. 2, 95–105, 2020.

SOUZA, M. M. O.; LEÃO, A.V.; SOUZA, J. D. Agrotóxicos no cerrado: impactos socioambientais e resistência popular. *Revista de Geografia da UEG*, v. 9, n. 2, 1-22, 2020.

ZAR, J. H. *Biostatiscal Analysis*. 2. ed. New Jersey, Prentice Hall, 1984. 718p.