



Litter arthropod communities in a Northeastern Cerrado area of Maranhão state, Brazil

Comunidades de artrópodes da serapilheira em uma área de Cerrado do nordeste do estado do Maranhão, Brasil

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The litter layer of forest ecosystems harbors a diverse community of terrestrial arthropods, which are notable for playing fundamental roles in ecological processes. In this study, our objective was to identify arthropod families and assess the occurrence of seasonality in arthropod communities within the litter environment of three Cerrado phytophysionomies in Northeast Brazil. The studies were conducted over twelve months in Chapadinha municipality, MA. Arthropods were sampled across three phytophysionomies: I - Clean Cerrado field, II - Shrubland Cerrado with recent deforestation history, and III - Typical Cerrado. Ninety pitfall traps were deployed, grouped into sets of 30 for each sampled environment along a linear transect of 300 meters. A total of 5.573 arthropods were collected across the three study areas, distributed among 19 orders, one infraorder, and 62 families. The arthropod community exhibited significant differences among the different seasonal periods analyzed. However, there was no significant difference in arthropod composition among the three Cerrado areas sampled. There was greater arthropod diversity during the transition from dry to rainy periods. The Typical Cerrado showed higher arthropod abundance, however, the Clean Cerrado exhibited greater diversity in arthropod composition. Cerrado with recent deforestation history demonstrated the lowest arthropod abundance and diversity. These results demonstrate the importance of seasonality for arthropod communities in different habitats, emphasizing the significance of Cerrado preservation to maintain the composition of arthropods in the soil. Key words: arthropod fauna, diversity, seasonality.

A serapilheira dos ecossistemas florestais abriga uma grande diversidade de artrópodes terrestres, que se destacam por desempenharem papéis fundamentais nos processos ecológicos. No presente estudo, objetivamos identificar famílias de artrópodes e verificar a ocorrência de sazonalidade em comunidades de artrópodes no ambiente de serapilheira de três fitofisionomias de Cerrado no Nordeste do Brasil. Os estudos foram realizados durante doze meses no município de Chapadinha - MA. Os artrópodes foram amostrados em três fitofisionomias compreendendo: I- Campo Limpo de Cerrado, II- Cerrado arbustivo com histórico recente de desmatamento e III- Cerrado Típico. Foram implantadas 90 armadilhas de queda, agrupadas em conjuntos de 30 para cada ambiente amostrado ao longo de um transecto linear de 300 metros. Um total de 5.573 artrópodes foram coletados nas três áreas de estudo, distribuídos em 19 ordens, uma infraordem e 62 famílias. A comunidade de artrópodes apresentou diferenças significativas entre os diferentes períodos sazonais analisados. No entanto, não houve diferença significativa na composição de artrópodes nas três áreas de Cerrado amostradas. Houve uma maior diversidade de artrópodes na transição do período seco para chuvoso. O Cerrado típico apresentou maior abundância de artrópodes, entretanto, o Campo limpo de Cerrado exibiu maior diversidade na composição da artropodofauna. O Cerrado com histórico recente de desmatamento demonstrou a menor abundância e diversidade de artrópodes. Esses resultados demonstram a importância da sazonalidade para a comunidade de artrópodes em diferentes habitats, além de ressaltar a importância da preservação do Cerrado para manter a composição de artrópodes no solo.

Palavras-Chave: artropodofauna, diversidade, sazonalidade.

1. INTRODUCTION

Arthropods comprise more than 1.2 million recorded species, with probably an equal number still unidentified [1]. Their enormous adaptive capacity has allowed them to thrive in virtually all environments, making them the most successful animals in colonizing terrestrial habitats [2]. Arthropods are widely distributed across different habitats, particularly in soil.

Soil harbors a great diversity of organisms exhibiting a vast array of sizes, shapes, and metabolic processes [3]. These organisms can be categorized as microbiota, mesobiota, and macrobiota based on body size [4]. Mesofauna includes mites, springtails, myriapods, other arachnids, and various orders of insects, while macrofauna includes beetles and certain species of oligochaetes, millipedes, and centipedes [5].

Soil arthropods are ecologically significant, regulating microbial communities, facilitating decomposition of plant material, modifying soil structure through excavation activities, and contributing to nutrient cycling and litter and soil quality modification [5]. According to Bezerra and de Matos Andrade (2021) [6], arthropods play pivotal roles in humification processes, agricultural system regulation, organic material decomposition, soil aggregation, and structuring, among other critical functions in terrestrial ecosystems. Consequently, they directly impact primary productivity and the physical, chemical, and biological properties of soil [2].

Litter constitutes the uppermost layer of soil in forest environments, comprising dry leaves, branches, flowers, fruits, and to a lesser extent, animal remains and fecal material [7]. Martins et al. (2018) [8] suggest that litter is the primary pathway for nutrient transfer to the soil, serving numerous ecosystem functions such as reducing erosion by enhancing soil water retention.

The litter environment hosts a rich fauna compared to other substrates, primarily composed of organisms belonging to the phylum Arthropoda. According to Correia (2002) [9], the number of arthropods in the soil and litter is generally five times greater than that found in the treetops of a forest.

Arthropod fauna plays a crucial role in organic matter degradation and nutrient cycling, primarily responsible for litter fragmentation. These organisms also serve as food for other arthropod species and terrestrial vertebrates [10]. Menta and Romeli (2020) [2] suggest that arthropods are among the principal bioindicators of environmental changes due to their high sensitivity to anthropogenic or natural alterations.

The composition and structure of arthropod communities in litter are influenced by several factors, including plant formation type, soil type, local climate, and microhabitat diversity [11]. These factors directly impact the decomposition process, affecting nutrient release from litter and influencing tree litter production rates [12].

Arthropods represent a highly diverse and abundant phylum, requiring significant sampling efforts and increased research focus on taxonomic and ecological studies for characterization and understanding. Thus, this study identified arthropod families occurring in the litter environment of three Cerrado phytophysionomies in Northeast Brazil and assessed seasonal variations in the analyzed soil arthropod community.

2. MATERIAL AND METHODS

2.1 Study Area

The studies were conducted for twelve months in an area of Cerrado in the Municipality of Chapadinha - MA (3°44'31"S and 43°21'36" W) (Figure 1).

The study area is situated at approximately 100 meters above sea level and falls within the B1WA'a'hot and sub-humid tropical climate classification, as defined by Thornthwaite (1948) [13], characterized by an annual average temperature ranging from 28°C to 30°C and average annual rainfall between 1600 mm and 2000 mm. Rainfall is concentrated in the first half of the year, defining a rainy season from January to June and a dry season from July to December [14].

The predominant vegetation in the region is classified as savanna (Cerrado *sensu stricto*) with remnants of cerradão - a closed forest formation with trees reaching heights of more than 10 meters [15]. The prevailing soil orders are Oxisols, Argisols, Neosols, and Plinthosols [16].

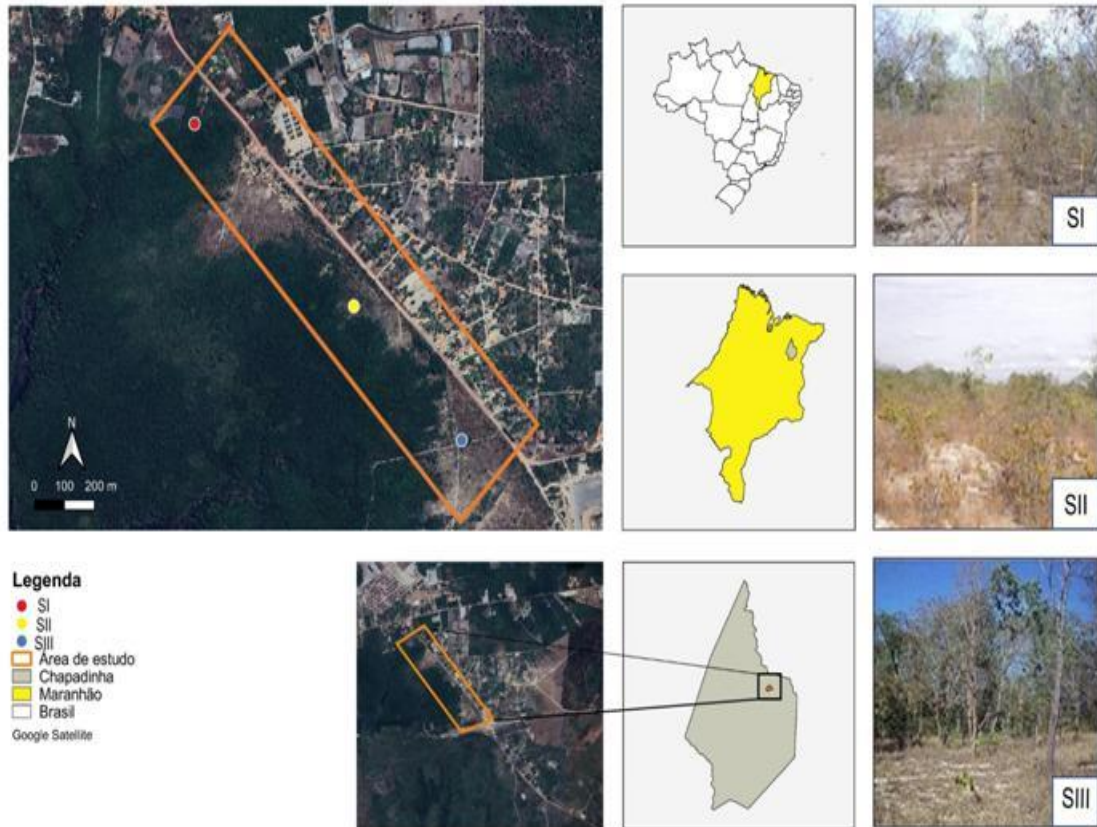


Figure 1: Study area and arthropod sampling environments in an area of Cerrado in the Northeast of the State of Maranhão. SI: Clean Cerrado field; SII: Shrubby Cerrado with a recent history of deforestation; SIII: Typical Cerrado.

Arthropods were sampled in three Cerrado physiognomies in the municipality of Chapadinha-MA, which include: Site I - Clean Cerrado field, Site II - Shrubby Cerrado with a recent history of deforestation, and Site III - Typical Cerrado (Figure 1). The separation of environments was based on woodland structure, utilizing phytosociological data and the Brazilian vegetation classification manual [16]. Further details regarding phytosociological parameters and the dry mass of litter produced by plant species are presented in (Table 1).

Table 1: Phytosociological parameters and litter dry mass produced by the most frequent plant species in Site I (Cerrado clean field), Site II (shrubby Cerrado with a recent history of deforestation) and Site III (Typical Cerrado) in the Northeast of the State of Maranhão.

Site I		Site II		Site III	
Species	FR (%)	Species	FR (%)	Species	FR (%)
<i>Anacardium humile</i>	7.14	<i>Bowdichia virgilioides</i>	3.70	<i>Anacardium humile</i>	5.00
<i>Hirtella glandulosa</i>	2.38	<i>Copaifera martii</i>	18.52	<i>Bowdichia virgilioides</i>	5.00
<i>Bowdichia virgilioides</i>	7.14	<i>Dimorphandra mollis</i>	3.70	<i>Copaifera martii</i>	2.50
<i>Copaifera martii</i>	9.52	<i>Ouratea spectabilis</i>	14.81	<i>Himatanthus drasticus</i>	5.00
<i>Dimorphandra mollis</i>	14.29	<i>Qualea parviflora</i>	22.22	<i>Parkia platycephala</i>	5.00
<i>Ouratea spectabilis</i>	7.14	<i>Sclerolobium paniculatum</i>	7.41	<i>Platonia insignis</i>	5.00
<i>Qualea parviflora</i>	4.76	<i>Stryphnodendron coriacium</i>	14.81	<i>Qualea parviflora</i>	5.00
<i>Sclerolobium paniculatum</i>	9.52	<i>Vatairea macrocarpa</i>	14.81	<i>Sclerolobium paniculatum</i>	5.00
<i>Stryphnodendron coriacium</i>	2.38			<i>Stryphnodendron coriaceum</i>	2.50
<i>Vatairea macrocarpa</i>	7.14			<i>Vatairea macrocarpa</i>	5.00
Average height (m)	3.70	3.36		9.47	
Average diameter (cm)	8.30	7.81		5.20	
Litter (kg.ha⁻¹)	3.080	1.436		6.430	

2.2 Sampling of arthropods

The collection of arthropods was conducted during key months representing transitions and peaks of the climatic seasons: January (transition from dry to rainy season), April (rainy season), July (transition from rainy season to dry season), and October (dry period), under license SISBIO N° 22178-2. Ninety pitfall traps were deployed, grouped in sets of 30 for each sampled environment along a linear transect spanning 300 meters. The traps were spaced 10 meters apart to ensure adequate coverage. To prevent escape and decomposition of captured specimens, each trap was baited with a preservative solution containing 70% ethanol and 30% formaldehyde.

The traps were checked weekly during the transitional and peak months of the dry and rainy seasons. Specimens collected were carefully labeled, stored in plastic bottles, and transported to the laboratory for sorting and identification of arthropods down to the family level using illustrated identification keys [17, 18].

2.3 Data analysis

The abundance data from each sampling site (I, II, and III) and seasonal periods were subjected to the Shapiro-Wilk normality test. Normality was not detected for any of the treatments.

To analyze the diversity of arthropod fauna across different seasons and locations, Shannon-Wiener diversity indices (H'), Simpson's Dominance (D), Evenness (J), and Brioulin, among others, were calculated. The significance of the obtained Shannon and Simpson diversity index values for different collection periods and locations was compared using Hutcheson's t-test [19] at a significance level of 5% ($p < 0.05$).

To assess whether the composition of arthropod families varies between seasons and sampled locations, Permutational Multivariate Analysis of Variance (PERMANOVA) based on the Bray-Curtis dissimilarity matrix was employed. To assess the multivariate characteristics of arthropod orders across sampled periods and locations, a Principal Component Analysis (PCA) was conducted using the PRINCOMP procedure, and a biplot was prepared using the PRINQUAL procedure in the Statistical Analysis System [20].

The Indicator Value Index (IndVal) was used to indicate which families were associated with each of the different locations and seasonal periods studied. Ecological index analyses were performed using Past.4.16 software [21].

3. RESULTS AND DISCUSSION

3.1 Arthropod families sampled in different phytophysiognomies and seasonal periods

A total of 5573 arthropods were collected in the three study areas, distributed in 19 orders, one infraorder and 62 families (Table 2).

The order Hymenoptera was the most abundant, representing 77.3% of all collected arthropods. Studies by Zardo et al. (2010) [22] and Lara-Pérez et al. (2023) [23] also found this same pattern. This result was anticipated, as these arthropods are commonly found in all terrestrial ecosystems [24]. The suborder Isoptera also had a high number of individuals collected (4.5%), with 250 individuals distributed across three families: Termitidae, Rhinotermitidae, and Kalotermitidae (Table 2). In Caatinga areas, this order also showed high abundance, followed by the order Hymenoptera [25]. The dry season and the transition from dry to rainy season had the highest number of termites, with 50% of individuals collected during the dry season and 43.6% during the transition.

Table 2: Litter arthropods in three sample sites located in the municipality of Chapadinha - MA.

Order	Family	SITE I				SITE II				SITE III			
		D	DR	R	RD	D	DR	R	RD	D	DR	R	D
Araneae	Actinopodidae	0	0	0	0	0	1	0	0	0	3	0	0
	Amaurobiidae	8	0	0	0	0	0	0	0	0	0	0	0
	Amphinectidae	0	2	0	0	0	0	0	0	0	2	0	0
	Anapidae	0	0	0	0	0	0	0	0	1	2	0	0
	Corinnidae	0	0	0	0	0	0	0	0	0	1	0	0
	Ctenidae	1	1	2	4	4	0	1	1	5	4	3	9
	Diguetidae	0	0	0	0	1	0	0	0	0	0	0	0
	Dipluridae	0	1	0	2	0	0	1	3	0	0	1	4
	Hersiliidae	1	0	0	0	0	0	0	0	0	0	0	0
	Idiopidae	0	0	1	0	0	0	0	0	0	0	0	2
	Lycosidae	0	0	0	3	0	0	4	1	0	0	2	2
	Lyniphidae	6	0	0	0	0	0	0	0	0	0	0	0
	Oecobidae	0	0	0	0	0	0	1	0	1	0	0	0
	Pholcidae	1	2	3	0	23	0	7	2	0	1	2	0
	Pisauridae	0	0	0	0	0	0	0	0	1	0	0	0
	Salticidae	3	8	7	5	8	1	7	3	3	6	7	1
	Symphytognathidae	0	0	0	0	0	0	0	0	1	0	0	0
	Tetragnathidae	2	0	0	0	0	0	0	0	0	0	0	0
	Theraphosidae	0	1	3	0	0	0	2	0	0	1	5	0
	Theridiidae	1	0	0	0	3	0	0	0	0	0	0	0
Titanoecidae	0	0	0	0	0	0	0	0	1	2	0	1	
Trochanteridae	0	0	0	0	1	0	0	0	0	0	0	0	
Uloboridae	19	6	8	20	5	3	10	4	71	16	7	11	
Blattaria	Blattidae	7	2	1	17	1	0	0	3	19	9	10	46
Collembola	Entomobryidae	0	0	2	0	0	0	0	0	0	0	0	1
Coleoptera	Carabidae	4	27	7	6	5	13	3	3	0	6	2	4
	Cicindelidae	0	21	0	0	0	10	0	0	0	20	0	0
	Curculionidae	0	1	2	0	0	0	0	1	6	3	3	2
	Scarabaeidae	0	72	0	0	0	13	3	0	0	146	0	0
Diptera	Asilidae	0	2	0	0	0	1	0	0	0	2	0	0
	Fanniidae	0	44	0	0	0	8	0	0	0	13	0	0
	Muscidae	0	11	0	0	0	18	10	0	0	60	23	1
	Sarcophagidae	0	0	0	0	0	0	0	0	0	4	0	0
Scorpioniones	Bothriuridae	0	0	0	0	0	0	0	0	0	1	1	0
	Buthidae	5	1	0	2	0	0	0	0	11	1	0	1
Hemiptera	Coreidae	0	0	2	0	0	0	1	0	0	0	2	2
	Reduviidae	0	0	0	1	0	0	0	2	0	0	0	1
	Rhyparochromidae	0	0	0	0	0	1	0	0	0	0	0	0
	Cicadellidae	0	0	1	1	0	0	0	0	0	6	1	3

(continued)

Table 2: (continued)

Order	Family	SITE I				SITE II				SITE III			
		D	DR	R	RD	D	DR	R	RD	D	DR	R	D
Hymenoptera													
	Cynipidae	0	0	0	0	3	0	0	0	0	0	0	0
	Diapriidae	0	0	0	0	0	2	0	0	0	0	0	0
	Formicidae	642	89	117	215	438	82	212	202	937	203	203	500
	Pompilidae	0	1	0	0	0	0	0	0	0	0	0	0
	Sphecidae	0	0	0	0	0	0	0	0	0	0	1	0
	Tenthredinidae	0	0	0	5	0	0	0	0	0	1	0	1
	Vespidae	0	1	0	0	0	2	2	1	0	0	0	2
Isoptera*													
	Kalotermitidae	0	4	4	0	2	0	3	0	8	1	0	0
	Rhinotermitidae	21	0	0	0	11	0	2	2	0	0	0	0
	Termitidae	56	4	1	1	16	1	1	1	11	99	1	0
Isopoda													
	Armadillidiidae	0	0	0	0	0	0	0	0	0	1	0	0
Julida													
	Julidae	0	2	0	0	1	0	0	0	4	27	0	0
Lepidoptera													
	Noctuidae	0	2	0	0	0	0	0	0	0	13	0	0
	Pyalidae	0	0	0	0	0	2	0	0	0	0	0	0
	Saturniidae	0	1	0	0	0	0	0	0	0	1	0	0
Mantodea													
	Mantidae	0	0	3	1	2	1	0	1	1	0	2	0
Neuroptera													
	Myrmeleontidae	0	0	0	0	0	0	0	0	0	0	0	2
Opilionida													
	Opilionida**	19	1	3	5	0	1	0	1	1	1	10	2
Orthoptera													
	Acrididae	0	0	3	1	4	2	1	1	1	0	0	0
	Gryllidae	0	16	26	5	1	1	6	4	17	36	62	14
Phasmida													
	Phasmidae	0	0	0	0	1	0	0	1	0	0	0	0
Pseudoscorpionida													
	Cheiridiidae	0	0	0	1	0	0	0	0	0	0	0	0
Thysanura													
	Machilidae	0	0	1	0	0	0	0	0	0	0	0	0
	Projapygidae	0	0	1	0	0	0	0	0	0	0	1	0
Total		796	323	198	295	530	163	277	237	1100	692	349	612

Notes: D= Dry period (October); DR= Transition dry/rainy period (January); R= Rainy period (April); RD=Transition rainy/dry period (July). *Isoptera is an infraorder. **Opilionida identified only at order level.

Some arthropods, like Diptera and Lepidoptera, were only occasionally collected in this study, as pitfall traps are not suitable for these orders. Other traps, such as malaise traps or light traps, are more appropriate for collecting these arthropods [26]. The order Lepidoptera had 19 individuals distributed across three families: Noctuidae, Pyralidae, and Saturniidae. The family Noctuidae was the most abundant, with 15 individuals, followed by Pyralidae and Saturniidae,

each with 2 individuals. All Lepidoptera families were found only during the transition from dry to rainy season (Table 2). Meanwhile, 197 individuals of the order Diptera were sampled across four families. The family Muscidae was the most abundant, with 123 individuals, accounting for 62.43% of the total flies collected. The other families were Fanniidae, Asilidae, and Sarcophagidae, comprising 65.5%, 30.5%, and 4% of the collected individuals, respectively (Table 2).

3.2 The diversity of arthropod orders in different phytophysionomies and seasonal periods

The results of diversity indices indicated that site I exhibited higher diversity ($H' = 1.67$) compared to sites 02 ($H' = 1.24$) and 03 ($H' = 1.55$). The higher diversity at site I supports the statement by Silva and Siqueira (2022) [27] that the most abundant area is not necessarily the most diverse, as diversity depends on other factors such as microclimate, food resource availability, [28] and vegetation type [29]. A greater diversity of habitats with signs of deforestation compared to preserved Cerrado environments was also found by Silva et al. (2019) [25]. Site II showed higher relative dominance ($D = 0.60$), while site I exhibited higher evenness (44%) compared to the other sites (Site II = 34% and Site III = 40%) (Table 3).

The transition period from dry to rainy season showed moderately high diversity ($H' = 2.35$) compared to other periods: rainy ($H' = 1.58$), transition from rainy to dry ($H' = 1.01$), and dry period, which exhibited the lowest diversity of arthropod orders ($H' = 0.89$). Similar results were found by Buskirk and Buskirk (1976) [30], who observed higher arthropod diversity at the end of the dry season and beginning of the rainy season, and lower diversity during the dry season. Lana-Pérez et al. (2023) [23] also found higher arthropod diversity in the early months of the rainy season, a pattern also observed in studies by Razo-González et al. (2014) [31]. This is likely due to the fact that the first rains of the transition period from dry to rainy season act as a trigger for the return of many arthropod types, thereby increasing their composition and diversity [32]. Lana-Pérez (2023) [23] relates the statistical differences found between drier and rainy periods to the high abundance of certain orders such as Hymenoptera, Orthoptera, and Araneae found more abundantly in the rainy season, as observed in this study.

The dry period exhibited the highest value of species relative dominance ($D = 0.69$), while the transition from rainy to dry had the lowest dominance values ($D = 0.16$). Consequently, evenness during the dry period was the highest (64%) compared to the other collection periods (Table 3). Seasonal changes, slight temperature variations between seasonal periods, and resource availability are associated with changes in arthropod species abundance, richness, and composition [33].

Table 3: Diversity indices of arthropod families in different climatic periods and collection sites in areas of the Cerrado in the Northeast of Maranhão.

	D	DR	R	RD	Site I	Site II	Site III
Families	31	40	30	29	44	37	47
Individuals	2.426	1.178	824	1.144	1.612	1.207	2.753
Dominance_D	0.6945	0.1622	0.4337	0.6475	0.4427	0.6017	0.4584
Simpson_1-D	0.3055	0.8378	0.5663	0.3525	0.5573	0.3983	0.5416
Shannon_H	0.8956	2.353	1.576	1.016	1.668	1.24	1.551
Evenness_e ^{H/S}	0.079	0.263	0.1612	0.09525	0.1204	0.0934	0.1004
Brillouin	0.8674	2.278	1.498	0.964	1.608	1.176	1.513
Menhinick	0.6294	1.165	1.045	0.8574	1.096	1.065	0.8958
Margalef	3.849	5.515	4.319	3.976	5.822	5.073	5.808
Equitability_J	0.2608	0.638	0.4634	0.3017	0.4407	0.3434	0.4029
Fisher_alpha	5.013	8002	6.107	5.412	8.353	7.219	8.051
Berger-Parker	0.8314	0.3175	0.6456	0.8016	0.6594	0.7738	0.6695

The Shannon and Simpson diversity index values for each period and location analyzed, although very close, showed differences in diversity. Diversity values for the dry period (D) were statistically different from the transition from dry to rainy (DR) and rainy (R) periods. The transition from dry to rainy (DR) period showed statistical differences from the rainy (R) period and the transition from rainy to dry (RD). Additionally, the rainy (R) period also exhibited significant differences in diversity compared to the transition from rainy to dry (RD) (Table 4).

The collection sites also showed statistical differences in their diversities. Site I exhibited statistical differences in diversity compared to site II. Site II showed significant differences in diversity compared to sites 01 and 03 (Table 4).

*Table 4: Significance of the t-test ($p < 0.05$) for the Shannon (H') and Simpson (D) diversity indices between collections of arthropod families carried out in different periods and locations in the Cerrado of Northeast Brazil. Where *s* is significant and *ns* is not significant, according to Bonferroni ranking.*

Period	H'	D	D	DR	R	RD
D	0.89	0.30		s	s	ns
DR	2.35	0.84			s	s
R	1.57	0.57				s
RD	1.02	0.35				
Area	H'	D'	Site I	Site II	Site III	
Site I	1.67	0.56		s	ns	
Site II	1.24	0.39			s	
Site III	1.55	0.54				

3.3 The composition of orders in different phytophysiognomies and seasonal periods

PERMANOVA results indicated statistically significant differences in arthropod family abundance across different climatic periods ($F = 4.21$; $p = 0.001$; Figure 2). Seasonal changes in arthropod composition were also observed in other studies, such as Majeed et al. (2020) [34] and Stanford and Huntly (2010) [35]. Arthropod diversity was highest during the transition from the dry season to the rainy season at all collection sites and lowest during the dry season (Figure 2). Carvalho et al. (2015) [32] explained that this is because the first rains after the dry season trigger the reactivation of many arthropods. There was no statistical difference in arthropod family abundance between sites I, II, and III ($F = 0.81$; $p = 0.55$; Figure 3).

Coleoptera, Diptera, Isopoda, Julida, and Lepidoptera were the orders that contributed the most to the formation of the first component, explaining about 44% of the multivariate data. Collembola, Scorpiones, Hemiptera, and Isoptera were the orders that most influenced the formation of the second component, explaining 31.6% of the data. PCA explained about 76% of the variance and covariance in arthropod order incidence across the different climatic periods studied (Figure 2).

Principal Component Analysis (PCA) indicated that the dry season (D) was characterized by a high incidence of arthropods from the orders Scorpiones, Araneae, Hymenoptera, Opiliones, and Phasmida, and a low incidence of Orthoptera. The order Hymenoptera showed a high number of individuals during the dry season, primarily due to the family Formicidae, which, according to Hölldobler and Wilson (1990) [36], thrives in warm climates and increases in abundance during the dry season when there are more microhabitats with high temperatures for these ants. In Cerrado and Gallery Forest areas, Zardo et al. (2010) [37] also found that Hymenoptera was the most abundant order across all collection sites.

The order Araneae also exhibited high family abundance during the dry season. According to Varjão et al. (2010) [38], this increase in spider richness is due to the greater presence of leaves in the litter layer; the increase in leaf abundance provides greater heterogeneity in litter microhabitat, creating thermally comfortable environments for spiders during the dry season, preventing water loss for these arachnids. Spaces between leaves, the basal leaf surface, and openings between them provide foraging sites for spiders, as well as protection against intense light, which affects their behavior, forcing them to inhabit new areas [38]. Studies by Zagrafou et al. (2017) [28] in forest and pasture areas also found a higher number of spiders at the beginning of the dry season. Spider richness is likely related to their breeding period, during which most spider groups, especially those with short life cycles, concentrate their reproductive events in warmer regions and periods where food availability is higher for these animals [39].

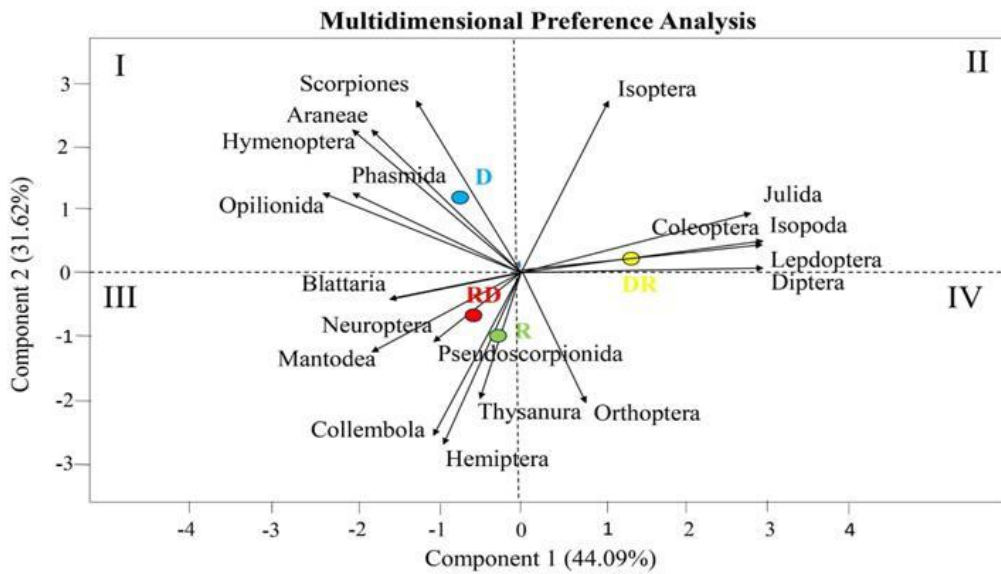


Figure 2: Biplot graph of principal component analysis for arthropod orders in different climatic periods. D- dry period. DR - Transition dry/rainy period. A - Rainy period. RD - Transition rainy/dry period.

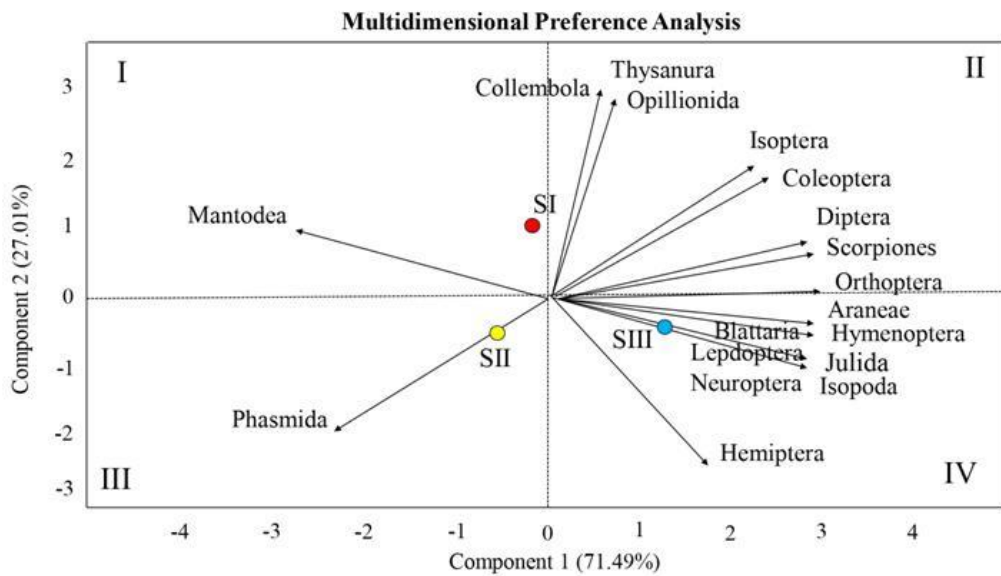


Figure 3: Biplot graph of principal component analysis for arthropod orders at different collection sites. Site I – Cerrado clean field. Site II- Shrubby Cerrado with a recent history of deforestation. Site III- Typical Cerrado.

The rainy season (R) and the transition from rainy to dry season (RD) exhibited more similar multivariate characteristics and were characterized by a high incidence of omnivorous orders such as Hemiptera and Blattaria, and detritivores like Collembola. According to Fischer et al. (2022) [40], seasonal rains lead to increased vegetation cover and activity density of omnivorous and detritivorous arthropods, while herbivores such as Isoptera, Isopoda, and Lepidoptera tend to decrease. Consequently, in this study, the transition period from dry to rainy season (DR) exhibited a pattern opposite to periods R and RD (Figure 2).

There was equal contribution of orders to the formation of the first principal component, which explained about 72% of the multivariate data across the analyzed collection sites. The orders Collembola, Hemiptera, Opiliones, and Thysanura contributed most to the formation of the second principal component, explaining about 28% of the data.

The PCA conducted for the different sampled sites indicated that site III (Typical Cerrado) was characterized by a high incidence of the following orders: Araneae, Hymenoptera, Julida, Isopoda, Hemiptera, Blattodea, Lepidoptera, and Neuroptera, with a low incidence of the order Mantodea. Silva and Siqueira (2022) [27], studying the same type of phytophysionomy, found a high abundance of the orders Hemiptera, Araneae, Blattodea, and Lepidoptera, similar to findings by Silva et al. (2019) [25]. The high incidence of these orders is primarily due to the fact that Typical Cerrado is a heterogeneous phytophysionomy [29], consequently providing more favorable microhabitats for these orders.

Site I (Cerrado Grassland) exhibited an opposite pattern to site III. One explanation for the low incidence of arthropods at this site may be related to the low biomass production associated with this phytophysionomy [41]. Studies by de Carvalho et al. (2022) [42] across different Cerrado phytophysionomies found that Cerrado Grassland had the lowest biomass production. According to Saint-Germain et al. (2007) [43], biomass is a crucial factor in determining the abundance of terrestrial arthropods in an area.

Site II (Shrub Cerrado with recent deforestation history) exhibited more prevalent multivariate characteristics of the order Phasmida and a low characterization of the orders Thysanura, Opiliones, Coleoptera, Diptera, Scorpiones, Orthoptera, and the suborder Isoptera (Figure 3). These results were expected, as areas with recent deforestation history tend to have lower abundance of soil macrofauna [44]. Lingbeek et al. (2017) [45] also found that deforested or desertified environments result in a high loss of arthropod abundance. The PCA explained about 98,5% of the variance and covariance in the incidence of arthropod orders across the different collection sites (Figure 3).

3.4 Arthropod families indicative of phytophysionomies and seasonal periods

Three arthropod families were classified as indicators of the dry season: Theridiidae (IndVal = 66.7; $p = 0.05$), Formicidae (IndVal = 52.5; $p = 0.01$), and Rhinotermitidae (IndVal = 59.3; $p = 0.05$). Pitilin et al. (2019) [46], in studies conducted in forest environments, also found that the spider family Theridiidae was among the most representative during the dry period. The increased reproduction of various species within this family during the dry season may explain this presence [39]. The presence of Formicidae as an indicator family for dry periods was expected, as this family is more abundant in arid periods and regions [47]. According to Hölldobler and Wilson (1990) [36], some ants benefit from warm climates and can increase in abundance during the dry season when there is greater availability of microhabitats with high temperatures.

The transition period from dry to rainy season showed a higher number of indicator families: Actinopodidae (IndVal = 66.7; $p = 0.05$), Amphinectidae (IndVal = 66.7; $p = 0.05$), Carabidae (IndVal = 57.5; $p = 0.01$), Cicindelidae (IndVal = 100; $p = 0.001$), Noctuidae (IndVal = 66.7; $p = 0.05$), Saturniidae (IndVal = 66.7; $p = 0.05$). The presence of young individuals from spider families Actinopodidae and Amphinectidae as indicators can be explained by the peak abundance of adults of some spider species occurring at the beginning of the dry season, followed by egg laying, with juvenile occurrence in late summer and immatures in winter [48], similar to the Theraphosidae family, which was indicative of the rainy season. However, the peak abundance

of spider immatures depends on the phenology of each species [46]. Beetle families Carabidae and Cicindelidae also showed higher prevalence at the beginning of the rainy season in studies by Stork and Paarmann (1992) [49], which, according to the authors, is related to the reproductive peak of species in these families. The presence of Lepidoptera families (Noctuidae and Saturniidae) occurred occasionally because the trap type used in this study is not suitable for collecting these arthropods, as mentioned earlier.

The families Theraphosidae (IndVal = 83.3; $p = 0.01$), Coreidae (IndVal = 71.43; $p = 0.02$), and Projapygidae (IndVal = 66.7; $p = 0.05$) were indicators of the rainy season. For the transition from rainy to dry season, the indicator families were: Dipluridae (IndVal = 75; $p = 0.01$), Lycosidae (IndVal = 50; $p = 0.05$), and Reduviidae (IndVal = 100; $p = 0.01$). The Dipluridae and Lycosidae families consisted mainly of adult individuals, and as mentioned earlier, adult arachnids generally show greater representativeness in dry periods [50].

Site I had no indicator families present. At site II, only the family Acrididae (IndVal = 61.5; $p = 0.03$) was identified as an indicator of the collection area. According to Sergeev (2021) [51], some species of the Acrididae family are more commonly found in anthropized areas. In studies by Agrippine et al. (2020) [52], the Acrididae family was also a better indicator in environments with signs of ecological disturbance, considered a good bioindicator of disturbed habitats [53].

Site III had the highest number of indicator families: Ctenidae (IndVal = 60; $p = 0.02$), Titanocidae (IndVal = 75; $p = 0.02$), Blattidae (IndVal = 73; $p = 0.02$), Curculionidae (IndVal = 77.8; $p = 0.02$), and Gryllidae (IndVal = 68.6; $p = 0.02$). Ctenidae spiders mainly use organic matter in the soil as foraging grounds and are important predators of other arthropods in many ecosystems, and the greater environmental heterogeneity of site III may have favored the high occurrence of these spiders in this area, as well as the Titanocidae family. The same pattern applies to the Blattidae family. The Curculionidae family was a good indicator at site III, where there is greater structural complexity compared to other areas, likely providing a greater variety of nesting sites and food resources for these beetles. According to Ambrogi et al. (2009) [54], larvae and adults of Curculionidae are generally phytophagous, able to feed on virtually any living or dead part of the plant. The presence of Gryllidae as an indicator species of the typical Cerrado mainly in wetter periods is likely due to the family's preference for cooler temperatures, greater leaf litter, and high organic matter stock, similar characteristics found in the typical Cerrado sampled.

4. CONCLUSION

The orders Hymenoptera, Araneae, Orthoptera, and the infraorder Isoptera were the most abundant in this study. The analyses conducted in this study revealed significant differences in the arthropod community among the different seasonal periods analyzed. However, there was no significant difference in arthropod composition across the three sampled Cerrado areas. There was greater arthropod diversity during the transition from the dry to rainy period. The Typical Cerrado exhibited higher arthropod abundance, however, the Clean Cerrado field showed greater diversity in arthropod composition. The Cerrado with recent deforestation history demonstrated the lowest arthropod abundance and diversity. These results highlight the importance of seasonality for the arthropod community in different habitats. This study also underscores the significance of preserving and conserving the Cerrado to maintain the composition of different types of arthropods in the soil.

5. BIBLIOGRAPHIC REFERENCES

1. Santos JC, De Almeida WR, Fernandes GW. Arthropods: Why it is so crucial to know their biodiversity? In: Santos JC, Fernandes GW, editor. *Measuring arthropod biodiversity*. Cham: Springer International Publishing; 2021. p. 3-11. doi: 10.1007/978-3-030-53226-0_1
2. Menta C, Remelli S. Soil health and arthropods: From complex system to worthwhile investigation. *Insects*. 2020 Jan;11(1):54. doi: 10.3390/insects11010054
3. Jacot AP. The fauna of the soil. *Q Rev Biol*. 1940 Mar;15(1):28-58. doi: 10.1086/394600

4. Hansen G, Macedo J. *Urban ecology for citizens and planners*. 1. ed. Florida (US): University of Florida Press; 2021.
5. de Aquino AM, Correia MEF. *Invertebrados edáficos e o seu papel nos processos do solo*. Seropédica (RJ): Embrapa Agrobiologia; 2005. (Documentos, 201). Available from: <https://www.infoteca.cnptia.embrapa.br/infoteca/handle/doc/626880>
6. Bezerra CWF, de Matos Andrade L. Interaction of macroinvertebrates in leaf litter in forest ecosystems: a review. *J Environ Anal Prog*. 2021 Jun;6(2):153-66. doi: 10.24221/jeap.6.2.2021.3365.153-166
7. Fernandes IM, Signor CA, Penha J. *Biodiversidade no pantanal de Poconé*. 1. ed. Cuiabá (MT): Centro de Pesquisa do Pantanal; 2010.
8. Martins WBR, Ferreira GC, Souza FP, Dionísio LFS, Oliveira FA. Deposição de serapilheira e nutrientes em áreas de mineração submetidas a métodos de restauração florestal em Paragominas, Pará. *Floresta*. 2018 Jan;48(1):37-48. doi: 10.5380/ufpa.v48i1.49288
9. Correia MEF. *Relações entre a diversidade da fauna de solo e o processo de decomposição e seus reflexos sobre a estabilidade dos ecossistemas*. Seropédica (RJ): Embrapa Agrobiologia; 2002. (Documentos, 156). Available from: <https://www.infoteca.cnptia.embrapa.br/infoteca/handle/doc/597327>
10. Culliney TW. Role of arthropods in maintaining soil fertility. *Agriculture*. 2013 Sep;3(4):629-59. doi: 10.3390/agriculture3040629
11. Schowalter TD, Sabin TE. Litter microarthropod responses to canopy herbivory, season and decomposition in litterbags in a regenerating conifer ecosystem in Western Oregon. *Biol Fertil Soils*. 1991 May;11:93-6. doi: 10.1007/BF00336370
12. Begon M, Townsend CR. *Ecologia: De indivíduos a ecossistemas*. 4. ed. Porto Alegre (RS): Artmed; 2007.
13. Thornthwaite CW. An approach toward a rational classification of climate. *Geogr Rev*. 1948 Jan;38(1):55-94. doi: 10.2307/210739
14. Nogueira VF, Correia MF, Nogueira VS. Impacto do plantio de soja e do oceano pacífico equatorial na precipitação e temperatura na cidade de Chapadinha-MA. *Rev Bras Geogr Física*. 2012 Oct;5(3):708-24. doi: 10.26848/rbgf.v5i3.232870
15. Instituto Brasileiro de Geografia e Estatística (IBGE). *Manual técnico da vegetação brasileira* [Internet]. Rio de Janeiro (RJ): Manuais técnicos de geociência; 2012. Available from: <https://biblioteca.ibge.gov.br/index.php/biblioteca-catalogo?view=detalhes&id=263011>
16. Universidade Estadual do Maranhão (UEMA). *Atlas do Maranhão*. São Luís (MA): GEPLAN; 2002. Available from: <https://www.bellalex.net/arquivos/studio-idro-geologico-climatico-ed-altro.pdf>
17. Borror DJ, DeLong DM. *Introdução ao estudo dos insetos*. 1. ed. São Paulo (SP): Edgard Blucher; 1988.
18. Brescovit AD, Rheims CA, Bonaldo AB. *Chave de identificação para famílias de aranhas brasileiras*. São Paulo (SP): Inst Butantan; 2007.
19. Baptista-Neto J, Gingele F, Leipe T, Zar JH. *Biostatistical analysis*. 3. ed. Nova Jersey (US): Environ Pollut; 1999.
20. Cary N. *Statistical analysis system, User's guide*. Statistical version 9. United States: SAS Inst Inc USA; 2012. Available from: https://support.sas.com/documentation/onlinedoc/91pdf/sasdoc_91/stat_ug_7313.pdf
21. Hammer Ø, Harper DA. *Past: paleontological statistics software package for education and data analysis version 4.16*. *Palaeontol Electron*; 2001. Available from: https://doc.rero.ch/record/15326/files/PAL_E_2660.pdf
22. Zardo DC, Carneiro ÂP, de Lima LG, dos Santos Filho M. Comunidade de artrópodes associada a serrapilheira de Cerrado e mata de galeria, na Estação Ecológica Serra das Araras—Mato Grosso, Brasil. *Rev Bras Multidiscip*. 2010 Dez;13(2):105-13. doi: 10.25061/2527-2675/ReBraM/2010.v13i2.143
23. Lara-Pérez LA, Villanueva-López G, Oros-Ortega I, Aryal DR, Casanova-Lugo F, Ghimire R. Seasonal variation of arthropod diversity in agroforestry systems in the humid tropics of Mexico. *Arthropod-Plant Interact*. 2023 Sep;17(6):799-810. doi: 10.1007/s11829-023-10001-0
24. Alonso LE, Agosti D. Biodiversity studies, monitoring, and ants: an overview. In: Agosti D, Majer JD, Alonso LE, Schultz TR, editors. *Ants: standard methods for measuring and monitoring biodiversity*. Washington (US): Washington and London: Smithsonian Institution Press; 2000. p. 1-8.
25. Silva RA, Aguiar ADCF, Rebêlo J, Silva EFF, Silva GF, Siqueira GM. Diversidade da fauna edáfica em diferentes sistemas de ocupação do solo. *Rev Caatinga*. 2019 Set;32:647-57. doi: 10.1590/1983-21252019v32n309rc
26. Lamarre GP, Molto Q, Fine PV, Baraloto C. A comparison of two common flight interception traps to survey tropical arthropods. *ZooKeys*. 2012 Aug;(216):43. doi: 10.3897/zookeys.216.3332

27. Silva RA, Siqueira GM. Edaphic fauna and physico-chemical attributes of soil in different phytophysionomies of Cerrado. *Rev Bras Eng Agríc e Ambient.* 2022 Feb;26:103-10. doi: 10.1590/1807-1929/agriambi.v26n2p103-110
28. Franco ALC, Sobral BW, Silva ALC, Wall DH. Amazonian deforestation and soil biodiversity. *Conserv Biol.* 2019 Oct;33(3):590-600. doi: 10.1111/cobi.13234
29. Azevedo GHF, Faleiro BT, Magalhães ILF, Benedetti AR, Oliveira U, Pena-Barbosa JPP, et al. Effectiveness of sampling methods and further sampling for accessing spider diversity: a case study in a Brazilian Atlantic rainforest fragment. *Insect Conserv Divers.* 2014 Dec;7(4):381-91. doi: 10.1111/icad.12061
30. Buskirk RE, Buskirk WH. Changes in arthropod abundance in a Highland Costa Rican Forest. *Am Midl Nat.* 1976 Apr;95(2):288-98. doi: 10.2307/2424394
31. Razo-González M, Castaño-Meneses G, Callejas-Chavero A, Pérez-Velázquez D, Palacios-Vargas JG. Temporal variations of soil arthropods community structure in El Pedregal de San Ángel Ecological Reserve, Mexico City, Mexico. *Appl Soil Ecol.* 2014 Nov;83:88-94. doi: 10.1016/j.apsoil.2014.02.007
32. Carvalho LS, Sebastian N, Araújo HFP, Dias SC, Ventincique E, Brescovit AD, et al. Climatic variables do not directly predict spider richness and abundance in semiarid caatinga vegetation, Brazil. *Environ Entomol.* 2015 Feb;44(1):54-63. doi: 10.1093/ee/nvu003
33. Mavasa R, Yekwayo I, Mwabvu T, Tsvuura Z. Preliminary patterns of seasonal changes in species composition of surface-active arthropods in a South African savannah. *Austral Ecol.* 2022 Jun;47(6):1222-31. doi: 10.1111/aec.13213
34. Majeed W, Rana N, Koch E, Nargis S. Seasonality and climatic factors affect diversity and distribution of arthropods around wetlands. *Pak J Zool.* 2020 Sep;52:2135-44. doi: 10.17582/journal.pjz/20200112020107
35. Sanford MP, Huntly NJ. Seasonal patterns of arthropod diversity and abundance on big sagebrush, *Artemisia tridentata*. *West North Am Nat.* 2010 Apr;70(1):67-76. doi: 10.3398/064.070.0108
36. Hölldobler B, Wilson EO. *The ants.* 1. ed. Cambridge (US): Harvard University Press; 1990.
37. Zardo D, Carneiro Â, Lima L, Santos-Filho M. Comunidade de artrópodes associada à serrapilheira de Cerrado e Mata de Galeria, na Estação Ecológica Serra Das Araras – Mato Grosso, Brasil. *Rev Bras Multidiscip.* 2010 Jul/Dec;13(2):105-13. doi: 10.25061/2527-2675/ReBraM/2010.v13i2.143
38. Varjão SLS, Benati KR, Peres MCL. Efeitos da variação temporal na estrutura da serrapilheira sobre a abundância de aranhas (Arachnida: Araneae) num fragmento de Mata Atlântica (Salvador, Bahia). *Rev Biociências.* 2010 Abr;16(1): 1-10.
39. Azevedo GHF, Faleiro BT, Magalhães ILF, Benedetti AR, Oliveira U, Pena-Barbosa JPP, et al. Effectiveness of sampling methods and further sampling for accessing spider diversity: a case study in a Brazilian Atlantic rainforest fragment. *Insect Conserv Divers.* 2014 Dec;7(4):381-91. doi: 10.1111/icad.12061
40. Fischer C, Gerstmeier R, Wagner TC. Seasonal and temporal patterns of rainfall shape arthropod community composition and multi-trophic interactions in an arid environment. *Sci Rep.* 2022 Mar;12(1):3742. doi: 10.1038/s41598-022-07716-0
41. Roquette JG. Distribuição da biomassa no Cerrado e a sua importância na armazenagem do carbono. *Ciênc Florest.* 2018 Sep;28:1350-63. doi: 10.5902/1980509833354
42. de Carvalho AS, Soares Neto JP, Nunes HB. Estimation of carbon stock in the soil plant system of the main phytophysionomies of the Cerrado of west bahia, Brazil. *Colloq Agrar.* 2022 Feb;18(1):10-9. doi: 10.5747/ca.2022.v18.n1.a474
43. Saint-Germain M, Buddle CM, Larrivée M, Mercado A, Motchula T, Reichert E, et al. Should biomass be considered more frequently as a currency in terrestrial arthropod community analyses? *J Appl Ecol.* 2007 Feb;44(2):330-9. doi: 10.1111/j.1365-2664.2006.01269.x
44. Franco ALC, Sobral BW, Silva ALC, Wall DH. Amazonian deforestation and soil biodiversity. *Conserv Biol.* 2019 Oct;33(3):590-600. doi: 10.1111/cobi.13234
45. Lingbeek BJ, Higgins CL, Muir JP, Kattes DH, Schwertner TW. Arthropod diversity and assemblage structure response to deforestation and desertification in the Sahel of western Senegal. *Glob Ecol Conserv.* 2017 Jul;11:165-76. doi: 10.1016/j.gecco.2017.06.004
46. Pitilin R, Prado Júnior J, Brescovit A, Buschini ML. Climatic conditions drive the abundance and diversity of spiders community in an atlantic forest fragment. *Oecol Aust.* 2019 Feb;23:39-55. doi: 10.4257/oeco.2019.2301.04
47. Pérez-Sánchez AJ, Lattke JE, Vilorio AL. Patterns of ant (Hymenoptera: Formicidae) richness and relative abundance along an aridity gradient in western Venezuela. *Neotrop Entomol.* 2013 Dec;42(2):128-36. doi: 10.1007/s13744-012-0096-y
48. Villanueva-Bonilla GA, Safuan-Naide S, Vasconcellos-Neto J. Population dynamics and phenology of two congeneric and sympatric lynx spiders *Peucetia rubrolineata* Keyserling, 1877 and *Peucetia flava*

- Keyserling, 1877 (Oxyopidae). J Nat Hist. 2018 Feb;52(5-6):361-76. doi: 10.1080/00222933.2018.1433339
49. Stork NE, Paarmann W. Reproductive seasonality of the ground and tiger beetle (Coleoptera: Carabidae, Cicindelidae) fauna in North Sulawesi (Indonesia). Stud Neotropical Fauna Environ. 1992 Nov;27(2-3):101-15. doi: 10.1080/01650529209360871
50. Arango AM, Rico-Gray V, Parra-Tabla V. Population structure, seasonality, and habitat use by the green lynx spider *Peucetia viridans* (Oxyopidae) inhabiting *Cnidoscolus aconitifolius* (Euphorbiaceae). J Arachnol. 2000 Apr;28(2):185-94. doi: 10.1636/0161-8202(2000)028[0185:PSSAHU]2.0.CO;2
51. Sergeev MG. Distribution patterns of grasshoppers and their kin over the Eurasian steppes. Insects. 2021 Jan;12(1):77. doi: 10.3390/insects12010077
52. Agrippine YFJ, Sévilor K, Martin K, Didier MA, Xu SQ. Diversity, abundance and distribution of grasshopper species (Orthoptera: Acrididea) in three different types of vegetation with different levels of anthropogenic disturbances in the Littoral Region of Cameroon. J Insect Biodivers. 2020 Jan;14(1):16-33. doi: 10.12976/jib/2020.14.1.3
53. Saha HK, Haldar P. Acridids as indicators of disturbance in dry deciduous forest of West Bengal in India. Biodivers Conserv. 2009 Feb;18(9):2343-50. doi: 10.1007/s10531-009-9591-9
54. Ambrogi BG, Vidal DM, Zarbin PHG, Rosado-Neto GH. Aggregation pheromone in curculionidae (insecta: coleoptera) and their taxonomic implication. Quim Nova. 2009 Oct;32:2151-8. doi: 10.1590/S0100-40422009000800029