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Ecology

Abundance and seasonality of insects in urban fragments of the Brazilian Cerrado

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Abstract. Insects are important ecosystem agents, however a decline in the abundance and composition changes of these animals around the globe has been observed. In the urban environment, this characteristic has been more critical, due to the lack of diversity and quality of habitats in these environments, which feature fragmentation of habitats. Thus, processes that naturally affect the composition of animals in the environment can be observed, shaping the abundance of species in their environments, such as seasonality, especially in tropical regions, with well-defined rain and dry seasons. The aim of this work was to evaluate the seasonality and abundance of insects in urban fragments in the Brazilian savannah (Cerrado). For this purpose, four urban fragments were sampled in Campo Grande/MS, during the months of January to December 2012 using Malaise traps. A total of 26,890 individuals of 19 orders were collected, with Diptera the most abundant order sampled followed by Hymenoptera, Coleoptera, Lepidoptera, Hemiptera and Trichoptera. A peak in general insect abundance was found in November, and there were significant differences over the months between different orders. However, no difference was found between the fragments although it was observed a trend towards changes in the diversity of orders related to the size of the fragments. The different strategies to deal with the well-marked water stress for the Cerrado is an important factor for the composition of the insect fauna of the domain and variations in the habitat, such as area size and phytophysiognomies composition directly affect the orders found.

Keywords: Brazilian savannah; Coleoptera; Diptera; Habitat fragmentation; Hymenoptera

Insects (Hexapoda: Insecta) are the most diverse and abundant organisms in terrestrial and aquatic ecosystems, being important agents of ecosystem services such as pollination (performed mainly by bees and butterflies, some wasps, flies and beetles), biological control (parasitoid wasps and predators in general), seed dispersal (some ants) and nutrient cycling (larvae of various soil and litter insects, in addition to cockroaches, termites and beetles) (Crespo-Peréz *et al.* 2020; Ramos *et al.* 2020). In recent decades, there has been a recurrent record of declining abundance, biomass, and diversity in different regions of the globe for different taxonomic groups (Forister *et al.* 2019; Goulson 2019; Jansen & Hallwachs 2019). In urban environments, these impacts are more accentuated with different characteristics. Since this scenario does not provide a diversity of habitats and sufficient quality to maintain diverse populations and communities, efforts to understand the processes and mechanisms that ensure the diversity of insects in these environments are still necessary (McIntyre 2000; Sattler *et al.* 2011; New 2015), and identification up to insect order level can be a useful source for identifying human impact (Driessen & Kirkpatrick 2017).

One of the main changes in urban environments is alteration in habitat composition, which locally affects microhabitats, affecting phenological aspects in insects (Rosseti *et al.* 2014; Yang & Gratton 2014). Seasonality is an important factor in an organism's life cycle, especially insects. Determined variations in climate and temperature affect the activity of organisms (Wolda 1980; Fedorka *et al*. 2013). Some species are even only active during one period of the year. The seasonal characteristic and its effects are particularly variable in the tropics, where the temperature change is minimal, and the seasons are defined by rain and drought (Wolda 1988; Anu *et al.* 2009; Vasconcellos *et al*. 2010; da Silva *et al*. 2011; Rosseti *et al.* 2014). Thus, it is expected that seasonality will have an effect on the abundance of insects throughout the year, since several fators such as humidity, food availability and interactions with other organisms, are directly or indirectly associated to this phenomenon (Wolda 1978; Novotny *et al*. 1998; Southwood *et al*. 2004).

In addition to seasonality, which directly affect the insect development and bionomy, habitat fragmentation can be accentuated in this scenario of temporal variations in abundance patterns (Ribeiro & Freitas 2011; Aranda & Graciolli 2015; Salomão *et al*. 2018; Salomão *et al*. 2019). The diversity and abundance of insects and their trophic relationships are fundamental to ecosystem processes, and the fragmentation and alteration of the habitat landscape has a strong influence on the ecology of these animals, thus affecting the functionality of the ecosystem (Kruess & Tschantke 1994; Hunter 2002). Seasonality and fragmentation are factors that can shape and alter the composition of species through variations in habitat, edge effect and isolation from changes in the environments and depending on the phenological and physiological responses to adapt to such changes (Kruess & Tschantke 2000; Sánchez-Reyes *et al*. 2019).

The Brazilian Cerrado is characterized by two well-defined seasons; a a hot and rainy in October and March and a cold and dry season in April to September, the later with the predominant vegetation having a xeromorphic characteristic, adapted to these water extremes. However, several phytophysiognomies can be found within the domain, vegetation structures such as forests (Cerradão, riparian and gallery forests), wooded fields, fields with a predominance of shrubs and open fields and in many times sets of these plant elements (Eiten 1972; Coutinho 1978). In the last decades, several factors threaten the domain, mainly the advance of the agricultural and livestock frontiers, which led to a high degree of fragmentation (Carvalho *et al.* 2009), and places it among one of the priority conservation areas in the country (Klink & Machado 2005; Sano *et al.* 2019).

Therefore, the present work aims to characterize the composition of insect orders in four urban fragments of Cerrado, evaluating the seasonality of the abundance of insect orders and the abundance and composition of them in relation to the size of the fragments, where we hope to find I) marked seasonality throughout the year and II) that insect orders will respond differently to seasonality; also IIII) the size of the fragments will influence the abundance and composition of insect orders according to the local characteristics of the fragments.

MATERIAL AND METHODS

Description of the area. The sampling was carried out in four urban fragments of Cerrado in Campo Grande, Mato Grosso do Sul, Brazil, between January and December 2012. Among the sampled fragments are two state parks and two private reserves of natural heritage (RPPN), as follows: Parque Estadual do Segredo (Segredo), Parque Estadual do Prosa (Prosa), RPPN of Universidade Federal do Mato Grosso do Sul (UFMS) and RPPN of Universidade Católica Dom Bosco (UCDB) (Table 1). The region is characterized as subtropical Aw (Alvares *et al.* 2014) with average annual precipitation between 1125 mm and average temperatures between 20 ºC, and two well-marked climatic seasons between October and March (rainy season) and April to September (dry season) (Figure 1).

Sampling. Malaise traps were used, which are indicated for capture by interception of winged insects (Fraser *et al.* 2008). Each trap has a dimension of 1.5 X 1.5 X 1.0 m (height, length, width) and the height was arranged on the ground. In each fragment, the total area was meshed with plots of 1,000 m^2 (1 ha), with the sampling plots being drawn without replication and proportionally to the size of the fragment (see "n" sample, Table 1). Eighteen Malaise traps were placed in each plot and were exposed for 72 h. The collections took place approximately every 15 days, with alternation between the fragments, totaling 31,104 hours/trap. The samples were stored in 70% alcohol, properly labeled, and later taken to the laboratory for screening. The insects were identified until order using specialized keys (Rafael *et al.* 2012), and the abundance was computed for each order. The identification of the Blattaria and Isoptera orders was considered separately during the sorting and processing of the material despite the current classification (Rafael *et al.* 2012).

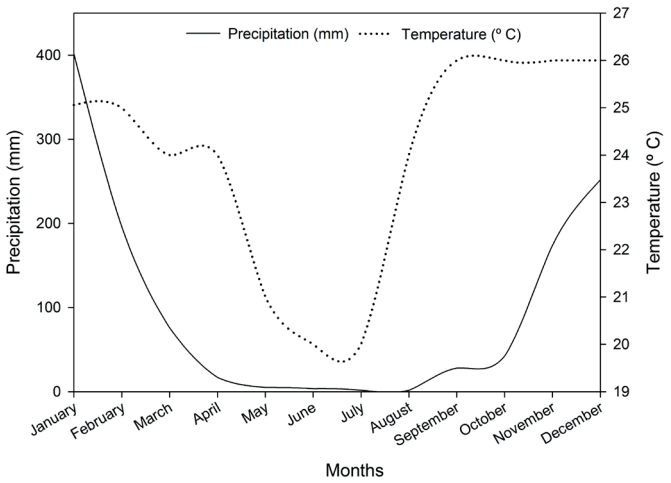

Figure 1. Average precipitation (mm) and temperature (º C) from January to December 2012 in the municipality of Campo Grande, Mato Grosso do Sul.

Statistical analysis. The insect orders found and their respective abundance were described. The constancy of the species was classified as: constant - present in more than 50% of the collections; accessory species - present in 25% to 50% of collections; accidental species - present in less than 25% of the collections, as proposed by Boodemheimer (1955) *apud* Silveira-Neto *et al*. (1976). To verify seasonality, the data were analyzed in two approaches: (i) categorically comparing the abundance between dry and rainy seasons through two-way ANOVA (Zar 1996) to verify the effect of the variation in abundance between seasons and between fragments and (ii) continuously between the months without considering the effect of the fragments through the Rayleigh uniformity

Table 1. Information of the Cerrado fragments sampled with: geographic coordinates, size, number of samples and characterization of vegetation.

Fragment	Geographic coordinates		Size (hectares)	Nº of samples	Typical vegetation
Parque Estadual Matas do Segredo (Segredo)	20°23'S	54°35'W	175	8	Most of its vegetation cover is composed of typical Cerrado, open areas with a predominance of grasses and gallery forest at the source of the Segredo stream.
O Parque Estadual do Prosa (Prosa)	20°27'S	54°33'W	128	6	Vegetation cover composed of gallery forest at the source of the Prosa stream and Cerradão type vegetation.
RPPN Universidade Federal de Mato Grosso do Sul (UFMS)	20°30'S	54°36'W	32	6	Typical vegetation of Cerrado stricto sensu and open areas with predominance of grasses.
RPPN Universidade Católica Dom Bosco (UCDB)	20°24'S	54°36'W	25	5	Typical vegetation of Cerrado stricto sensu.

test (Z) (Jammalamadaka & SenGupta 2001), being carried out in general for the total abundance of insects and for the main sampled orders. In addition, to characterize the composition of the orders between the fragments, Shannon's ecological indexes of diversity (H') and Pielou's Equitability (J) were evaluated, as well as the comparison of the composition of the orders between the fragments through non-Multidimensional Scaling (NMDS) with Bray-Curtis similarity measure (Magurran 1988; Legendre & Legendre 2012).

RESULTS AND DISCUSSION

A total of 26,890 individuals of 19 orders were collected, with Diptera the most abundant order sampled (10,337) followed by Hymenoptera (7,249), Coleoptera (3,132), Lepidoptera (2,481), Hemiptera (1,510), Trichoptera (1,128), and Psocoptera (378). The others insect orders had less than 300 individuals (Figure 2). In comparison with other studies of insect seasonality in the Cerrado, we found alternation between the main orders. In our study, Diptera was the most abundant order, being reported in the other studies Hymenoptera or Coleoptera as the predominant in Malaise and light traps (Pinheiro *et al.* 2002; da Silva *et al.* 2011). According to the constancy data, Diptera, Hymenoptera, Coleoptera and Lepidoptera can be considered as constant in 100% of the samples. Among the Lepidoptera, moths were the most predominant in the samples. The following orders can also be considered constant: Hemiptera (96%), Blattaria (76%), Psocoptera and Orthoptera (72% each one) Trichoptera (64%) and Isoptera (52%). Thysanoptera (48%), Neuroptera (44%) and Mantodea (28%) can be classified as accessory. On the other hand, the orders Dermaptera (20%), Embioptera (12%), Plecoptera, Odonata, Phasmatodea (8% each one) and Strepsiptera (4%) can be considered accidental or rare in the samples.

The specimens of Plecoptera (n = 4) and Odonata (n = 3) captured were adults present in the fragments (Prosa and Segredo) whose parcels were installed close to the aquatic environments. Eleven of the 15 specimens of Embioptera were captured in a single sampling point, possibly the location of the trap installation occurred close to a nest of these subsocial insects. Two male specimens of Strepsiptera were captured in the wet season at a single sampling point, which may reflect reproductive activity since the males are active and present only during this period (Pohl & Beutel 2008; Kathirithamby 2009).

Concerning the sampled areas, the higher abundance was found at the Segredo (10,607) followed by Prosa (7,291), UFMS (4,951) and UCDB (4,041). Diptera was the most abundant order in all fragments, with the exception of UFMS, where Hymenoptera exceeded its abundance, being followed by Coleoptera, Lepidoptera and Hemiptera as the main ones (Table 2). This abundance pattern was also observed when evaluating the fragments together although no significant differences were found between fragments ($F = 0.721$, $p = 0.55$), seasons ($F = 0.451$, $p = 0.51$) or the interaction of the two factors ($F = 0.27$, $p = 0.84$) (Figure 3).

However, when assessing the monthly seasonality, we found significant variations over the months for the abundance of insects in general and among the main orders. In general, the peak of abundance was observed in November (Mean Vector (μ) = 260°), with the average in September ($Z = 2261.873$, $p < 0.05$) (Table 3, Figure 4).

The main orders respond with varying patterns, including: Diptera peaks in August and November (Mean Vector (μ) = 233°, average in September ($Z = 886{,}475$, $p < 0.05$); Hymenoptera in November (Mean Vector (μ) = 247°, mean in September $Z = 347.895$, $p < 0.05$); Coleoptera in November (Mean Vector (μ) = 305°, mean in November ($Z = 884.744$, $p < 0.05$); Lepidoptera in July and November (Mean Vector (μ) = 217°, mean in August ($Z = 75.224$, $p < 0.05$); Hemiptera in November (Mean Vector (μ) = 272°, mean in October ($Z = 173.536$, $p < 0.05$) and Trichoptera in November (Mean Vector (μ) = 294°, mean in October ($Z = 310.947$, $p < 0.05$) (Table 3, Figure 5).

For insects in general, we obtained similar results in relation to the mean and peak abundance over the months. Regarding the main orders, there was a slight difference between the peak months for Diptera, Hymenoptera, Coleoptera, Lepidoptera and Hemiptera when compared to other studies, and for Trichoptera we found similarity in the pattern of occurrence already reported (Pinheiro *et al.* 2002; da Silva *et al.* 2011). Such variations may be related to the local characteristics of the sampling points within each fragment, since their distinct sizes and phytophysiognomies may favor certain groups throughout the year. Characteristics of plant formation and litter directly influence several orders of insects due to the microclimatic characteristics created (Wall *et al*. 2011).

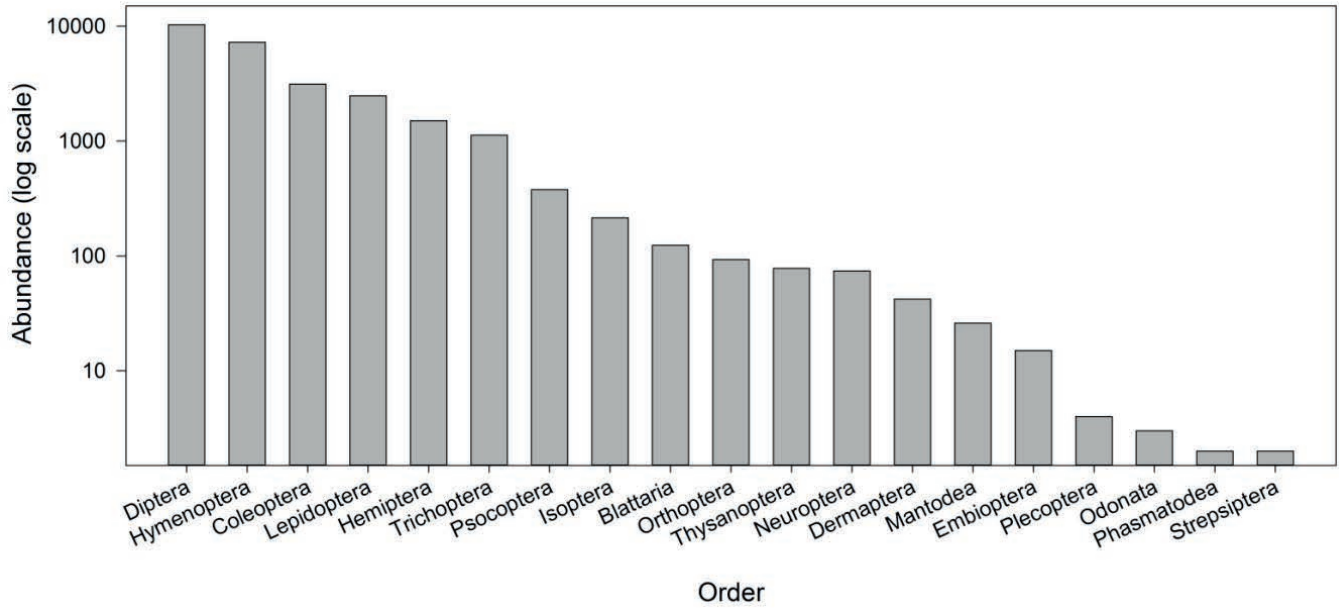

Figure 2. Log of the abundance of insect orders captured in urban fragments of Cerrado in the municipality of Campo Grande, Mato Grosso do Sul, between January and December 2012.

Table 2. Orders, individuals and percentage in the Prosa and Segredo State Park , Private Reserve of Natural Heritage of the Federal University of Mato Grosso do Sul (UFMS) and the Catholic University Dom Bosco (UCDB) in the municipality of Campo Grande, Mato Grosso do Sul, between January and December 2012.

Order	PROSA	%	SEGREDO	%	UCDB	%	UFMS	%
Diptera	2917	10,85	4340	16,14	1728	6,43	1352	5,03
Hymenoptera	1703	6,33	2587	9,62	1036	3,85	1920	7,14
Coleoptera	1026	3,82	1267	4,71	482	1,79	357	1,33
Lepidoptera	630	2,34	678	2,52	340	1,26	833	3,10
Hemiptera	290	1,08	727	2,70	202	0,75	291	1,08
Trichoptera	478	1,78	603	2,24	22	0,08	25	0,09
Psocoptera	133	0,49	64	0,24	153	0,57	28	0,10
Isoptera	29	0,11	147	0,55	5	0,02	34	0,13
Blattaria	6	0,02	88	0,33	10	0,04	20	0,07
Orthoptera	30	0,11	31	0,12	11	0,04	21	0,08
Thysanoptera	16	0,06	15	0,06	6	0,02	41	0,15
Neuroptera	4	0,01	9	0,03	45	0,17	16	0,06
Dermaptera	12	0,04	27	0,10	0	0,00	3	0,01
Mantodea	14	0,05	7	0,03	0	0,00	5	0,02
Embioptera	0	0,00	12	0,04	0	0,00	3	0,01
Plecoptera	3	0,01	1	0,00	0	0,00	0	0,00
Odonata	0	0,00	3	0,01	0	0,00	0	0,00
Phasmatodea	0	0,00	1	0,00	1	0,00	0	0,00
Strepsiptera	0	0,00	0	0,00	0	0,00	2	0,01
Total	**7291**	**27,11**	**10607**	**39,45**	**4041**	**15,03**	**4951**	**18,41**

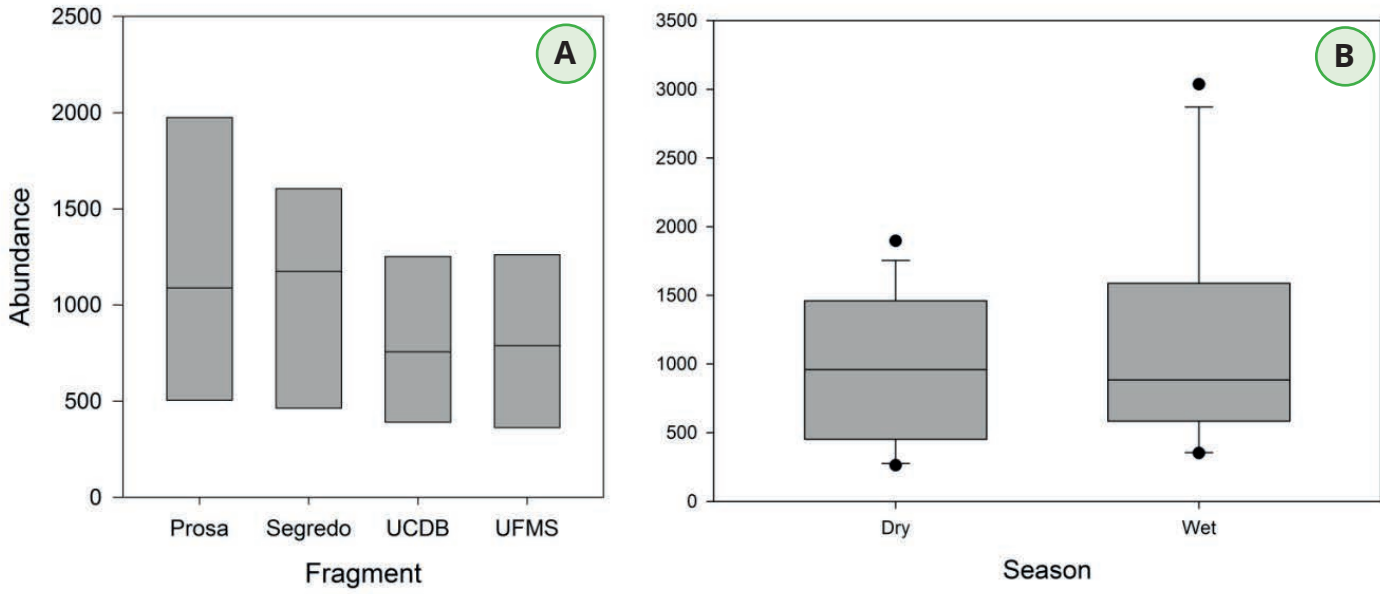

Figure 3. Abundance of insects between fragments (A) and stations (B) of urban fragments from Cerrado in the municipality of Campo Grande, Mato Grosso do Sul, between January and December 2012. Prosa (Prosa) and Segredo State Park (Segredo), Private Reserve of Natural Heritage of the Federal University of Mato Grosso do Sul (UFMS) and the Catholic University Dom Bosco (UCDB).

Changes in the circadian cycles as a response to different environmental conditions occurs differently in different insect orders, whether influencing aspects of migration, reproductive, emergence and physiological responses in an adaptive way (Denlinger *et al*. 2017). In seasonally marked environments, the models show a predominance of 1 to 2 more pronounced peaks in relation to species diversity, which reflects in abundance (Rossetti *et al*. 2014; Mellard *et al*. 2019). In the case of the Hymenoptera sampled in this study, the responses found between the different families have also been shown to vary in relation to seasonality (Aranda & Graciolli 2015).

Regarding the ecological indexes, although the abundance does not vary and the average of orders was similar (on average 10 orders), larger fragments contain more individuals and greater diversity (H ') and Equitability (J') (Table 4). As they are larger fragments and consequently also more diverse in their vegetal formations, Prosa and Segredo allow greater availability of niche to be shared by more orders, favoring greater diversity and equitability. Unlike the larger fragments, the smaller ones (UFMS and UCDB), where the main sampled orders (e.g. Diptera, Hymenoptera, Coleoptera, Lepidoptera and Hemiptera) turn out to be more frequent and there are a few occurrences of orders considered accidental or rare. The results for Hymenoptera (Aranda & Graciolli 2015) show how different families respond to environmental variations, both in the composition of vegetation and in the seasonality

Table 3. Circularity analysis of the main insect orders sampled in urban fragments of Cerrado in the municipality of Campo Grande, Mato Grosso do Sul, between January and December 2012.

Statistical Metrics	Diptera	Hymenoptera	Coleoptera	Lepidoptera	Hemiptera	Trichoptera	General
Number of Observations	10337	7246	3132	2481	1510	1128	25636
Mean Vector (μ)	233,296°	247,125°	305,104°	217,253°	272,068°	294,69°	260,505°
Mean Group	August	September	November	August	October	October	September
Length of Mean Vector (r)	0,293	0,219	0,531	0,174	0,339	0,525	0,297
Concentration	0,613	0,449	1,257	0,354	0,721	1,228	0,622
Circular Variance	0,707	0,781	0,469	0,826	0,661	0,475	0,703
Circular Standard Deviation	89,796°	99,838°	64,42°	107,129°	84,275°	65,04°	89,275°
Rayleigh Test (Z)	886,47	347,89	884,74	75,22	173,53	310,94	2261,87
Rayleigh Test (p)	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05

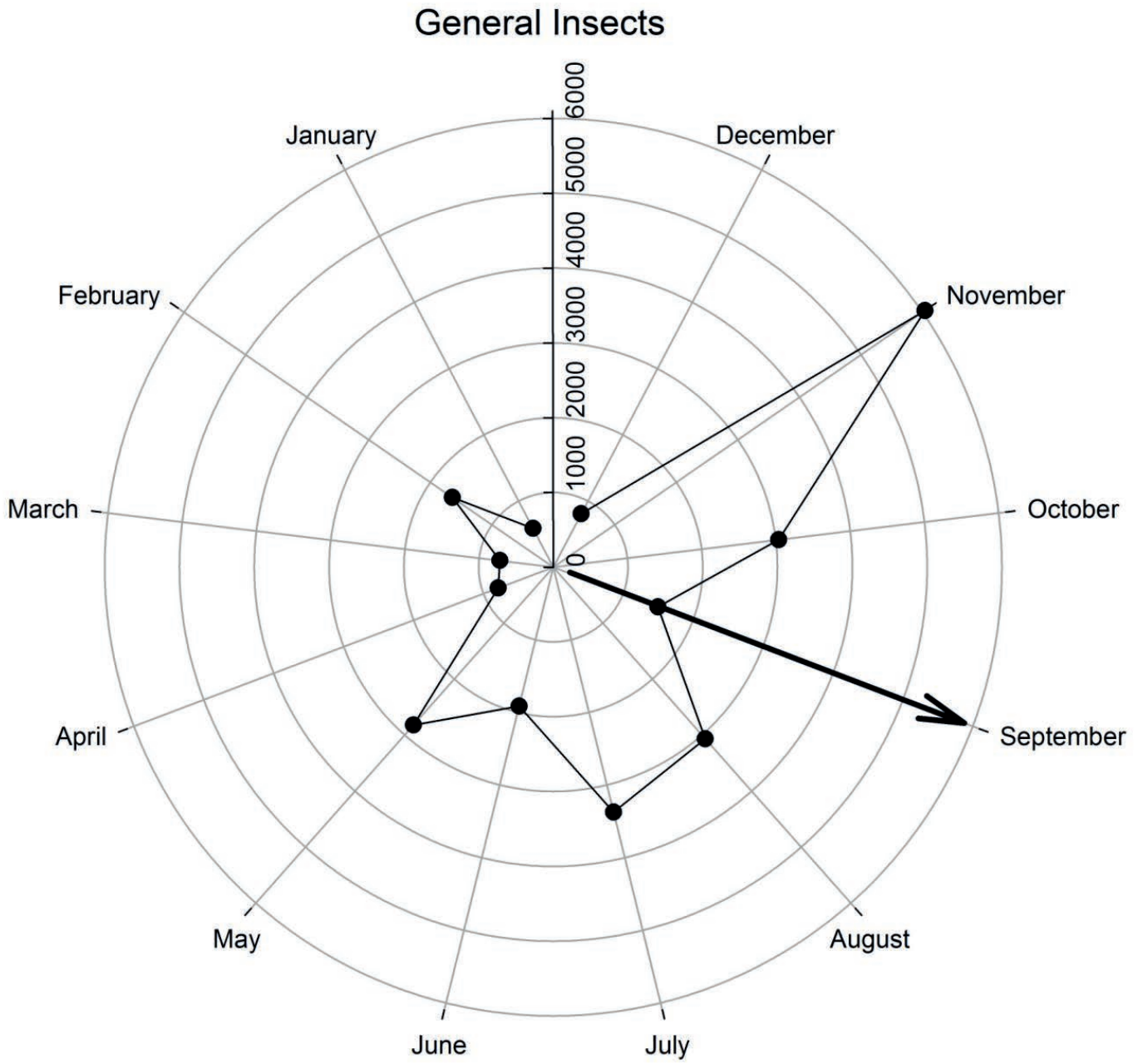

Figure 4. Circularity analysis of the abundance of insect orders collected in fragments of Cerrado in the municipality of Campo Grande, Mato Grosso do Sul, between January and December 2012.

Table 4. Orders, individuals Shannon's diversity index (H) and Pielou's equitability (J) sampled in the Prosa (Prosa) and Segredo State Park, Private Reserve of Natural Heritage of the Federal University of Mato Grosso do Sul (UFMS) and the Catholic University Dom Bosco (UCDB) in the municipality of Campo Grande, Mato Grosso do Sul, between January and December 2012.

Fragment/Size	Ecological índex			
	Order (S)	Individuals	Shannon(H')	Equitability (J)
Prosa/Large	11	499	1,67	0,70
	13	1292	1,57	0,61
	10	1896	1,36	0,59
	5	507	0,25	0,16
	13	884	1,73	0,68
	11	2213	1,56	0,65
Mean	**10,5**	**1215,17**	**1,357**	**0,564**
Segredo/Large	13	1611	1,46	0,57
	12	1424	1,30	0,52
	7	351	1,51	0,78
	11	1409	1,57	0,65
	13	3036	1,70	0,66
	12	1587	1,89	0,76
	6	262	1,03	0,57
	10	927	1,53	0,66
Mean	**10,50**	**1325,88**	**1,50**	**0,65**
UCDB/Small	7	291	1,13	0,58
	12	1049	1,63	0,66
	9	1455	1,32	0,60
	7	490	1,34	0,69
	11	756	1,51	0,63
Mean	**9,20**	**808,20**	**1,39**	**0,63**
UFMS/Small	10	991	1,54	0,67
	11	1476	1,40	0,58
	11	584	1,62	0,68
	8	370	1,57	0,76
	11	339	1,39	0,58
	9	1191	1,52	0,69
Mean	**10,00**	**825,17**	**1,51**	**0,66**

between the areas studied, reflecting the biological aspects of each group. The fragments of Segredo and UCDB are the closest to each other, however the spatial proximity did not influence the similarity of the orders found, indicating that the size of the fragment and local characteristic is an important factor for the occurrence of the orders.

Comparing the composition of the orders in relation to the size of the fragments, we see the tendency for the larger fragments (Prosa and Segredo) to have a greater number of orders and individuals when compared to the smaller ones (UFMS and UCDB) (Stress = 0.10, R2- axis 1: 0.77, axis 2: 0.10; Figure 6). This trend is in line with the well-known relationship between habitat size and structure, and its effects on species composition in this environment, as described by the theory of island biogeography (MacArthur & Wilson 1967). Thus, it is to be expected that sites of different sizes and structures will present a different composition of insects due to the greater availability of resources provided by a larger and more heterogeneous environment (Kruess & Tscharntke 2000; Hunter 2002; Kadmons & Allouche 2007; Sánchez-Reyes *et al*. 2019).

In conclusion, the abundance of insects in urban fragments is directly affected by the seasonal variations, related to precipitation and temperature in urban fragments. Depending on the biology and bionomy of each order of insects, the peaks of abundance can varies between the dry and rainy seasons. Diptera, Hymenoptera, Lepidoptera and Hemiptera are more constant throughout the year despite fluctuations in their abundances, while other groups have well-marked seasonality such as Coleoptera and Trichoptera.

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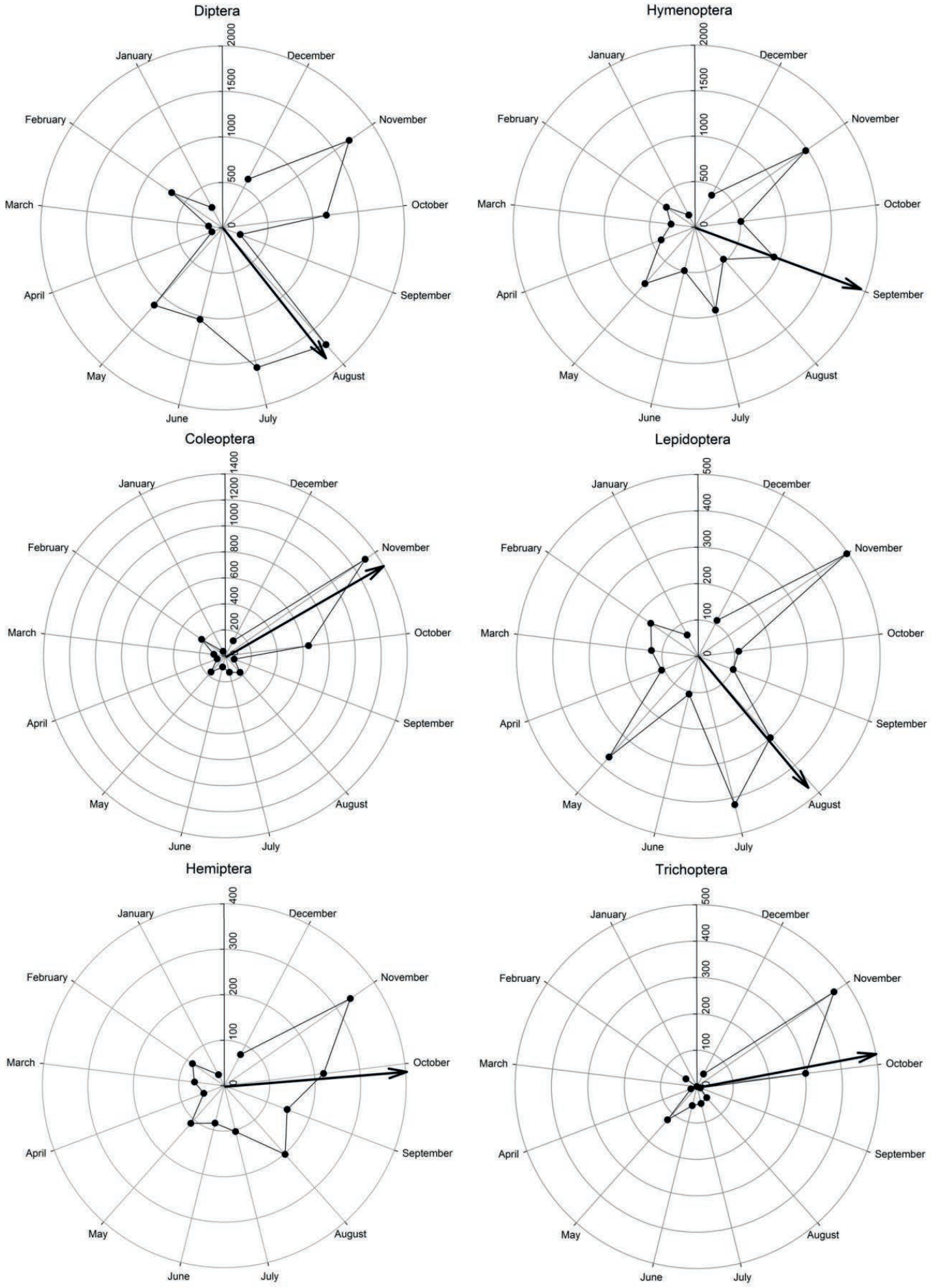

Figure 5. Analysis of the circularity of abundance of the six main orders of insects collected in fragments of Cerrado in the municipality of Campo Grande, Mato Grosso do Sul, between January and December 2012.

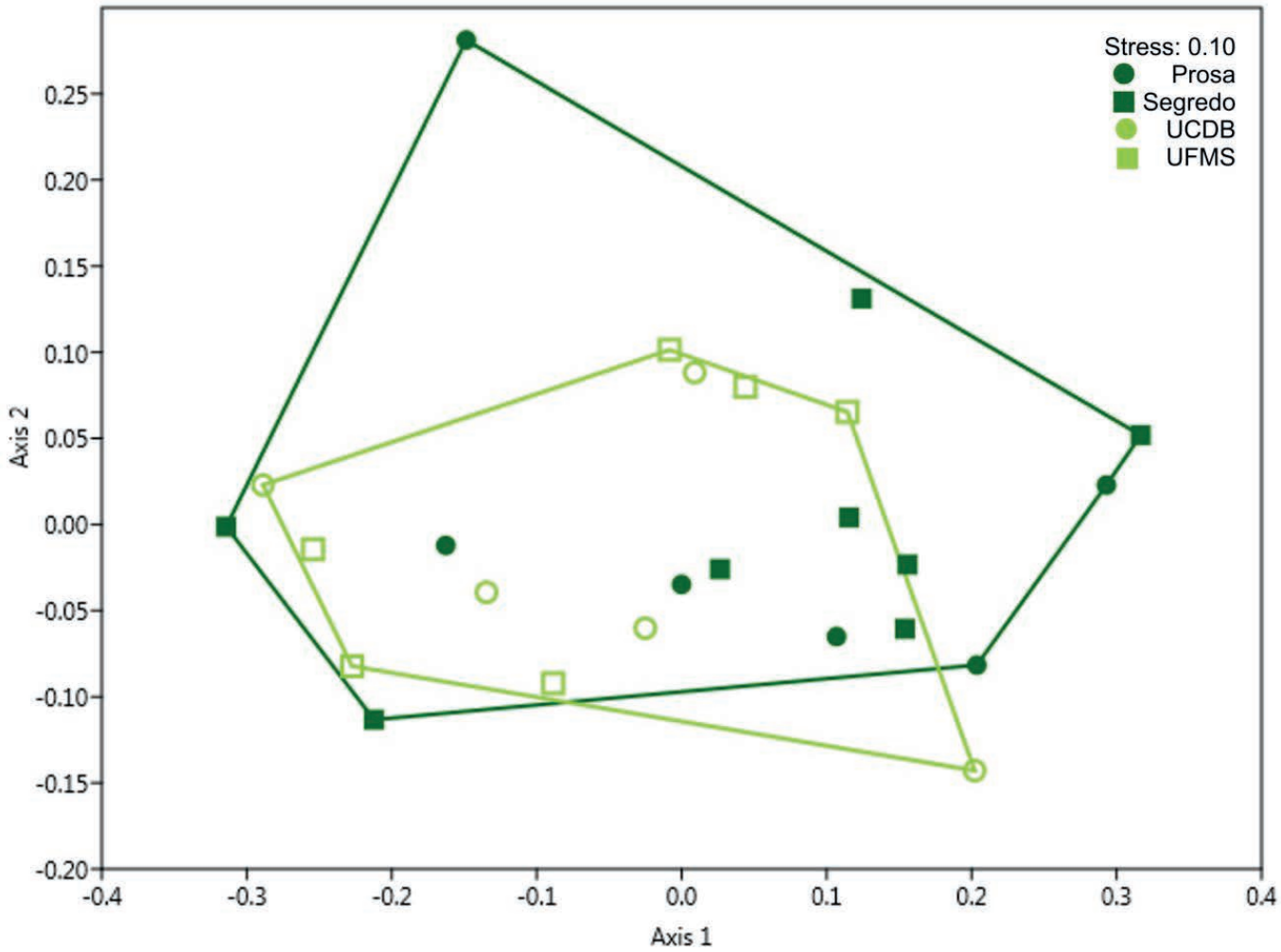

Figure 6. Non-parametric multidimensional scaling (NMDS) of the composition of insect orders between major urban fragments (Prosa and Segredo) and minor urban fragments (UFMS).

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