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Seasonality and distribution of Coleoptera families (Arthropoda, Insecta) in the Cerrado of Central Brazil

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ABSTRACT

Coleoptera order in Brazil presents 105 families with approximately 28,000 species. The life cycle and diversity of Coleoptera are strongly influenced by climate and vegetation. The objective of this study was to evaluate the seasonality and distribution of Coleoptera families in an area of the Cerrado in the Federal District (DF) of Brazil. The insects were collected monthly, between June 2015 and May 2016, using a light trap activated only in nights with a new moon, in an area of cerrado *sensu stricto* in Planaltina/DF, Brazil. The data were correlated with climatic variables. A total of 21,100 Coleoptera specimens belonging to 34 families were collected, with Melolonthidae (n = 11,075), Carabidae (n = 2,522), Scarabaeidae (n = 2,506), Bostrichidae (n = 1,196), and Chrysomelidae (n = 1,086) being the most abundant. Coleoptera were significantly more abundant in the first half of the rainy season. There was a significant and positive correlation between the abundance of Coleoptera and the climatic variables temperature and precipitation. The data presented in this study are related to an atypical year under the strong influence of the El Niño phenomenon, which may influence the abundance of Coleoptera. Circular analysis revealed that Coleoptera, and the most abundant families, presented seasonality throughout the year with a grouped distribution at the beginning of the rainy season (October to December). This study demonstrates that the richness and abundance of the Coleoptera order, in the Cerrado, is strongly influenced by the characteristic climatic seasons of the biome.

Introduction

Climate is one of the main factors responsible for regulating insect populations, directly influencing the biology and behavior of species. Environmental conditions (i.e., temperature, relative humidity, and precipitation) act together to determine the occurrence, model the distribution, and influence the biological cycles of insects (Wellington, 1957; Messenger, 1959; Cammell and Knight, 1992; Peacock et al., 2006; Sable and Rana, 2016; Kellermann and van Heerwaarden, 2019).

In tropical regions, factors such as irregular rainfall distribution can decisively influence the development and biology of many species (Wolda, 1988; Pinheiro et al., 2002; Silva et al., 2011; Oliveira and Frizzas, 2013, 2019) and can affect the seasonality patterns of insects. However, ecologically and taxonomically different groups cannot be expected to respond in the same way to changes in climate variables (Wolda and Fisk, 1981).

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The Cerrado, the second largest Brazilian biome, is one of the most distinctive in terms of climatic characteristics, with a bimodal distribution of rainfall; there is a rainy period (October-March), during which approximately 87% of annual precipitation falls, and a well-defined dry season (April-September) (Silva et al., 2008). This variable has been identified as determining the seasonality observed in insect populations in this biome. The first rains occur in September and October of each year, seeming to be the trigger for most species to resume their activity (Oliveira and Frizzas, 2008, 2013, 2019; Evangelista Neto et al., 2018; Frizzas et al., 2020).

Coleoptera is the most diverse order in the animal kingdom, whose species are associated with different trophic environments and niches, forming guilds (Marinoni and Dutra, 1997; Casari and Ide, 2012). In addition to their great diversity, these organisms are remarkable for the great abundance of individuals generated each year (Oliveira, 2019; Oliveira and Frizzas, 2019). In Brazil, 105 families and 28,000 Coleoptera species are registered (Casari and Ide, 2012).

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Studies have shown that representatives of Coleoptera are more abundant at the beginning of the rainy season (Holtz et al., 2001; Pinheiro et al., 2002; Oliveira and Frizzas, 2008; Silva et al., 2011). However, few studies have evaluated the emergence and behavior of Coleoptera populations in relation to the climatic characteristics of the Cerrado. Studies focusing on an order or a single group within the order may not reflect the behavior of different families, since Coleoptera is a megadiverse order (Grimaldi and Engel, 2005) and there may be groups that adopt different survival strategies in relation to the climatic characteristics of the Cerrado.

Coleoptera studies have used different sampling methods, for example light trap, pheromone, fermented bait, malaise trap, flight interception traps and pitfalls (Ganho and Marinoni, 2003; Silva et al., 2017a; Gonçalves et al., 2020; Puker et al., 2020; Evangelista et al., 2021; Oliveira et al., 2021), and more than one method is often used in a complementary way. However, since many Coleoptera are phototropic, light traps have been one of the main collection methods for studies aimed at evaluating adult diversity (Miyazaki and Dutra, 1995; Freitas et al., 2002; Jocque et al., 2016; Gonçalves et al., 2020). Thus, the objective of this study was to evaluate the seasonality and distribution of Coleoptera families in an area of the Cerrado biome in the Federal District (DF) of Brazil, using light trap.

Material and methods

Study area

The study was conducted in an area (≈700 ha) of cerrado *sensu stricto* located in Embrapa Cerrados (Planaltina/DF, Brazil) (15°36´24.52″ S; 47°44´42.45″ W; 1,169 m a.s.l.) (Fig. 1). The vegetation is characterized by low trees, tortuous trunks, and irregular and twisted branches (Ribeiro and Walter, 2008). The climate of the region is classified as tropical with dry winter (Aw), with altitudes between 600 and 1200 m, average annual temperatures ranging between 20 and 24°C, and an average annual rainfall of between 1300 and 1900 mm (Alvares et al., 2013), with a bimodal distribution of rainfall; dry period (April-September) and rainy period (October-March) (Silva et al., 2008).

Collection and sorting

The collections were made using a Pennsylvania model light trap attached to a 96% alcohol-containing collection container (Fig. 1). Only one light trap was used and it was always installed at the same collection point. Sampling was done monthly between June 2015 and May 2016. The trap was activated in the field for five consecutive nights, during the novilunium period (nights with a new moon) of each month, remaining on for 12 hours (18:00 to 6:00). The sample effort was 60 h/month, totaling 720 h of collection. Most Coleoptera (adult) representatives are phototropic and can be captured by light traps (Miyazaki and Dutra, 1995). In this context, simultaneous studies using light (Miyazaki and Dutra, 1995) and Malaise (Marinoni and Dutra, 1997) traps demonstrated that the light trap captured a greater number of families and specimens.

The insects were transported to the Coleoptera Biology and Ecology Laboratory of the University of Brasília (UnB) (Brasília/DF, Brazil) and sorted under a stereoscopic microscope at 60x magnification (Stemi SV6, Zeiss, Jena, Germany). The Coleoptera were identified at the family level based on an identification key (Casari and Ide, 2012). The specimens were mounted, labeled, and deposited in the Entomological Collection of the Department of Zoology of the University of Brasilia (DZUB).

Climatic variables

Climatic variables (average monthly temperature, average monthly relative air humidity, and monthly accumulated precipitation) were recorded during the entire study period through the Embrapa Cerrados weather station.

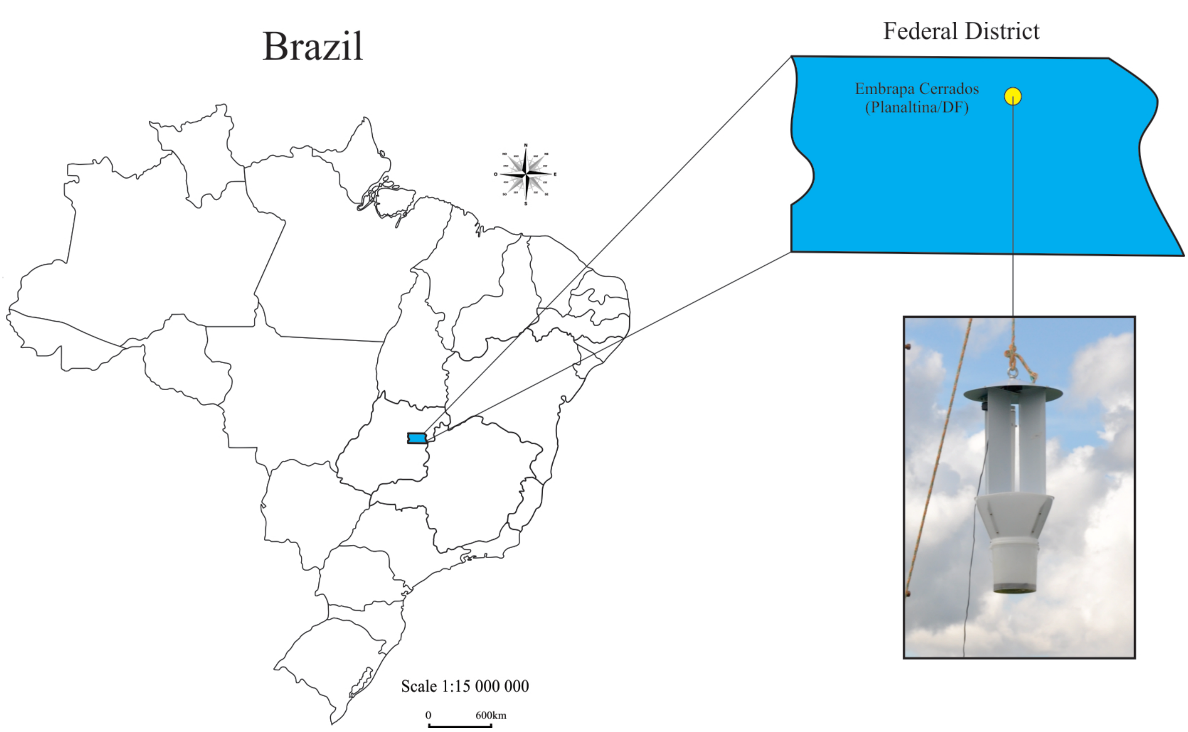

Figure 1. Map of Brazil showing the collection point in the Federal District and the light trap used for Coleoptera sampling.

Data analysis

All statistical analyses were performed using R version 3.2.3 (R Core Team, 2016). The data on the abundance of Coleoptera, at order or family level, did not meet the assumptions of normality related to residues and homogeneity of variance (Shapiro-Wilk test and Bartlett test, $p < 0.01$). Comparisons between dry and rainy seasons based on mean abundances for Coleoptera and families, and based on the mean number of families, were performed using the Wilcoxon-Mann Whitney U test using the 'PMCMRplus' package (Pohlert, 2014).

To verify the relationship between Coleoptera abundance (monthly total of specimens) and climatic variables (monthly average temperature, monthly average relative humidity, and monthly accumulated precipitation), a Spearman correlation analysis was performed.

Since the abundance of insects over time does not show a linear increment, constituting rather a periodic process (Pinheiro et al., 2002), the existence of seasonality in the abundance of the Coleoptera order and the most abundant families were verified using a circular analysis (Zar, 1999), which allows for the determination of the occurrence of population peaks. The concentration measure (r) was calculated, whose value varied from 0 (maximum data dispersion) to 1 (maximum data concentration in the same direction) (Zar, 1999) using the Oriana 4 program (Kovach, 2011).

Results

A total of 21,100 Coleoptera specimens belonging to 34 families were collected. The most abundant families were Melolonthidae (n = 11,075), Carabidae (n = 2,522), Scarabaeidae (n = 2,506), Bostrichidae (n = 1,196), and Chrysomelidae (n = 1,086), which together represented 87.1% of the total specimens collected (Table 1). In this study, we adopted the classification proposed by Endrödi (1966) and Cherman and Morón (2014) who considered Melolonthidae and Scarabaeidae as separate taxa.

Regarding the distribution of families throughout the year, it was observed that Melyridae was not recorded in the rainy period and Cantharidae, Erotylidae, Geotrupidae, Histeridae, Mordellidae, Phengodidae, Rhysodidae, and Trogidae were not recorded during the dry period (Table 1). Melolonthidae was the most abundant family in the rainy period (55.3% of Coleoptera collected during the rainy period) and Scarabaeidae was the most abundant in the dry period (28.6% of Coleoptera collected during the dry period). The average number of

Table 1
Total number of Coleoptera per family collected monthly using a light trap in an area of cerrado *sensu stricto* in Planaltina/DF between June 2015 and May 2016. The columns in green represent the dry period and those in blue represent the rainy period.

Family	2015							2016					Total
	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	
Melolonthidae	0	0	3	0	1071	2739	5303	1439	299	41	163	17	11075
Carabidae	2	0	0	22	1254	424	702	28	7	41	38	4	2522
Scarabaeidae	0	0	0	0	64	607	1243	167	11	16	363	35	2506
Bostrichidae	0	0	14	13	472	275	155	21	33	8	136	69	1196
Chrysomelidae	1	0	1	2	147	626	138	53	20	11	79	8	1086
Staphylinidae	0	0	1	12	95	47	256	47	91	57	64	21	691
Nitidulidae	0	0	1	1	109	81	276	6	5	7	121	14	621
Elateridae	1	0	0	0	59	185	145	17	6	2	6	1	422
Chelonariidae	0	0	0	0	0	163	39	0	0	0	11	0	213
Hydrophilidae	0	0	2	0	17	27	57	10	10	2	12	1	138
Cerambycidae	0	0	1	0	44	40	10	1	4	1	13	3	117
Elmidae	0	0	0	0	0	5	12	2	2	5	78	10	114
Tenebrionidae	0	0	0	0	8	59	12	3	1	0	5	0	88
Rhysodidae	0	0	0	0	1	18	33	2	0	0	0	0	54
Ptilodactylidae	0	0	0	0	1	8	36	0	0	0	1	0	46
Curculionidae	0	0	0	1	7	15	12	1	0	1	2	0	39
Meloidae	1	0	0	1	10	11	9	0	1	0	4	0	37
Coccinellidae	0	0	0	0	11	5	8	2	0	0	6	1	33
Geotrupidae	0	0	0	0	0	5	5	0	4	0	0	0	14
Trogossitidae	0	0	0	0	3	4	1	0	0	0	3	0	11
Cantharidae	0	0	0	0	1	7	1	0	0	0	0	0	9
Rhizophagidae	0	0	0	0	0	5	0	0	0	0	3	1	9
Cleridae	0	0	0	0	1	0	0	0	0	0	1	5	7
Melyridae	0	0	0	0	0	0	0	0	0	0	1	6	7
Melandryidae	0	0	0	0	1	2	1	1	0	0	1	0	6
Silvanidae	0	0	0	0	1	2	2	0	0	0	1	0	6
Trogidae	0	0	0	0	1	4	1	0	0	0	0	0	6
Bolboceratidae	0	0	1	0	0	0	2	0	1	0	1	0	5
Phengodidae	0	0	0	0	0	0	5	0	0	0	0	0	5
Silphidae	1	0	1	0	2	0	1	0	0	0	0	0	5
Histeridae	0	0	0	0	0	2	2	0	0	0	0	0	4
Mordellidae	0	0	0	0	0	2	2	0	0	0	0	0	4
Erotylidae	0	0	0	0	0	2	0	0	0	0	0	0	2
Lagriidae	0	0	1	0	0	0	0	1	0	0	0	0	2
Total	6	0	26	52	3380	5370	8469	1801	495	192	1113	196	21100

families collected was significantly higher during the rainy period ($W = 30.5$; $p = 0.054$) (Fig. 2).

Coleoptera abundance was significantly higher ($W = 456$; $p < 0.0001$) in the rainy season, when 93.4% of the specimens were collected (Table 1; Fig. 2). The highest abundances were recorded between October and December, with a population peak in December (40.1%), and the lowest abundances were found between June and September, with no Coleoptera collected in July (Table 1).

The total precipitation in the study period was 855.2 mm, and the average temperature was 22.4°C, with the highest temperature (25.3°C)

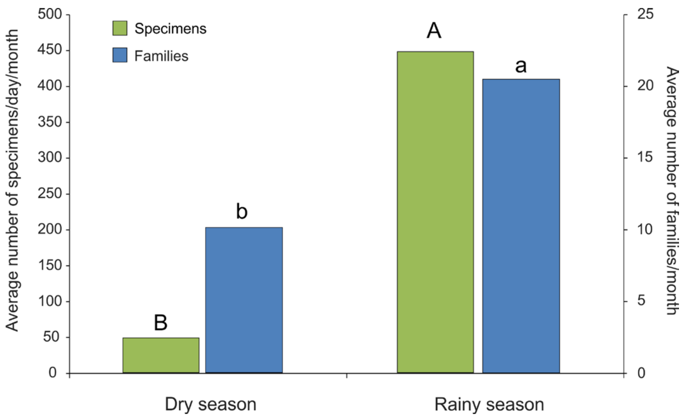

Figure 2. Average number of Coleoptera specimens and families collected using a light trap in an area of cerrado *sensu stricto* in Planaltina/DF in the dry period (April to September) and in the rainy period (October to March) between the years 2015 and 2016. Bars followed by different letters, for the number of species (capital letters) and for the number of families (lowercase letters), differ significantly by Wilcoxon-Mann Whitney U test ($p < 0.01$).

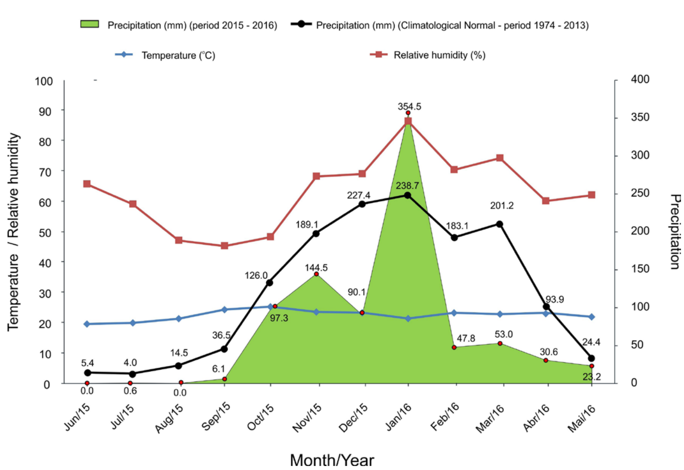

Figure 3. Monthly average temperature and relative air humidity, monthly accumulated precipitation from June 2015 to May 2016, and climatological normal values for the period 1974-2013 (monthly accumulated precipitation) in Planaltina/DF, Brazil.

Table 2
Measurements of the concentration (r), Rayleigh Test, distribution, and season of the year with the greatest total abundance of Coleoptera and the main families captured using a light trap in an area of cerrado *sensu stricto* in Planaltina/DF between June 2015 and May 2016.

Order/family	r	Rayleigh Test (Z)	p - value	Distribution	Season
Coleoptera	0.775	12682.26	< 0.0001	Clustered	Rainy
Melolonthidae	0.875	8470.793	< 0.0001	Clustered	Rainy
Carabidae	0.840	1779.568	< 0.0001	Clustered	Rainy
Scarabaeidae	0.703	1237.437	< 0.0001	Clustered	Rainy
Bostrichidae	0.547	357.885	< 0.0001	Clustered	Rainy
Chrysomelidae	0.768	640.517	< 0.0001	Clustered	Rainy

recorded in October. From November to March, the highest values of relative humidity were registered, and from October to January, the highest values of precipitation. The peaks of relative humidity (86.6%) and precipitation (354.5 mm) occurred in January (Fig. 3). The entire sampling period was characterized by a strong effect of the El Niño phenomenon, whose Oceanic Nino Index (ONI) varied from 1.2 (June 2015) to 2.6 (December 2015), returning to 1.0 in May 2016 [ONI values above 0.5 are considered El Niño, between 0.5 and -0.5 are considered neutral, and below -0.5 are considered La Niña (NOAA, 2020)].

Positive and significant correlations were observed between the number of Coleoptera specimens and temperature ($R^2 = 0.6643$; $S = 96.00$; $p = 0.0185$) and precipitation ($R^2 = 0.8386$; $S = 46.16$; $p < 0.0001$), but there was no correlation with the relative humidity ($R^2 = 0.3187$; $S = 194.84$; $p = 0.3126$).

There was temporal variation in the abundance of Coleoptera, with representatives of this order presenting seasonality throughout the year, and with distribution clustered in the rainy period. This behavior was also verified for the most abundant families: Melolonthidae, Carabidae, Scarabaeidae, Bostrichidae, and Chrysomelidae. The highest concentration of specimens occurred between October and December (Table 2; Fig. 4).

Discussion

Our results showed that in the Cerrado, the greatest abundance and number of Coleoptera families occurs in the first half of the rainy season. Similar results have also been observed in most studies of Coleoptera in this biome (Freitas et al., 2002; Pinheiro et al., 2002; Borges and Santos, 2004; Oliveira and Frizzas, 2008; Silva et al., 2011; Oliveira et al., 2012). This behavior is probably related to the fact that the beginning of the rainy season in the Cerrado marks an increase in the availability of food provided by plants that resume their development (Morais and Diniz, 2004; Oliveira, 2008).

In the different ecosystems, the occupation of niches is associated with the food and reproductive needs of species. This implies that each species searches for spaces that not only supply these needs, but also provide protection (Marinoni, 2001). Coleoptera can be classified in five trophic groups (guilds) - herbivores, algivores, fungivores, detritivores and carnivores (Marinoni, 2001) - that occupy different niches within ecosystems. Since guilds refer to groups of organisms that use the same food resources (Wilson, 1999; Marinoni, 2001), the distribution and seasonality of food resources seem to influence the occurrence and abundance of the different trophic guilds. For example, sites that provided greater heterogeneity of trees and hollow microhabitats determined higher saproxylic guild diversity (Quinto et al., 2014). Rhizophagous (herbivorous) species of Melolonthidae, such as *Phyllophaga capillata* (Blanchard), *P. nitididorsis* Frey and *Aegopsis bolboceridus* (Thomson), concentrate their peak population soon after the first rains in the Cerrado, synchronizing the swarming and mating periods with the sowing of soybean and maize, crops whose roots serve as food for larvae (Oliveira and Frizzas, 2013, 2019; Oliveira et al., 2019).

The Cerrado presents several types of phytophysiognomies, with a vegetation gradient that includes a herbaceous stratum, grasses, shrubs, and forests (Ribeiro and Walter, 2008), which provide different microclimates and wide variation in the availability of food resources. Therefore, these differences in vegetation are expected to affect the occurrence and distribution of the guilds in this biome. Although the different guilds present specific ecological requirements (Wilson, 1999), the pattern of abundance of the guilds observed in this study was similar to that recorded for the order Coleoptera, and its main families, with higher abundance in the first half of the rainy season.

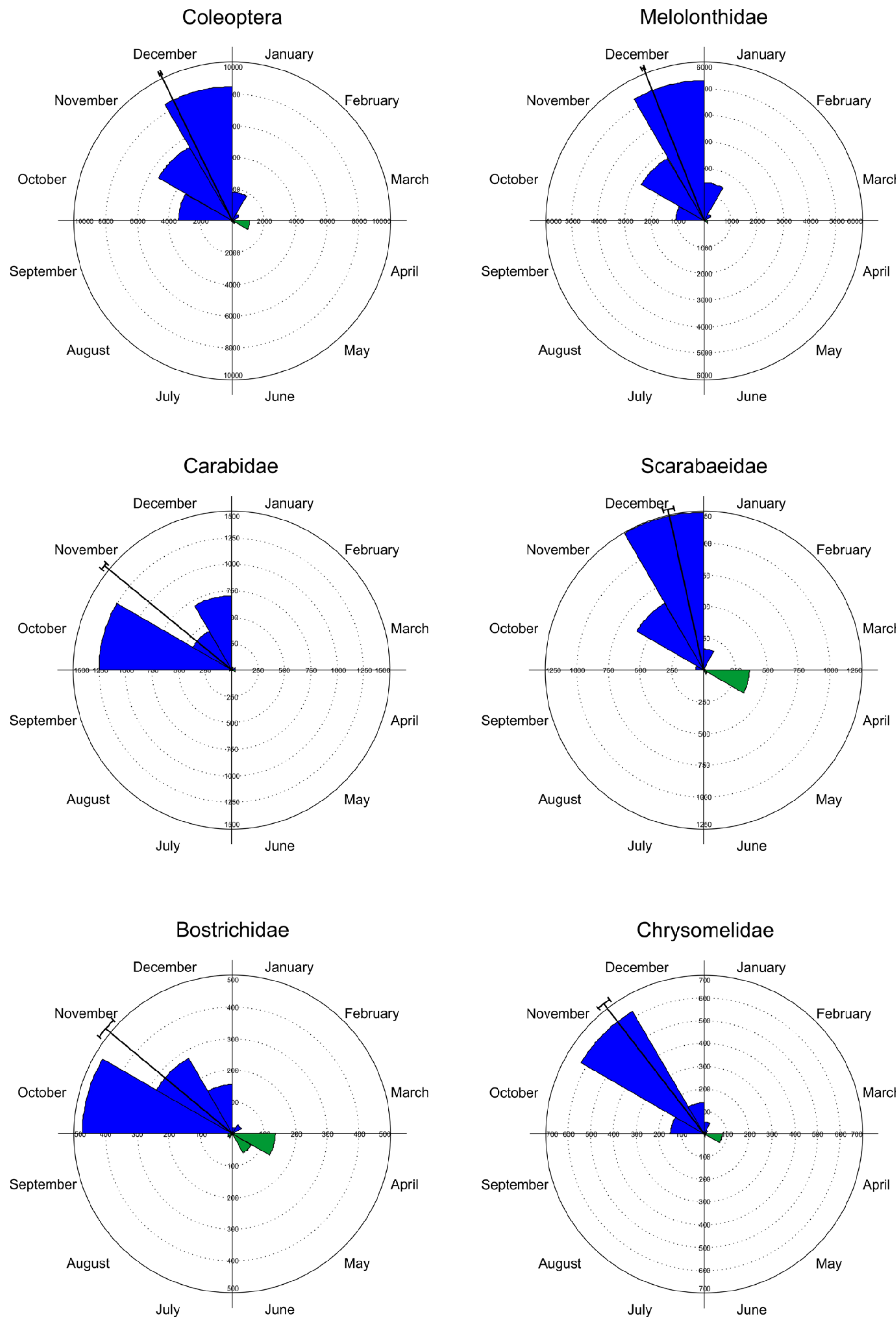

Figure 4. Circular graph of abundance of Coleoptera and the main families (Melolonthidae, Carabidae, Scarabaeidae, Bostrichidae, and Chrysomelidae) captured using a light trap in an area of cerrado *sensu stricto* in Planaltina/DF, Brazil, from June 2015 to May 2016. The areas in blue represent the rainy season (October to March) and the areas in green represent the dry season (April to September).

In the Cerrado, adult populations of Coleoptera (phytophagous and saprophagous) seem to synchronize their activity during the rainy season, when plants resume their vegetative development, ensuring that their offspring find the available food resources, which is essential to face and survive the shortage of these resources in the dry period of the year (Silva et al., 2011). Consequently, the greater abundance of insect species in the rainy season, especially phytophagous and saprophagous species, can also lead to an increased abundance of predatory beetle species. We observed that Carabidae, a family containing a large number of predatory species (Lövei and Sunderland, 1996), were recorded at their highest abundance in the first half of the rainy season.

The development of the ability of flight in many Carabidae species depends on environmental and hormonal stimuli (Lövei and Sunderland, 1996; Desender, 2000; Venn, 2016), and many species have distinct seasonal patterns of flight muscle functionality, including the reproductive state of females with an "oogenesis-flight syndrome". The flight muscle development in each species depends on biotic and abiotic factors (Desender, 2000). We collected about 95% of the Carabidae between October and December (Table 1; Fig. 4), demonstrating that in the Cerrado, as elsewhere in the World, there is a seasonality of flight in the representatives of this family (Boiteau et al., 2000; Desender, 2000). Thus, the ability of the Carabidae to fly at the beginning of the rainy season may be associated with the opportunity these representatives have to feed on prey, during flight, as there are a large number of insects that are swarming at that time of year, such as social insects (termites and ants).

Despite the limitations of the use of light traps in the collection of Carabidae, especially because collection depends on flight, some studies have demonstrated the importance of their use, especially in relation to seasonality and even diversity studies (Kádár and Lövei, 1992; Liu et al., 2007; Jocque et al., 2016). However, the abundance of Carabidae recorded in this study may be only a fraction of the real population abundance of these organisms, since in other periods of the year many species may be unable to fly.

The eight families recorded only during the rainy season (Cantharidae, Erotylidae, Rhysodidae, Geotrupidae, Mordellidae, Trogidae, Histeridae, and Phengodidae) are characterized by representatives that feed on nectar and pollen (Cantharidae), fungi (Erotylidae and Rhysodidae), decomposing organic matter (Geotrupidae, Mordellidae, Trogidae), or are predators (Histeridae, Phengodidae). Most of these resources are associated with the rainy season, and other studies have also pointed out that some of these families are more abundant during this period (Zaragoza–Caballero, 2004; Correa et al., 2013; Rodrigues and Puker, 2013).

On the other hand, among the most abundant families, Scarabaeidae (28.6%) and Bostrichidae (16.6%) were those that comparatively occurred more frequently during the dry period. Species of Scarabaeidae have coprophagous, necrophagous, or generalized habits (Hanski and Cambefort, 1991). These species do not depend directly on vegetation to feed themselves, but rather they depend on resources such as feces and animal carcasses that are scarcer and more ephemeral. We believe that some species of Scarabaeidae may have greater adult activity during the dry season as a strategy to reduce competition for food resources within the group. Another important fact is that during the dry season in the Cerrado, the presence of natural enemies (predators, parasitoids, and microorganisms), mainly fungi, is reduced (Ramos and Diniz, 1993; Morais and Diniz, 1999), which can favor the presence of some Coleoptera species during this season, as has been observed for Lepidoptera and Hemiptera (Morais and Diniz, 1999, 2004; Oliveira and Frizzas, 2015). As Bostrichidae are xylophagous, many species may be able to develop during the dry season, as these food resources are available throughout the year. Other studies with Bostrichidae have reported this family as more abundant during the dry season in the Cerrado (Rocha, 2010; Rocha et al., 2011).

It was observed that 100% of Melyridae, 85.7% of Cleridae, and 77.2% of Elmidae were collected during the dry period. Adults of Melyridae are polyphagous and feed on pollen, nectar, and other insects (Mayor, 2002), which can be found throughout the year. The presence of this family in the dry season may be a strategy to reduce competition with other groups of insects that are more abundant in the rainy season. Studies conducted in the state of Minas Gerais also registered a greater abundance of Melyridae representatives early in the dry period (Matioli and Figueira, 1988). Adults of Cleridae are, in their majority, predators of larvae of wood borer beetles (Casari and Ide, 2012), a food resource available throughout the year, which may have allowed the collection of these insects during the dry period. It is also possible that the volatiles of its hosts (affected by its prey, basically stem borers) are more notable in this climatic period, as has already been observed with semiochemicals mediating the prey (Scolytinae) - predator (Cleridae) interaction (Herms et al., 1991). Adults of Elmidae, although aquatic or semi-aquatic, with a diet based mostly on periphyton (Fernandes and Hamada, 2012), are attracted by light. Sporadically, its adult forms leave the water to disperse through rapid flights (Passos et al., 2007), which may have favored the collection of these individuals by the light trap. This family was also more abundant during the dry season in São Paulo state (Kikuchi and Uieda, 2005).

The analysis of the distribution pattern of Coleoptera, and of the most abundant families, by means of circular analysis, confirmed the seasonal and grouped patterns in the rainy period for these organisms, although some less abundant families presented grouped distribution in the dry period. The same analysis was used in studies conducted in the state of Goiás and in other locations within the Federal District, with similar results for this order (Pinheiro et al., 2002; Silva et al., 2011).

In our study, the families Melolonthidae, Carabidae, Scarabaeidae, Bostrichidae, and Chrysomelidae were the most abundant. Other studies with light traps also recorded Carabidae, Scarabaeidae, and Chrysomelidae among the most abundant families (Miyazaki and Dutra, 1995; Freitas et al., 2002). However, in studies conducted in Brazil with other trap types, the most abundant families varied. Coccinellidae, Chrysomelidae, Mordellidae, and Curculionidae were the most abundant in Goiás (Borges and Santos, 2004), Chrysomelidae, Curculionidae, Cerambycidae, Elateridae, and Staphylinidae in the state of Paraná (Ganho and Marinoni, 2003), and Nitidulidae, Curculionidae, Scarabaeidae, and Staphylinidae in the state of Rio de Janeiro (Teixeira et al., 2009). The type and structure of vegetation, as well as the microclimatic conditions, strongly influence the local fauna of Coleoptera (Hutcheson, 1990; Hanski and Cambefort, 1991; Macedo et al., 2020). Thus, the differences in Coleoptera diversity among studies conducted in Brazil may be related to factors such as differences in vegetation and climate, as well as the type of trap used. Another important fact is that some families are highly diverse, such as Chrysomelidae with 4,362 species in Brazil, Scarabaeidae with 1,777 species, and Carabidae with 1,132 species (Casari and Ide, 2012) and families that have a larger number of species may have a greater chance of being collected.

Climatic factors (temperature, precipitation, and relative humidity) influence the distribution and development of most insects (Messenger, 1959; Silva et al., 2011; Sable and Rana, 2016). We observed that temperature and precipitation were positively correlated with Coleoptera abundance. In fact, there was an increase in temperature and precipitation in the transition months between the dry and rainy periods (September/October) (Fig. 3), which coincides with the increase in Coleoptera collection. Studies conducted in the Cerrado have shown that the increase in temperature and water availability in the soil, provided by precipitation, are the main triggers for the resumption of the activity of several orders of insects, including Coleoptera (Oliveira and Frizzas, 2008; Pinheiro et al., 2002; Silva et al., 2011). However, no direct relationship has been found between this relative humidity and insect abundance in the Cerrado (Pinheiro et al., 2002; Silva et al., 2011).

The data presented in this study are related to an atypical year under the strong influence of the El Niño phenomenon (NOAA, 2020) where the annual precipitation (855.2 mm) was much lower than the expected average based on the climatological normal (1,345.8 mm) (Silva et al., 2017b), as well as the accumulated precipitation at the beginning of the rainy season (Fig. 3). Studies conducted in 2013 in the same area (Embrapa Cerrados) revealed that, in November, a large number of Lepidoptera (Santos et al., 2017; Piovesan et al., 2018; Fonseca-Medrano et al., 2019) and other insects, including Coleoptera, were collected and associated with high precipitation. This suggests that there may be annual variation in Coleoptera abundance as a function of climatic inter-annual variation. Thus, besides the seasonality of Coleoptera families in relation to the rainy and dry seasons, it is also possible to have changes in the peaks of abundance. between years and months due to variations in monthly and annual meteorological factors (Silva et al., 2017b).

Although the seasonal pattern and the clustered distribution of Coleoptera in the Cerrado have been verified in other studies conducted in this order (Pinheiro et al., 2002; Silva et al., 2011; Evangelista Neto et al., 2018), the number of families and the relative abundance of these families seem to receive strong influence from factors such as climate, on a micro-and macro-scale, and are affected heavily by the occurrence of local vegetation. Thus, as the Brazilian Cerrado is a vast mosaic with 11 types of phytophysiognomies and three vegetational formations (Ribeiro and Walter, 2008), it is important to conduct studies in other environments to better understand the behavior of representatives of this order in different environments. Our studies were conducted to evaluate superior taxa (order and family), and studies at a more specific level may reveal patterns different from those found by us.

In the Cerrado biome, several studies have focused on specific Coleoptera families, for example, Bostrichidae and Curculionidae (Rocha et al., 2011), Cerambycidae (Evangelista et al., 2021), Cetoniidae (Evangelista Neto et al., 2018), Geotrupidae (Rodrigues and Puker, 2013), and Scarabaeidae (Almeida and Louzada, 2009; Nunes et al., 2012; Silva et al., 2020). Most of these studies have evaluated how anthropic impacts, such as urbanization (Correa et al., 2019a, 2021; Frizzas et al., 2020), habitat fragmentation (Pimenta and De Marco, 2015; Silva et al., 2020) and land use (Martello et al., 2016; Correa et al., 2019b; Oliveira et al., 2021), have affected the beetle community. For most families, however, several knowledge gaps still exist, as a reflection of this, new species (Fernandes and Hamada, 2012; Vaz-de-Mello et al., 2020) and new species distribution (Gonçalves et al., 2020; Evangelista et al., 2021) are frequently recorded in the Cerrado. Our study, however, evaluated several Coleoptera families in the Cerrado throughout the year, allowing us to have an overview of the diversity and distribution of these families in native vegetation areas. Studies related to Coleoptera community structure in conserved areas are important for future assessments of how these communities may be impacted over time by anthropogenic actions. In addition, the Cerrado is considered to be Brazil's last agricultural frontier (Sano et al., 2019). In recent years, the biome has suffered systematically from anthropic pressures, mainly in relation to deforestation and expansion of agricultural activities. Therefore, studies aimed at understanding patterns of seasonality and distribution are important to guide conservation planning programs, and are of great relevance in defining public conservation policies, since they can indicate priority sites for conservation.

The data presented here confirm the marked influence of the main characteristic of the Brazilian Cerrado, the bimodal distribution of the rains, with a dry season and a well-defined rainy season, which seems to mold the distribution pattern and seasonality of Coleoptera in this biome.

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Conflicts of interest

The authors declare no conflicts of interest.

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