



Ecology

Post-fire recovery of arthropod assemblage in an area of Brazilian savanna

Hélida Ferreira da Cunha^{1✉}, Werther Pereira Ramalho^{1,2}, Amanda Martins Dias³,
Brenda Romeiro Peixoto¹, Gabriel Sampaio Jesus¹, Jennifer de Paula Oliveira¹ &
Thamara Missel Pereira da Silva¹

1. Universidade Estadual de Goiás, Anápolis-GO - Brasil. 2. Instituto Boitatá de Etnobiologia e Conservação da Fauna, Jardim América, Goiânia - GO - Brasil. 3. Universidade Federal do Paraná - Brasil.

EntomoBrasilis 13: e0885 (2020)

Edited by:

William Costa Rodrigues

Article History:

Received: 30.xii.2019

Accepted: 21.iv.2020

Published: 30.iv.2020

✉ Corresponding author:

Hélida Ferreira da Cunha

✉ cunhaf@gmail.com

orcid.org/0000-0002-2821-3986

Funding agencies:

↗ CNPq; CAPES

Abstract. Fire is a frequent agent of disturbance in tropical savannas (e.g., Brazilian Cerrado), but relatively few studies have analyzed how the arthropod community responds to fire disturbance. Following the incursion of an accidental fire into a Cerrado fragment in Central Brazil, we investigated whether the arthropod community is structured by abiotic (climate or fire) or biotic (succession) factors. Our study commenced one week after fire and during the six months afterward. We found 22 arthropod orders, of which Diptera, Hymenoptera, Hemiptera, Blattaria and Coleoptera were the most representative. More than 40% of the arthropod abundance was recorded 40 days after the fire event. The overall arthropod abundance and richness fluctuated in the six months following the fire and does not seem to be related to climatic variables. Temporal beta diversity was explained by a reduction in richness differences along the intervals of time, but the community recovery needs to be treated with caution. The increase in replacement in the last intervals in relation to the fire event indicates that biotic interactions may occur with the arrival of late colonizers and suggest that arthropod communities need a long time to be restructured. These results indicate that the processes of restructuring of the arthropod communities after human-induced fire events are temporally complex, involving loss, gain and taxon replacement, but long-term studies are still needed to understand the dynamics of communities.

Keywords: Beta diversity; burned cerrado *stricto sensu*; Epigeic fauna; insects.

Fire is one of the main elements of vegetation structure and diversity in the Brazilian Cerrado, the largest and most threatened savanna biome of South America (MIRANDA *et al.* 2002; OLIVEIRA-FILHO & RATTER 2002). The occurrence of natural fires in the Cerrado region is ancient, dating back to 32,000 years before the present (SALGADO-LABOURIAU & FERRAZ-VICENTINI 1994). Although relatively little is known about the natural frequency of fires in the Cerrado, it is clear that the intensification of human activities in Central Brazil, especially during recent decades, has increased the frequency and extent of fires well above historical levels (VASCONCELOS *et al.* 2009). The fire occurrence at intervals of one to three years is now common in many areas (COUTINHO 1990; HOFFMANN 1998), mostly caused by agricultural activities (MIRANDA *et al.* 2002).

It has been suggested that the altered frequency and intensity of fires in the Cerrado is causing widespread change in this ecosystem (HOFFMANN & MOREIRA 2002; FRIZZO *et al.* 2011). While the effect of fire on vegetation is relatively well established, however, few studies have evaluated how fire influences the Cerrado's fauna (ARRUDA *et al.* 2018). Fire causes physical changes in the habitat and/or availability of resources that favors some species while others are harmed (FARIA *et al.* 2004; SOUZA *et al.* 2015). Some studies show quick recovery for most arthropod taxa in savannas (MAJER 1984; PRADA *et al.* 1995; VIEIRA *et al.* 1996; ANDERSEN & MÜLLER 2000; VASCONCELOS *et al.* 2009), but in forests indicate that changes are detectable up to several years following a fire (SPRINGETT 1976; COLEMAN &

RIESKE 2006). However, different responses about abundance and diversity to fire have been observed within and between arthropod orders (e.g., WARREN *et al.* 1987; PRYKE & SAMWAYS 2012; KRAL *et al.* 2017), and even studies focused in post-fire responses in the first six months find positive and negative results (KRAL *et al.* 2017).

The effects of fire on beta diversity of arthropods are poorly known and still controversial. Beta diversity is the difference in species composition between communities (WHITTAKER 1972), that can be attributed to two components: species replacement (turnover), where substitution occurs in species composition among sites; and richness differences, which are associated with loss or gain of species (BASELGA 2010; CARVALHO *et al.* 2011). Richness differences may also result in nestedness, when species-poor communities are constituted of subsets of richer communities (ALMEIDA-NETO *et al.* 2008). In general, arthropod populations are fire resistant (PRYKE & SAMWAYS 2012) and comparative studies in Cerrado have not identified effects on species composition in burned areas (VASCONCELLOS *et al.* 2009; ANJOS *et al.* 2016). However, changes in arthropods composition have been attributed mainly to changes in vegetation density (DRIESSEN & KIRKPATRICK 2017), with low congruence in temporal recovery among taxa (PRYKE & SAMWAYS 2012). For example, it is noticed a drastic turnover in epigeic ant communities of burned areas in Cerrado (ANJOS *et al.* 2015), which need a long period of time to re-establish the composition (CANEDO-JÚNIOR *et al.* 2016).

Most of the epigeic fauna of the Cerrado' forested physiognomies (e.g., *cerradão*) uses the leaf litter layer, which provides a significant amount of fuel for wildfires in this ecosystem (HOFFMANN 1996; MIRANDA *et al.* 2002). These organisms can be highly impacted by constant and human-induced fire events. However, we still have much to learn about how communities of epigeic arthropod can be restructured after the disturbance. This study investigated the variations in abundance, richness, and beta diversity components of epigeic arthropod community in a possible recolonization scenario after anthropic fire in a Cerrado fragment. Specifically, we hypothesized that (1) the utilization of order levels may be a valuable alternative to verify fluctuations after fire events in communities composed by taxonomically complex groups; (2) temporal variations in the frequency and richness of arthropods after the fire event are primarily not determined by abiotic factors; and (3) recolonization in the arthropod community composition after the fire event occur in a non-random way, in which we may expect a temporal beta diversity with an increase of replacement in relation to the early community due to recruitment of colonizing taxons from the nearby unburned remnants of Cerrado. To resolve among these questions, we conducted a monitoring of arthropod recovery in a burned Cerrado site throughout six months after a human-induced fire event.

MATERIAL AND METHODS

Study area. The study area was a fragment of cerrado *stricto sensu* with approximately 58 ha (almost 40 ha were burned), located in the Campus of Universidade Estadual de Goiás (UEG) in the municipality of Anápolis, state of Goiás, Brazil (16°22'54" S and 48°56'43" W). The Campus is surrounded by farms, roads that give access to them and by the Agribusiness District of Anápolis. The fragment is bordered by areas of seasonal semideciduous forest and gallery forest along the banks of the Barreiro stream. The altitude is 1,110 m a.s.l, the annual average temperature is 22 °C, the average annual rainfall is 1,450 mm (Cwb Köppen), the soil type is red latosol and the climate is seasonal with warm rainy season in spring and summer, and mild dry season in autumn and winter.

Arthropod sampling. The study area was burned in late September 2010 from the fire of neighboring farms. One week after the fire, we performed a total of 27 samplings grouped in nine sampling intervals (I1, I2, I3, I4, I5, I6, I7, I8 and I9), commenced on September 30th, 2010 and lasted until April 12th, 2011, coinciding with the rainy period (Figure 1). The samples occurred during this period in order to coincide with the recolonization of arthropod fauna with the regeneration of vegetation. The sampling period was structured in intervals of 20 days, from the first day of rain after fire to the last day of rain from the rainy season.

Three 100 m long transects, 100 m apart, were demarcated on site. In each transect, we distributed 10 white plastic trays (44 cm x 28 cm x 7.5 cm) arranged with 10 m of distance among them, totaling 30 trays. A solution of formaldehyde, water and detergent was placed inside the trays in an amount sufficient to cover the entire bottom. The trays were placed on the soil surface and remained in the field during the entire sampling period (180 days). Initially the monitoring of the trays was done daily and with the decrease of the rainy period weekly. Arthropods were collected with polypropylene mesh sieves, sorted under stereomicroscope and stored in properly labeled 80% alcohol glass bottles. All samples were identified to the taxonomic order level and deposited in the Entomological Collection of the Laboratório de Pesquisa Ecológica e Educação Científica (Lab-PEEC) of the UEG.

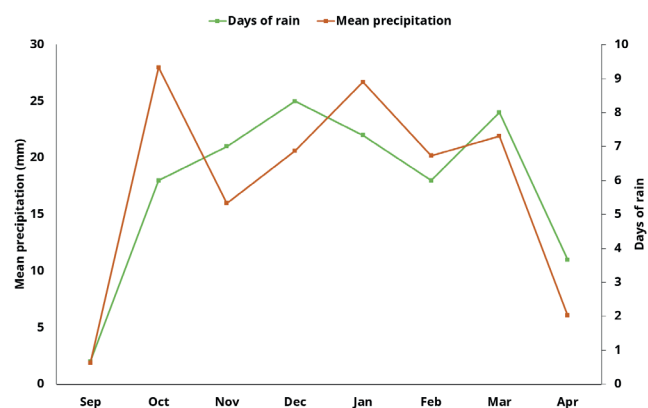


Figure 1. Concentration of rainy season from September 2010 to April 2011 during the sampling period. Climatic data obtained from Station 22 of the Rede Meteorológica da Secretaria de Ciência e Tecnologia do Estado de Goiás, municipality of Anápolis, GO.

Data analyses. Quantitative data are displayed as mean \pm standard deviation. The orders were categorized using a dominance index, defined as $D\% = (i/T) \times 100$, where i is the total number of individuals of a given taxon and T is the total number of individuals throughout the sample. The categories were established as: eudominant > 10%; dominant = 5–10%; subdominant = 2–5%; eventual = 1–2% and rare < 1% (FRIEBE 1983).

We evaluated the efficiency of sample effort through sample-based species accumulation curves (COLWELL *et al.* 2012), created from a frequency matrix where each line represents a taxon and each column one sample (transects per time interval). We used two estimators to obtain the expected richness for the study area: first-order Jackknife, based on species rarity data; and Bootstrap, based on species incidence. The relation between observed and estimated was demonstrated in percentage. Values for creating species accumulation curves for observed and estimated species were created with 100 randomizations using the functions *specaccum* and *poolaccum* of *vegan* package (OKSANEN *et al.* 2017) in R software (R CORE TEAM 2017).

Due to high variability of data, as well as different units of measurements, we transformed the climatic variables using the logarithmic unit ($\log + 1$) to meet the tests assumptions. Initially, we used the following predictive climatic variables: precipitation (P, mm), precipitation accumulated during interval (Pacc, mm), wind velocity (WV, m/s), no-rain days (NRD), minimum relative humidity (Umin, %), average relative humidity (Umean, %), maximum temperature (Tmax, °C) and mean temperature (Tmean, °C). We used the means of each variable for each 20-day interval following fire from the first day of collection. We used the Variance Inflation Factor (VIF) to verify multicollinearity among these variables, where we selected four variables with lowest inflation factor ($VIF < 3$) to comprise the predictor variables group: P ($VIF = 1.75$), Pacc ($VIF = 1.37$), WV ($VIF = 2.57$) and Tmean ($VIF = 2.07$). This analysis was performed using *vif* function of *faraway* package (FARAWAY 2016) in R software (R CORE TEAM 2017).

We determined the influence of climatic variables on richness and frequency of each order of dominant arthropods by sampling interval using stepwise multiple regression analyses with backward elimination. For each dependent variable, we built full models with the four predictor variables previously selected. The selection was done by removing the least significant variables in the model (based on F value), and the procedure was repeated until the final model was composed only of variables with a significant F value ($p < 0.05$). These analyses were performed using functions *lm* and *drop1* of *vegan* package (OKSANEN *et al.* 2017) in R software (R CORE TEAM

2017).

To determine the components involved in structuring the arthropod community after the fire event, we decomposed the beta diversity in general and among sampling intervals using the approach proposed by CARVALHO *et al.* (2011). In this approach, the Jaccard dissimilarity (β_{jac}) is partitioned into species replacement (turnover, β_{rep}) and richness differences (β_{ric}) components. We used the metric NODF (Nestedness metric based on Overlap and Decreasing Fill; ALMEIDA-NETO *et al.* 2008) to test if richness difference in intervals following the fire event is composed of a subset (BASELGA 2010) of taxa found at late intervals when the community is theoretically restructured. We used null models to test whether the overall patterns of each component differ from the expected by chance. Thus, we used null models that randomize the taxa composition among sampling intervals, keeping the sum of columns fixed. We then verified the variations in the beta diversity components along the post-fire intervals in relation to the fire event (first interval) using simple linear regressions. Beta diversity analyses were performed using functions *oecosimu* and *beta.pair* of *vegan* package (OKSANEN *et al.* 2017) and *betapart* (BASELGA *et al.* 2017), respectively; and linear regression using the function *lm* of *vegan* package in R software (R CORE TEAM 2017).

RESULTS

We found 33,216 individuals distributed among 22 arthropod orders, 19 of insect orders. The most abundant orders represented 93% of the specimens and were classified as eudominants (Diptera and Hymenoptera) and dominants (Hemiptera, Blattaria and Coleoptera). Orthoptera and Araneae were classified as subdominants and the 15 remaining orders as rare (Table 1).

The stabilization tendency of the "species" (here, considered at the order level) accumulation curve in the last post-fire sampling demonstrates the efficiency of sample effort

(Figure 2). Observed richness represents 79% and 89% of the expected by Jackknife 1 (28 ± 2.55 order) and Bootstrap (25 ± 0 order), respectively.

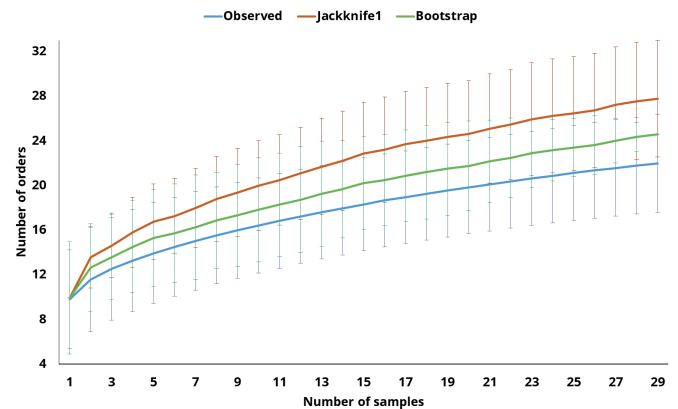


Figure 2. Accumulation curves of observed and estimated (Jackknife 1 and Bootstrap estimators) arthropod orders recorded in a post-fire Cerrado remnant.

Frequency and richness of arthropods varied among sampling intervals. The highest frequency was found during the interval I2 (264 occurrences), while the lowest in the interval I5 (149). The highest richness was found in the intervals I1, I2 and I9 (15 orders each), while the lowest richness was found in I5 (nine orders) (Figure 3). No climatic variable significantly influenced ($p > 0.05$) order richness, total frequency and frequency of eudominant and dominant orders during sampling period.

The total beta diversity among post-fire time intervals ($\beta_{jack} = 0.63$, Mean = 0.80, $p < 0.01$) was explained mainly by replacement ($\beta_{rep} = 0.40$, Mean = 0.75, $p < 0.01$) in comparison to richness differences ($\beta_{ric} = 0.23$, Mean = 0.05, $p < 0.01$), latter higher than expected by chance. We did not find a nested pattern in richness differences among all intervals,

Table 1. Abundance of each arthropod group sampled in a post-fire Cerrado remnant.

Order	Abundance	Mean	Standard Deviation	Dominance (%)	Status
Diptera	12,528	464.00	449.59	37.60	Eudominant
Hymenoptera	10,908	404.00	325.88	32.74	Eudominant
Hemiptera	2,997	111.00	98.57	9.00	Dominant
Blattaria	2,752	101.93	164.03	8.26	Dominant
Coleoptera	1,919	71.07	81.10	5.76	Dominant
Orthoptera	898	33.26	30.31	2.70	Subdominant
Araneae	798	29.56	25.15	2.40	Subdominant
Lepidoptera	232	8.59	6.22	0.70	Rare
Thysanura	184	6.81	10.36	0.55	Rare
Phasmatodea	51	1.89	3.39	0.15	Rare
Acarina	21	0.78	1.83	0.06	Rare
Odonata	11	0.41	1.37	0.03	Rare
Embioptera	4	0.15	0.60	0.01	Rare
Archaeognatha	3	0.11	0.32	0.01	Rare
Strepsiptera	2	0.07	0.27	0.01	Rare
Scolopendromorpha	2	0.07	0.27	0.01	Rare
Ephemeroptera	1	0.04	0.19	0.00	Rare
Psocoptera	1	0.04	0.19	0.00	Rare
Mantodea	1	0.04	0.19	0.00	Rare
Diplura	1	0.04	0.19	0.00	Rare
Thysanoptera	1	0.04	0.19	0.00	Rare
Dermaptera	1	0.04	0.19	0.00	Rare

thus attributed to chance (NODF = 26.61, Mean = 29.25, $p = 0.80$). In a pairwise perspective, beta diversity values tended to decrease and replacement to increase as the sampling intervals increased, whereas the occurrence of zero at some intervals generated non-significant relationships between these components and the intervals post-fire ($p < 0.05$). Richness differences decrease significantly as the sampling intervals increased ($R^2 = 0.48$, $F = 5.71$, $p = 0.05$; Figure 4 and Table 3).

and diversity of taxonomic groups (22 arthropod orders), we show our results in order level. However, the slope of the species accumulation curve in early samplings shows that the data sufficiently represent the arthropod community of this Cerrado fragment. Our results are relatively higher in order richness and abundance of specimens when compared to other studies that collected arthropods in Cerrado using pitfalls (DINIZ & MORAIS 2008; VASCONCELOS et al. 2009; UEHARA-PRADO et al. 2010; LUZ et al. 2013).

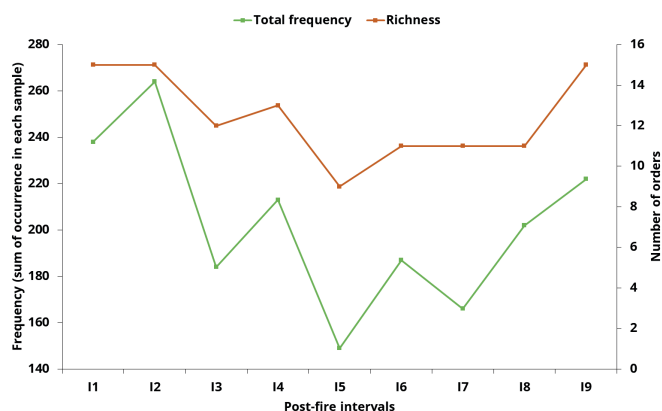


Figure 3. Frequency and arthropod order richness by sampling interval in a post-fire Cerrado remnant.

DISCUSSION

Our results show that sampling effort was sufficient to characterize the arthropod fauna, allowing inferences about the determinant processes of the community structure in the post-fire time intervals. Insects and other arthropods play broad ecological roles in tropical savannas and represent a diverse and abundant group of soil fauna in tropical ecosystems (ANDERSEN & MULLER 2000). Due to this high biodiversity, a great part of studies on arthropod communities show their results at higher taxonomic levels, because the need of taxonomical specialization to identify specimens at the species level. In this way, due to the high number of arthropods sampled (> 30 thousand individuals)

The epigeaic arthropod fauna comprises the community of invertebrates present in the litter-soil interface (Moço et al. 2005) and most of them use the leaf litter layer, which provides a significant amount of fuel for wildfires in the Cerrado (HOFFMANN 1996; MIRANDA et al. 2002). As the samples of epigeaic arthropods can be performed using different methods (e.g., pitfalls, Malaise traps, Winkler extractor, plots etc), the result will always be biased towards the sampling method used. Regarding the few studies conducted in the Cerrado so far, UEHARA-PRADO et al. (2010) point out that the majority have dealt with one or few taxonomic groups and have reached different conclusions about fire effects. In Cerrado, fires appear to have poor short-term effects on either composition or abundance of the arthropod assemblages at the ordinal level (DINIZ & MORAIS 2008; VASCONCELOS et al. 2009; UEHARA-PRADO et al. 2010; LUZ et al. 2013; ANJOS et al. 2016).

The rainy period started one week after fire, which facilitated the vegetation regeneration. In fact, this may have collaborated to fast recovery of the arthropod fauna, since the highest peaks of abundance and order richness were 20 days after fire (interval 12). Diptera and Hymenoptera presented the highest abundance peaks in the nine intervals and thus, were classified as eudominants. Other studies also found these groups as the most abundant (CANEDO-JUNIOR et al. 2016; CARDOSO et al. 2011). ANJOS et al. (2016) attributed the high Diptera abundance to accumulation of arthropods in traps, which attracts decomposing flies. Hymenoptera was massively represented by ants, which are also attracted to the traps to predate the collected arthropods. Blattaria was massively represented by termites due to the swarms in the rainy seasons.

Table 2. Contribution of beta diversity and their components of replacement and richness differences. NODF resumes the richness differences by nestedness. Pairwise comparisons were made in relation to the fire event interval (I1).

Component	Statistic	Mean	p	Pairwise comparison in relation to the fire event								
				I2	I3	I4	I5	I6	I7	I8	I9	
Beta	0.63	0.80	<0.01	0.38	0.27	0.38	0.40	0.35	0.20	0.33	0.24	
Turnover	0.40	0.75	<0.01	0.17	0.00	0.17	0.00	0.27	0.00	0.33	0.24	
Richness	0.23	0.05	<0.01	0.21	0.27	0.21	0.40	0.09	0.20	0.00	0.00	
NODF	26.61	29.25	0.80	0.00	91.67	84.62	100.00	90.91	100.00	0.00	0.00	

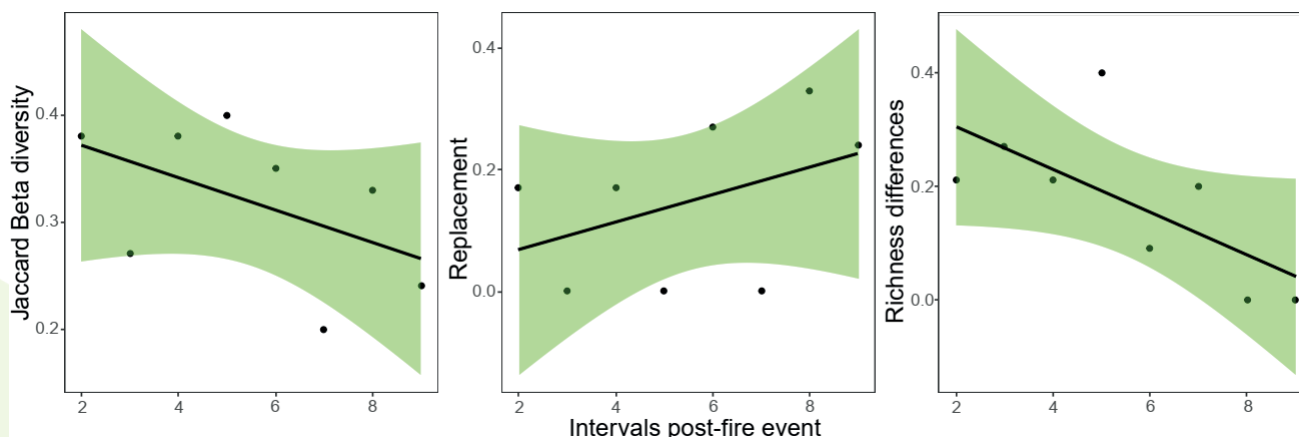


Figure 4. Variation in beta diversity and its additive components in a post-fire Cerrado remnant. Components values for each interval were obtained from pairwise comparison with the fire event interval (I1).

In general, our results show that accidental fire causes a low impact on epigeic arthropod fauna in the cerrado *stricto sensu*. Studies comparing burned and non-burned areas in the Cerrado found no difference in arthropod fauna composition (VASCONCELLOS *et al.* 2009; ANJOS *et al.* 2016). In some cases, they found a positive relationship between arthropods abundance and fire frequency (UEHARA-PRADO *et al.* 2010), which can be found in communities more diversified in sites disturbed by fire (BRUNBJERG *et al.* 2015). Here, most taxa were found shortly after fire (e.g., I1 and I2), followed by loss and gain periods of taxa in the following six months, so that at the end of this period there was no increase in richness. Moreover, restriction to the rainy season supports the assertion that climatic variables did not represent a limiting factor for arthropod fauna after fire. However, there are studies that have shown variation in arthropod diversity between dry and rainy seasons for consecutive years (PINHEIRO *et al.* 2002; VASCONCELLOS *et al.* 2009; ANJOS *et al.* 2016).

Differences in taxon composition through the time were not determined by the chance, although our hypothesis of increasing in replacement along the time has been only partially corroborated. Although we found variable patterns in the pairwise comparisons, a general pattern of richness differences greater than expected by chance explained the temporal variation. However, we cannot expect the community found shortly after the fire event to be composed of generalist subgroups nested to the original community (CARVALHO *et al.* 2011). In this case, the constant recruitment of taxons from non-burned adjacent natural environments, probably allowed a rapid recolonization and a decrease of richness differences in response to the vegetation reestablishment. We then assume that there was a certain resistance of arthropod community after fire disturbance (ANDERSEN & MÜLLER 2000), reinforced by an environmental dynamic independent of external factors (e.g. climate). That makes sense once that, despite the rapid recolonization of a burned area together with the plants' regrowth (DRIESSEN & KIRKPATRICK 2017), the reestablishment of arthropod populations can be tardy and take more than two years (ANJOS *et al.* 2015, 2016; CANEDO-JÚNIOR *et al.* 2016). Therefore, the linear decrease in richness differences along the time intervals and the increase in species replacement in the last two sampling intervals raised two questions about the restructuring of the arthropod community: (1) there is a tendency towards homogenization of the community in terms of richness differences, in a way that the number of orders six months after the fire appears to be similar to the number of orders that colonized the area shortly after the fire event; (2) biotic interactions in the community due to the arrival of late colonizers (e.g. potential competitors and predators) that follow the vegetation succession appear to replace a considerable part of the initial colonizing arthropods. These results indicate that the processes of restructuring of the arthropod communities after human-induced fire events are temporally complex, involving loss, gain and taxon replacement, but long-term studies are still needed to understand the dynamics of communities.

Our results, despite the small spatial and temporal scale, showed fast recovery of epigeic arthropod community in the Cerrado, where most orders were found shortly after the fire event, when the first rains made possible vegetation regrowth. However, climatic variables were not important in this study. Temporal beta diversity was explained by a reduction in richness differences along the intervals of time, but the community recovery needs to be treated with caution. The increase in replacement in the last intervals in relation to the fire event indicates that biotic interactions may occur with the arrival of late colonizers and suggest that arthropod communities need a long time to be restructured. Moreover, despite certain resistance of arthropod communities to the fire in Cerrado biome, constant burning may prevent the

vegetation to recover and, consequently, cause irreversible losses to communities with complex structuring.

ACKNOWLEDGMENTS

HFC is supported by productivity fellowship of Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) (process 465610/2014-5). WPR thanks Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) for Doctoral scholarship. AMD, BPR, GSJ, JPO, TMPS thanks CNPq for PIBIC scholarships.

REFERENCES

- Almeida-Neto, M, P Guimarães, PR Guimarães Jr., RD Loyola & W Ulrich, 2008. A consistent metric for nestedness analysis in ecological systems: reconciling concept and measurement. *Oikos*, 117: 1227-1239. DOI: <https://doi.org/10.1111/j.0030-1299.2008.16644.x>
- Andersen, AN & WL Müller, 2000. Arthropod responses to experimental fire regimes in an Australian tropical savannah: ordinal-level analysis. *Austral Ecology*, 25: 199-209. DOI: <https://doi.org/10.1046/j.1442-9993.2000.01038.x>
- Anjos, D, E Alves-Silva & SP Ribeiro, 2016. Do fire and seasonality affect the establishment and colonization of litter arthropods? *Journal of Insect Conservation*, 20: 653-661. DOI: <https://doi.org/10.1007/s10841-016-9896-4>
- Anjos, DV, RB Campos & SP Ribeiro, 2015. Temporal turnover of species maintains ant diversity but transforms species assemblage. *Sociobiology*, 62: 389-395. DOI: <https://doi.org/10.13102/sociobiology.v62i3.726>
- Arruda, FV, DG Sousa, FB Teresa, VHM Prado, HF Cunha & TJ Lzo, 2018. Trends and gaps of the scientific literature about the effects of fire on Brazilian Cerrado. *Biota Neotropica*, 18: e20170426. DOI: <https://doi.org/10.1590/1676-0611-bn-2017-0426>
- Baselga, A, 2010. Partitioning the turnover and nestedness components of beta diversity. *Global Ecology and Biogeography*, 19: 134-143. DOI: <https://doi.org/10.1111/j.1466-8238.2009.00490.x>
- Baselga, A, D Orme, S Villeger, J De Bortoli & F Leprieur, 2017. Betapart: Partitioning Beta Diversity into Turnover and Nestedness Components. R package version 1.4-1. Available in: <https://CRAN.R-project.org/package=betapart>. [Downloaded on: 01.ii.2018].
- Brunbjerg, AK, GP Jørgensen, KM Nielsen, ML Pedersen, J Svenning & R Ejrnæs, 2015. Disturbance in dry coastal dunes in Denmark promotes diversity of plants and arthropods. *Biological Conservation*, 182: 243-253. DOI: <https://doi.org/10.1016/j.biocon.2014.12.013>
- Canedo-Júnior, EO, RG Cuissi, NHA Curi, CJ Lasmar, K Malves & CR Ribas, 2016. Can anthropic fires affect epigeic and hypogaic Cerrado ant (Hymenoptera: Formicidae) communities in the same way? *Revista de Biología Tropical*, 64: 95-104. DOI: <https://doi.org/10.15517/rbt.v64i1.18239>
- Cardoso, JDC, MB de Paula, A Fernandes, E Santos, MAB Almeida, DF Fonseca & MAM Sallum, 2011. Ecological aspects of mosquitoes (Diptera: Culicidae) in an Atlantic forest area on the north coast of Rio Grande do Sul State, Brazil. *Journal of Vector Ecology*, 36: 175-186. DOI: <https://doi.org/10.1111/j.1948-7134.2011.00155.x>
- Carvalho, JC, P Cardoso & P Gomes, 2011. Determining the relative roles of species replacement and species richness differences in generating beta-diversity patterns. *Global Ecology and Biogeography*, 21: 760-771. DOI: <https://doi.org/10.1111/j.1466-8238.2011.00694.x>
- Coleman, TW & LK Rieseke, 2006. Arthropod response to prescription burning at the soil-litter interface in oak-pine forests. *Forest Ecology and Management*, 233: 52-60. DOI: <https://doi.org/10.1016/j.foreco.2006.06.001>
- Colwell, RK, A Chao, NJ Gotelli, SY Lin, CX Mao, RL Chazdon & JT

- Longino, 2012. Models and estimators linking individual-based and sample-based rarefaction, extrapolation, and comparison of assemblage. *Journal of Plant Ecology*, 5: 3-21. DOI: <https://doi.org/10.1093/jpe/rtr044>
- Coutinho, LM, 1990. Fire in the ecology of the Brazilian Cerrado. In: Goldammer, J.G. ed. Fire in the tropical biota: ecosystem processes and global challenges. Berlin: Springer-Verlag. p. 82-105.
- Diniz, ALR & HC Morais, 2008. Efeito do fogo na abundância de insetos do cerrado: o que sabemos? *Herengeriana*, 2: 39-46.
- Driessen, MM & JB Kirkpatrick, 2017. The implications of succession after fire for the conservation management of moorland invertebrate assemblages. *Journal of Insect Conservation*, 21: 15-37. DOI: <https://doi.org/10.1007/s10841-016-9948-9>
- Faraway, J. 2016. faraway: Functions and Datasets for Books by Julian Faraway. R package version 1.0.7. Available in: <https://CRAN.R-project.org/package=faraway>. [Downloaded on: 01.ii.2018].
- Faria, AS, AP Lima & WE Magnusson, 2004. The effects of fire on behaviour and relative abundance of three lizard species in an Amazonian savanna. *Journal of Tropical Ecology*, 20: 591-594. DOI: <https://doi.org/10.1017/S0266467404001798>
- Friebe, B, 1983. Zur Biologie eines Buchenwaldbodens: 3. Die Käferfauna. *Carolinea*, Karlsruhe, 41: 45-80.
- Frizzo, TLM, C Bonizário, MP Borges & HL Vasconcelos, 2011. Revisão dos efeitos do fogo sobre a fauna de formações savânicas do Brasil. *Oecologia Australis*, 15: 365-379. DOI: <https://doi.org/10.4257/oeco.2011.1502.13>.
- Hoffmann, WA & AG Moreira, 2002. The role of fire in population dynamics of woody plants, pp 159-177. In: Oliveira, PS & RJ Marquis (Eds.). *The cerrados of Brazil: ecology and natural history of a Neotropical savanna*. New York: Columbia University Press.
- Hoffmann, WA, 1996. The effects of cover and fire on seedling establishment in a neotropical savanna. *Journal of Ecology*, 84: 383-393. DOI: <https://doi.org/10.2307/2261200>
- Hoffmann, WA, 1998. Post-burn reproduction of woody plants in a neotropical savanna: the relative importance of sexual and vegetative reproduction. *Journal of Applied Ecology*, 35: 422-433. DOI: <https://doi.org/10.1046/j.1365-2664.1998.00321.x>
- Kral, KC, RF Limb, JP Harmon & TJ Hovick, 2017. Arthropods and fire: Previous research shaping future conservation. *Rangeland Ecology and Management*, 70: 589-598. DOI: <https://doi.org/10.1016/j.rama.2017.03.006>
- Luz, RA, LS Fontes, SRS Cardoso & EFB Lima, 2013. Diversity of the Arthropod edaphic fauna in preserved and managed with pasture areas in Teresina-Piauí-Brazil. *Brazilian Journal of Biology*, 73: 483-489. DOI: <https://doi.org/10.1590/S1519-69842013000300004>
- Majer, JD, 1984. Short-term responses of soil and litter invertebrates to a cool autumn burn in jarrah (*Eucalyptus marginata*) forest in Western Australia. *Pedobiologia*, 26: 229-247.
- Miranda, HS, MC Bustamante & AC Miranda, 2002. The fire factor, pp. 51-68. In: Oliveira, PS & RJ Marquis (Eds.). *The Cerrados of Brazil: Ecology and Natural History of a Neotropical Savanna*. New York, Columbia University Press.
- Moço, MK da S, EF da Gama-Rodrigues, AC da Gama-Rodrigues & MEF Correia, 2005. Caracterização da fauna edáfica em diferentes coberturas vegetais na região Norte Fluminense. *Revista Brasileira de Ciência do Solo*, 29: 555-564. DOI: <https://doi.org/10.1590/s0100-06832005000400008>
- Oksanen, J, FG Blanchet, M Friendly, R Kindt, P Legendre, D McGlinn, PR Minchin, RB O'Hara, GL Simpson, P Solymos, MHH Stevens, E Szoecs & H Wagner, 2017. *Vegan: Community Ecology Package*. R package version 2.4-0. Available in: <http://CRAN.R-project.org/package=vegan>. [Downloaded on: 01.xii.2016].
- Oliveira-Filho, AT & JT Ratter, 2002. Vegetation physiognomies and woody flora of the Cerrado biome, pp. 91-120. In: Oliveira, PS & RJ Marquis (Eds.). *The cerrados of Brazil: ecology and natural history of a Neotropical savanna*. New York: Columbia University Press.
- Pinheiro, F, IR Diniz, D Coelho & MPS Bandeira, 2002. Seasonal pattern of insect abundance in the Brazilian cerrado. *Austral Ecology*, 27: 132-136. DOI: <https://doi.org/10.1046/j.1442-9993.2002.01165.x>
- Prada, M, OJ Marini-Filho & PW Price, 1995. Insects in flower heads of *Aspilia foliacea* (Asteraceae) after a fire in a central Brazilian savanna: Evidence for the plant vigor hypothesis. *Biotropica*, 27: 513-518. DOI: <https://doi.org/10.2307/2388965>
- Pryke, JS & MJ Samways, 2012. Importance of use many taxa and having adequate controls for monitoring impacts of fire for arthropod conservation. *Journal of Insect Conservation*, 16: 177-185. DOI: <https://doi.org/10.1007/s10841-011-9404-9>
- R Development Core Team. 2017. R: A language and environment for statistical computing. R Foundation for Statistical Computing. Available in: <http://www.R-project.org>. [Accessed on: 10.vii.2017].
- Salgado-Labouriau, ML & KR Ferraz-Vicentini, 1994. Fire in the Cerrado 32,000 years ago. *Current Research in the Pleistocene*, 11: 85-87.
- Souza, RF, DV Anjos, R Carvalho & K Del-Claro, 2015. Availability of food and nesting-sites as regulatory mechanisms for the recovery of ant diversity after fire disturbance. *Sociobiology*, 62, 1-9. DOI: <https://doi.org/10.13102/sociobiology.v62i1.1-9>
- Springett, JA, 1976. The effect of prescribed burning on the soil fauna and on litter decomposition in Western Australian forests. *Austral Ecology*, 1: 77-82. DOI: <https://doi.org/10.1111/j.1442-9993.1976.tb01094.x>
- Uehara-Prado, M, ADM Bello, JDO Fernandes, AJ Santos, IA Silva & MV Cianciaruso, 2010. Abundance of epigaic arthropods in a Brazilian savanna under different fire frequencies. *Zoologia*, 27: 718-724. DOI: <https://doi.org/10.1590/s1984-46702010000500008>
- Vasconcelos, HL, R Pacheco, RC Silva, PB Vasconcelos, CT Lopes, AN Costa, & EM Bruna, 2009. Dynamics of the Leaf-Litter Arthropod Fauna Following Fire in a Neotropical Woodland Savanna. *PLoS ONE*, 4: e7762. DOI: <https://doi.org/10.1371/journal.pone.0007762>
- Vieira, EM, I Andrade & PW Price, 1996. Fire effects on a *Palicourea rigida* (Rubiaceae) gall midge: A test of the plant vigor hypothesis. *Biotropica*, 28: 210-217. DOI: <https://doi.org/10.2307/2389075>
- Warren, SD, CJ Scifres & PD Teel, 1987. Response of grassland arthropods to burning - a review. *Agriculture, Ecosystems and Environment*, 19: 105-130. [https://doi.org/10.1016/0167-8809\(87\)90012-0](https://doi.org/10.1016/0167-8809(87)90012-0)
- Whittaker, RH, 1972. Evolution and measurement of species diversity. *Taxon*, 21: 213-251. <https://doi.org/10.2307/1218190>

Suggestion citation:

Cunha, HF, WP Ramalho, AM Dias, BR Peixoto, GS Jesus, JP Oliveira & TMP Silva, 2020. Post-fire recovery of arthropod assemblage in an area of Brazilian savanna. *EntomoBrasilis*, 13: e0885.

Available in: doi: [10.12741/ebrazilis.v13.e0885](https://doi.org/10.12741/ebrazilis.v13.e0885)

