doi:10.12741/ebrasilis.v12i3.842
e-ISSN 1983-0572
Publication of the project Entomologistas do Brasil
www.ebras.bio.br

Forensic Entomology/Entomologia Forense

Diversity of Sarcophagidae (Insecta, Diptera) associated with decomposing carcasses in a rural area of the State of Minas Gerais, Brazil

Maria Lígia Paseto[1]✉, Lucas Silva de Faria[2], Júlio Mendes[2] & Arício Xavier Linhares[1]

1. Universidade Estadual de Campinas. 2. Universidade Federal de Uberlândia.

EntomoBrasilis 12 (3): 118-125 (2019)

Abstract. Cerrado biome presents high biodiversity, but it still lacks works that focus on entomological inventories. New records for species of Sarcophagidae were provided, including the first record of *Blaesoxipha* (*Acridiophaga*) *caridei* (Brèthes) to Brazil, and new occurrences of the following species for the Cerrado and/or for the state of Minas Gerais, Brazil: *Blaesoxipha* (*Acanthodotheca*) *acridiophagoides* (Lopes & Downs), *Oxysarcodexia mineirensis* Souza & Paseto, *Oxysarcodexia occulta* Lopes, *Nephochaetopteryx orbitalis* (Curran & Walley), *Ravinia effrenata* (Walker) and *Sarcophaga* (*Neobellieria*) *polistensis* (Hall). These flies are necrophagous and lay first instar larvae directly of the substrate for feeding and development. Pig carcasses were used as animal model for monitoring the decaying process and attractiveness to insects. This study aimed to evaluate the diversity and abundance of adult Sarcophagidae collected from eight pig carcasses exposed in two different environments at a rural area, and to identify which species used the carcasses as rearing substrates for the immatures. The experiment was carried out until the end of the carcasses decomposition, and lasted 49 days during the dry and cool season (2012), and 30 days during the wet and warm season (2013). A total of 44,446 adults of Sarcophagidae, belonging to 12 genera, 46 species and two morphotypes were collected, mostly during the decay stage of decomposition. In addition, 389 adults of Sarcophagidae emerged from the immatures collected from the carcasses. The present study demonstrated the high diversity of Sarcophagidae attracted by pig carcasses and the high ecological relevance to develop similar studies in other Cerrado areas.

Keywords: Biodiversity; Cerrado Biome; Checklist; Decomposing Process; Flesh Flies.

Diversidade de Sarcophagidae (Insecta, Diptera) associada à decomposição de carcaças em uma área rural do Estado de Minas Gerais, Brasil

Resumo. O bioma Cerrado apresenta grande biodiversidade, mas trabalhos sobre levantamento entomológico ainda são escassos. Novos registros de espécies de Sarcophagidae foram relatados, incluindo o registro inédito de *Blaesoxipha* (*Acridiophaga*) *caridei* (Brèthes) para o Brasil e novas ocorrências das seguintes espécies para o Cerrado e/ou para o estado de Minas Gerais, Brasil: *Blaesoxipha* (*Acanthodotheca*) *acridiophagoides* (Lopes & Downs), *Oxysarcodexia mineirensis* Souza & Paseto, *Oxysarcodexia occulta* Lopes, *Nephochaetopteryx orbitalis* (Curran & Walley), *Ravinia effrenata* (Walker) e *Sarcophaga* (*Neobellieria*) *polistensis* (Hall). Essas moscas são necrófagas e depositam suas larvas de primeiro instar diretamente sobre o substrato para alimentação e desenvolvimento. Carcaças suínas foram utilizadas como modelo animal para monitorar o processo de decomposição e atratividade de insetos. Este estudo teve como objetivo avaliar a diversidade e abundância de sarcofagídeos adultos coletados em oito carcaças suínas expostas em dois diferentes ambientes de uma área rural, e identificar qual espécie utilizou a carcaça como substrato para criação dos imaturos. O experimento foi encerrado quando as carcaças atingiram o último estágio de decomposição, totalizando 49 dias durante a estação fria e seca (2012) e 30 dias durante a estação quente e úmida (2013). Um total de 44.446 sarcofagídeos adultos, pertencentes a 12 gêneros, 46 espécies e dois morfotipos, foi coletado, principalmente durante o estágio seco do processo de decomposição. Além disso, 389 sarcofagídeos adultos emergiram dos imaturos coletados nas carcaças. O presente estudo demonstrou a grande diversidade de Sarcophagidae atraídos por carcaças suínas e a relevância ecológica de desenvolver estudos similares em outras áreas do Cerrado.

Palavras-Chave: Biodiversidade; Bioma Cerrado; Levantamento; Processo de Decomposição; Sarcofagídeos.

There are about 3,000 species of Sarcophagidae (Insecta, Diptera, Oestroidea) distributed in all biogeographical areas, although the highest diversity of species is concentrated in regions of tropical and subtropical climates (Shewell 1987; Pape 1996; Pape *et al.* 2009; Pape *et al.* 2011). The Neotropical fauna of this family is quite diverse, but scarcely known, with approximately 800 described species (Pape 1996; Amorim *et al.* 2002; Brown 2005). Studies regarding biology of some species have already been carried out in Brazil (Lopes 1973; d'Almeida 1987, 1988, 1989, 1994; Loureiro *et al.* 2005; Oliveira-da-Silva *et al.* 2006; Nassu *et al.* 2014; Xavier *et al.* 2015).

Female flesh fly adults are ovoviviparous, depositing first instar larvae directly on the substrate for feeding and development (Denno & Cothran 1976). The size of adults generally range from

Edited by:
William Costa Rodrigues
Article History:
Received: 26.ii.2019
Accepted: 28.ix.2019

✉ **Corresponding author:**
Maria Lígia Paseto
ligiapaseto@gmail.com
http://orcid.org/0000-0003-1543-8710

Funding agencies:
CNPq

two to 25 mm; they are dull gray with three longitudinal black strips on the mesonotum, with checkered or spotted abdomen, with a row of setae in meron, and an undeveloped subscutellum, and immature are of medium size (8-14 mm) (Teskey 1981; Shewell 1987; Carvalho & Mello-Patiu 2008; Mello-Patiu *et al.* 2014; Vairo *et al.* 2015; Mello-Patiu 2016). Currently there are three recognized subfamilies: Miltogramminae, Paramacronychiinae and Sarcophaginae, the last one being the most abundant and diverse in the Neotropical Region. Immature Sarcophaginae also present the greatest diversity of habits among Sarcophagidae larvae, and they are the most important species of forensic interest (Pape 1996; Carvalho & Mello-Patiu 2008; Mello-Patiu *et al.* 2009).

Studies on Sarcophagidae associated with carcasses are more scarce than those on Muscidae and Calliphoridae, and are usually restricted to a list of species occurring in carcasses exposed under different locations and environments of a restrict region (*e.g.* Dias *et al.* 1984; Souza & Linhares 1997; Leandro & d'Almeida 2005; Cruz & Vasconcelos 2006; Barros *et al.* 2008; Barbosa *et al.* 2009; Rosa *et al.* 2009). The difficult identification of Sarcophagidae until species level has been the main cause of a lack of a more robust analysis about studies of succession on pig carrion. However, the data of necrophagous fauna have proved to be an important contribution to the expansion of taxonomic and biogeographic knowledge of Neotropical Sarcophagidae (Faria *et al.* 2013; Mello-Patiu *et al.* 2014; Faria *et al.* 2018).

Cerrado, the second largest Neotropical biome, is an understudied environment already highly fragmented and modified by human action (Ratter *et al.* 1997; Myers *et al.* 2000; Klink & Machado 2005). Thus, the present study aimed to evaluate and present a list of the diversity and abundance of adults of Sarcophagidae from an area of the Cerrado biome during two different seasons, and to identify which of those species uses the decomposing carcasses as rearing substrate.

MATERIAL AND METHODS

The experiment took place in two areas of the Experimental Farm of Glória, an experimental farm of the Federal University of Uberlândia (UFU), Uberlândia City, Minas Gerais State, Southeastern Brazil. The experimental area is placed two kilometers south from an urban area, (18°56'56" S and 48°12'21" W), and has 685 ha (Haridasan & Araújo 2005).

The first area consisted of a pasture with predominance of Gramineae and intense sunlight incidence at ground level. The second area was a fragment of mesophytic semideciduous forest, with some trees over five meters tall high and low incidence of direct sunlight at ground level. The region presents two defined seasons: a dry and cool season from April to September and a wet and warm season between October and March. The mean annual rainfall and temperature is around 1,750 mm and 22.5 °C, respectively (Rosa *et al.* 1991; Silva & Assunção 2004). Meteorological data were obtained from the Weather Station of Experimental Farm of Glória at UFU, located at the farm.

The experiment was performed during the dry and cool season in 2012 and wet and warm season in 2013. Four carcasses of domestic pig (*Sus scrofa* Linnaeus), with weights ranging from nine to 11.5 kg, were bought already died from a commercial slaughterhouse and were used in each season. The carcasses were placed inside metal cages (80 x 60 x 40 cm) and each cage was covered with a metal frame of conic shape, with dimensions of 1.80 m high and 1.40 m wide and a thin transparent nylon fabric, in order to retain the winged insects. A removable tray with sawdust was placed under each cage to collect immature Sarcophagidae that abandoned the carcasses to pupate. The tray content was collected daily and taken to the laboratory. The attracted insects had access to the carcasses through an opening of 30 cm from the ground to the base of the trap, and by the spaces between the bars of the cage (Souza & Linhares 1997; Rosa *et al.* 2009; Faria *et al.* 2018). Four points of exposure of pigs were defined: two in the pasture area and two in the forest area, lying at least 150 m from each other.

The collected adults of flesh flies were pinned and the males had their terminalia exposed to allow identification with the aid of taxonomic keys (Carvalho & Mello-Patiu 2008; Vairo *et al.* 2011) and by comparison with material deposited at the Laboratory of Entomology, Institute of Biomedical Sciences/ UFU and at the Entomological Collection of the National Museum (MNRJ). Immatures were kept in nylon-covered vials with sawdust until the emergence of the adults, and then identified to the lowest possible taxon, following the same procedure used for the attracted ones.

Comparisons of the absolute frequencies of Sarcophagidae, between the forest and pasture environments and between the different seasons, were done by Analysis of Variance (ANOVA) of three factors. The independent variables were species, area and season, and the response variable was the frequency. The means were compared by the Tukey test. The overall significance (α) was 0.05. The indexes of Shannon-Wiener (H') and Equitability (J) were calculated. The analyses were performed using PROC GLM/Statistical Analysis System (SAS 2006) and "DivEs - Diversidade de Espécies" (Rodrigues 2015).

RESULTS

The maximum mean temperatures and humidity during the dry and cool season experiment were 24.5 °C and 82 %, and the minimum values were 13.2 °C and 35 %, respectively. Precipitation levels of 6.0 mm and 0.40 mm occurred at the first and second days of the experiment, consecutively. In the wet and warm season, the means of maximum temperatures and humidity were 25.3 °C and 93 % and of the minimum were 20.4 °C and 71 %. There was precipitation during 16 days, totalizing 213.8 mm.

The adult Sarcophagidae (N = 44,446), collected from all the eight carcasses exposed, belonged to 46 species. Of the total, 29,950 individuals were collected during the dry and cool season and 14,496 during the wet and warm season. According to the collection area, 22,916 individuals were captured at the forest and 21,530 at the pasture. The most abundant species was *Peckia* (*Sarcodexia*) *lambens* (Wiedemann) (N = 13,091) followed by *Oxysarcodexia thornax* (Walker) (N = 9,796) (Table 1).

The pasture area provided the greater diversity and the individuals were more evenly distributed among the collected species (H' = 1.90, J = 0.50) than in the forest area (H' = 1.80, J = 0.48), although the forest area present a higher total absolute frequency of the species (X = 1.86 ± 1.31) than the pasture (X = 1.80 ± 1.22). There was significant difference between the areas (F = 8.76, p = 0.0031). A higher number of species were collected during the dry and cool season (X = 1.85 ± 1.24) than in the wet and warm season (X = 1.77 ± 1.33). The Shannon-Wiener and Equitability indexes showed that the dry and cool season (H' = 2.02, J = 0.53) were more diverse and had a more uniform distribution of species than the wet and warm season (H' = 1.02, J = 0.28).

The total duration of the carcasses decomposition was of 49 days for the dry and cool season and 30 days during the wet and warm season and there was significant difference between the seasons (F = 42.19, p < 0.0001). The decomposition process was divided in four stages, according to Jirón & Cartín (1981): I - fresh, II - bloated, III - decay and IV - dry. Concerning all the collected adults, 34 individuals were collected during stage I, 9,610 individuals during stage II, 21,962 individuals during stage III and 12,840 individuals during stage IV (Table 2). There was significant difference between the II, III and IV stages of decomposition

Table 1. Occurrence of Sarcophagidae associated to carcasses of domestic pigs (*Sus scrofa* L.) in pasture and forest areas of Experimental Farm Glória, Uberlândia, Minas Gerais, Brazil, during the dry and cool season in 2012 and wet and warm season in 2013.

Species	Wet and warm		Dry and cool		Forest		Pasture		Total	%
	AF*	%	AF	%	AF	%	AF	%		
Blaesoxipha (*Acanthodotheca*) *acridiophagoides* (Lopes & Downs)	1	0.007	0	0	1	0.004	0	0	1	0.002
Blaesoxipha (*Acanthodotheca*) *lanei* (Lopes)	60	0.414	0	0	13	0.056	47	0.218	60	0.135
Blaesoxipha (*Acanthodotheca*) *minensis* (Lopes & Downs)	7	0.048	6	0.020	3	0.013	10	0.046	13	0.029
Blaesoxipha (*Acridiophaga*) *caridei* (Brèthes)	0	0	6	0.020	0	0	6	0.027	6	0.013
Dexosarcophaga ampullula (Engel)	0	0	1	0.003	0	0	1	0.004	1	0.002
Dexosarcophaga carvalhoi (Lopes)	8	0.055	825	2.754	90	0.392	743	3.451	833	1.874
Dexosarcophaga paulistana (Lopes)	0	0	65	0.217	55	0.240	10	0.046	65	0.146
Dexosarcophaga transita Townsend	24	0.165	241	0.804	63	0.275	202	0.938	265	0.596
Helicobia aurescens (Townsend)	15	0.103	75	0.250	53	0.231	37	0.171	90	0.202
Helicobia borgmeieri Lopes	4	0.027	7	0.023	1	0.004	10	0.046	11	0.024
Helicobia morionella (Aldrich)	45	0.310	168	0.561	73	0.318	140	0.650	213	0.479
Helicobia rapax (Walker)	0	0	9	0.030	7	0.030	2	0.010	9	0.020
Lipoptilocnema crispina (Lopes)	0	0	1	0.003	1	0.004	0	0	1	0.002
Lipoptilocnema crispula (Lopes)	0	0	1	0.003	0	0	1	0.004	1	0.002
Microcerella erythropyga (Lopes)	5	0.034	3	0.010	1	0.004	7	0.032	8	0.018
Nephochaetopteryx orbitalis (Curran & Walley)	0	0	5	0.016	5	0.021	0	0	5	0.011
Oxysarcodexia admixta (Lopes)	27	0.186	50	0.167	58	0.253	19	0.088	77	0.173
Oxysarcodexia angrensis (Lopes)	123	0.848	463	1.546	542	2.365	44	0.204	586	1.318
Oxysarcodexia aura (Hall)	0	0	13	0.04	0	0	13	0.060	13	0.029
Oxysarcodexia avuncula (Lopes)	27	0.186	2,551	8.517	2,026	8.840	552	2.563	2,578	5.800
Oxysarcodexia carvalhoi Lopes	108	0.745	108	0.360	203	0.885	13	0.060	216	0.486
Oxysarcodexia diana (Lopes)	48	0.331	4,833	16.137	3,324	14.505	1,557	7.231	4,881	10.982
Oxysarcodexia fluminensis Lopes	0	0	34	0.113	16	0.070	18	0.083	34	0.076
Oxysarcodexia major Lopes	5	0.034	26	0.087	21	0.091	10	0.046	31	0.069
Oxysarcodexia meridionalis (Engel)	9	0.062	70	0.233	77	0.336	2	0.010	79	0.177
Oxysarcodexia mineirensis Souza & Paseto	5	0.034	22	0.073	26	0.113	1	0.004	27	0.060
Oxysarcodexia occulta Lopes	0	0	1	0.003	1	0.004	0	0	1	0.002
Oxysarcodexia paulistanensis (Mattos)	40	0.276	309	1.031	26	0.113	323	1.500	349	0.785
Oxysarcodexia simplicoides (Lopes)	0	0	50	0.167	14	0.061	36	0.167	50	0.112
Oxysarcodexia terminalis (Wiedemann)	7	0.048	8	0.026	0	0	15	0.070	15	0.033
Oxysarcodexia thornax (Walker)	947	6.533	8,849	29.546	2,474	10.795	7,322	34.008	9,796	22.040
Peckia (*Euboettcheria*) *anguilla* (Curran & Walley)	17	0.117	63	0.210	67	0.292	13	0.060	80	0.180
Peckia (*Euboettcheria*) *collusor* (Curran & Walley)	281	1.938	1,046	3.492	864	3.770	463	2.150	1,327	2.985
Peckia (*Pattonella*) *intermutans* (Walker)	38	0.262	33	0.110	42	0.183	29	0.134	71	0.159
Peckia (*Peckia*) *chrysostoma* (Wiedemann)	1	0.007	3	0.010	2	0.008	2	0.010	4	0.009

Continue...

Table 1. Continued...

Species	Wet and warm		Dry and cool		Forest		Pasture		Total	%
	AF*	%	AF	%	AF	%	AF	%		
Peckia (*Peckia*) *pexata* (Wulp)	1	0.007	40	0.133	32	0.140	9	0.041	41	0.092
Peckia (*Sarcodexia*) *florencioi* (Prado & Fonseca)	37	0.255	80	0.267	96	0.419	21	0.107	117	0.398
Peckia (*Sarcodexia*) *lambens* (Wiedemann)	10,776	74.337	2,315	7.729	8,382	36.577	4,709	21.871	13,091	29.45
Peckia (*Squamatodes*) *ingens* (Walker)	7	0.048	9	0.030	14	0.061	2	0.010	16	0.036
Peckia (*Squamatodes*) *trivittata* (Curran)	1	0.007	0	0	0	0	1	0.004	1	0.002
Ravinia advena (Walker)	18	0.124	142	0.474	49	0.213	111	0.515	160	0.360
Ravinia belforti (Prado & Fonseca)	484	3.339	423	1.412	84	0.366	823	3.822	907	2.040
Ravinia effrenata (Walker)	7	0.048	8	0.026	1	0.004	14	0.065	15	0.033
Sarcophaga (*Neobellieria*) *polistensis* (Hall)	2	0.013	1	0.003	1	0.004	2	0.010	3	0.006
Titanogrypa (*Cuccullomyia*) *larvicida* (Lopes)	0	0	7	0.023	1	0.004	6	0.027	7	0.015
Titanogrypa (*Sarconeiva*) *fimbriata* Aldrich	0	0	2	0.006	0	0	2	0.010	2	0.004
Tricharaea (*Sarcophagula*) *occidua* (Fabricius)	778	5.367	187	0.624	22	0.096	943	4.380	965	2.171
Oxysarcodexia spp. female	532	3.670	6,662	22.243	4,004	17.472	3,190	14.816	7,194	16.186
Sarcophagidae sp. 1	1	0.007	126	0.420	79	0.344	48	0.223	127	0.285
Tricharaea (*Sarothromyia*) sp. 1	0	0	3	0.010	2	0.008	1	0.004	3	0.006
Total	**14,496**	**100**	**29,950**	**100**	**22,916**	**100**	**21,530**	**100**	**44,446**	**100**

*Where AF is the absolute frequency of species.

(F = 72.08, p < 0.0001). Thirty-three species occurred at three stages of decomposition, II/III/IV. Three species were present during stages III and IV. Only *Nephochaetopteryx orbitalis* (Curran & Walley) occurred during stages II and III. *Oxysarcodexia angrensis* (Lopes), *Oxysarcodexia avuncula* (Lopes), *Oxysarcodexia* spp. female, *Peckia* (*Euboettcheria*) *collusor* (Curran & Walley) and *P.* (*S.*) *lambens* were collected during all the stages of the decomposition process. *Blaesoxipha* (*Acanthodotheca*) *acridiophagoides* (Lopes & Downs) was collected only during stage II. *Dexosarcophaga ampullula* (Engel), *Lipoptilocnema crispina* (Lopes), *Lipoptilocnema crispula* (Lopes), *Oxysarcodexia occulta* Lopes and *Tricharaea* (*Sarothromyia*) sp. 1 were collected only during stage III and *Peckia* (*Squamatodes*) *trivittata* (Curran) with *Titanogrypa* (*Sarconeiva*) *fimbriata* (Aldrich) were observed only during stage IV (Table 2).

Blaesoxipha (*A.*) *acridiophagoides* (N = 1), *L. crispina* (N = 1), *N. orbitalis* (N = 5) and *O. occulta* (N = 1) occurred only at the forest, while *Blaesoxipha* (*Acridiophaga*) *caridei* (Brèthes) (N = 6), *D. ampullula* (N = 1), *L. crispula* (N = 1), *Oxysarcodexia aura* (Hall) (N = 13), *Oxysarcodexia terminalis* (Wiedemann) (N = 15), *P.* (*S.*) *trivittata* (N=1) and *T.* (*S.*) *fimbriata* (N = 2) were collected only at the pasture (Table 4). *Blaesoxipha* (*A.*) *acridiophagoides* (N = 1), *Blaesoxipha* (*A.*) *lanei* (Lopes) (N = 60) and *P.* (*S.*) *trivittata* (N = 1) were collected only during the wet and warm season, while fourteen species were limited to the dry and cool season: *B.* (*A.*) *caridei* (N = 6), *D. ampullula* (N = 1), *Dexosarcophaga paulistana* (Lopes) (N = 65), *Helicobia rapax* (Walker) (N = 9), *L. crispina* (N = 1), *L. crispula* (N = 1), *N. orbitalis* (N = 5), *O. aura* (N = 13), *Oxysarcodexia fluminensis* Lopes (N = 34), *O. occulta* (N = 1), *Oxysarcodexia simplicoides* (Lopes) (N = 50), *Tricharaea* (*Cuccullomyia*) *larvicida* (Lopes) (N = 7), *T.* (S.) *fimbriata* (N = 2) and *Tricharaea* (*Sarothromyia*) sp. 1 (N = 3).

Blaesoxipha (*A.*) *acridiophagoides*, *B.* (*A.*) *caridei*, *O. occulta*, *N. orbitalis* and *Ravinia effrenata* (Walker) were recently recorded for the first time at the Cerrado biome (Mello-Patiu *et al.* 2014). *Sarcophaga* (*Neobellieria*) *polistensis* (Hall) was collected in the Cerrado biome of the states of Maranhão and Mato Grosso, but this was the first record for Minas Gerais.

Regarding immatures collected from the carcasses, 389 reached adult stage and belonged to five species and a group of females of the genus *Oxysarcodexia* (Table 3). *Peckia* (*Pattonella*) *intermutans* (Walker) was the most abundant species (N = 379) (Table 3), reared in carcasses from both areas, and in higher number during the wet and warm season. *Peckia* (*P.*) *intermutans* and *O. avuncula* occurred at both environments. *Oxysarcodexia diana* (Lopes), *O. thornax* and *P.* (*S.*) *lambens* were collected only at forest and the female group of *Oxysarcodexia* occurred only at the pasture. The abundance of species suffered interference of the season (F = 13.92, p = 0.0005). Analyzing the areas separately, the season interference occurred only at the abundance of the species collected at the forest (F = 13.38, p = 0.0006).

Evidence of the presence of a scavenger, possibly a vertebrate, was observed at July, 25th, 2012 in the carcass placed at the forest area, during stage III of the decomposition process. The pair of back legs of the pig carcass was removed, the carcass was displaced laterally and larvae present at the anus region fell out of the collecting tray and were not recovered.

DISCUSSION

Diversity of Sarcophagidae. The results obtained by Carvalho & Linhares (2001), Rosa *et al.* (2011), Faria *et al.* (2013) and Faria *et al.* (2018) also demonstrated a greater abundance of insects attracted during the dry and cool season. This fact can be explained by the longer duration of the pig

Table 2. Occurrence of Sarcophagidae associated to different stages of decomposition of carcasses of domestic pigs (*Sus scrofa* L.) in pasture and forest areas at Experimental Farm Glória, Uberlândia, Minas Gerais, Brazil, during the dry and cool season in 2012 and wet and warm season in 2013.

Species	Stages of decomposition			
	Fresh (I)	Bloated (II)	Decay (III)	Dry (IV)
Blaesoxipha (*Acanthodotheca*) *acridiophagoides* (Lopes & Downs)		✓		
Blaesoxipha (*Acanthodotheca*) *lanei* (Lopes)		✓	✓	✓
Blaesoxipha (*Acanthodotheca*) *minensis* (Lopes & Downs)			✓	✓
Blaesoxipha (*Acridiophaga*) *caridei* (Brèthes)		✓	✓	✓
Dexosarcophaga ampullula (Engel)			✓	
Dexosarcophaga carvalhoi (Lopes)		✓	✓	✓
Dexosarcophaga paulistana (Lopes)		✓	✓	✓
Dexosarcophaga transita Townsend		✓	✓	✓
Helicobia aurescens (Townsend)		✓	✓	✓
Helicobia borgmeieri Lopes		✓	✓	✓
Helicobia morionella (Aldrich)		✓	✓	✓
Helicobia rapax (Walker)			✓	✓
Lipoptilocnema crispina (Lopes)			✓	
Lipoptilocnema crispula (Lopes)			✓	
Microcerella erythropyga (Lopes)		✓	✓	✓
Nephochaetopteryx orbitalis (Curran & Walley)		✓	✓	
Oxysarcodexia admixta (Lopes)		✓	✓	✓
Oxysarcodexia angrensis (Lopes)	✓	✓	✓	✓
Oxysarcodexia aura (Hall)		✓	✓	✓
Oxysarcodexia avuncula (Lopes)	✓	✓	✓	✓
Oxysarcodexia carvalhoi Lopes		✓	✓	✓
Oxysarcodexia diana (Lopes)		✓	✓	✓
Oxysarcodexia fluminensis Lopes		✓	✓	✓
Oxysarcodexia major Lopes		✓	✓	✓
Oxysarcodexia meridionalis (Engel)		✓	✓	✓
Oxysarcodexia mineirensis Souza & Paseto		✓	✓	✓
Oxysarcodexia occulta Lopes			✓	
Oxysarcodexia paulistanensis (Mattos)		✓	✓	✓
Oxysarcodexia simplicoides (Lopes)		✓	✓	✓
Oxysarcodexia terminalis (Wiedemann)		✓	✓	✓
Oxysarcodexia thornax (Walker)		✓	✓	✓
Peckia (*Euboettcheria*) *anguilla* (Curran & Walley)		✓	✓	✓
Peckia (*Euboettcheria*) *collusor* (Curran & Walley)	✓	✓	✓	✓
Peckia (*Pattonella*) *intermutans* (Walker)		✓	✓	✓

Continue...

Table 2. Continued...

Species	Stages of decomposition			
	Fresh (I)	Bloated (II)	Decay (III)	Dry (IV)
Peckia (*Peckia*) *chrysostoma* (Wiedemann)			✓	✓
Peckia (*Peckia*) *pexata* (Wulp)		✓	✓	✓
Peckia (*Sarcodexia*) *florencioi* (Prado & Fonseca)		✓	✓	✓
Peckia (*Sarcodexia*) *lambens* (Wiedemann)	✓	✓	✓	✓
Peckia (*Squamatodes*) *ingens* (Walker)		✓	✓	✓
Peckia (*Squamatodes*) *trivittata* (Curran)				✓
Ravinia advena (Walker)		✓	✓	✓
Ravinia belforti (Prado & Fonseca)		✓	✓	✓
Ravinia effrenata (Walker)		✓	✓	✓
Sarcophaga (*Neobellieria*) *polistensis* (Hall)		✓	✓	✓
Titanogrypa (*Cuccullomyia*) *larvicida* (Lopes)		✓	✓	✓
Titanogrypa (*Sarconeiva*) *fimbriata* (Aldrich)				✓
Tricharaea (*Sarcophagula*) *occidua* (Fabricius)		✓	✓	✓
Oxysarcodexia spp. female	✓	✓	✓	✓
Sarcophagidae sp. 1		✓	✓	✓
Tricharaea (*Sarothromyia*) sp. 1			✓	
Total	**34**	**9,610**	**21,962**	**12,840**

Table 3. Absolute frequency (AF) of Sarcophagidae reared on domestic pig carcasses and reached adult stage, female (FE) and male (MA), collected in pasture (PA) and forest (FO) areas of the Experimental Farm Glória, Uberlândia, Minas Gerais, Brazil, during the dry and cool (DC) season in 2012 and wet and warm (WW) in 2013.

Species	AF	FE	MA	FO	PA	DC	WW
Oxysarcodexia avuncula (Lopes)	**2**	0	2	1	1	2	0
Oxysarcodexia diana (Lopes)	**1**	0	1	1	0	1	0
Oxysarcodexia thornax (Walker)	**1**	1	0	1	0	0	1
Peckia (*P.*) *intermutans* (Walker)	**379**	207	172	376	3	158	221
Peckia (*S.*) *lambens* (Wiedemann)	**4**	4	0	4	0	0	4
Oxysarcodexia spp. female	**2**	2	0	0	2	2	0
Total	**389**	**214**	**175**	**383**	**6**	**163**	**226**

carcasses decomposing process during this season, enabling the attraction of insects for a longer period, than during wet and warm season.

Stage of decomposition. Similar differences in the time of decomposition between the two seasons had been previously observed at Cerrado biome (Rosa *et al.* 2009; Faria *et al.* 2018). These differences appear to be explained basically by the lower humidity, resulting from the absence of rain during the dry season and the higher ventilation and sunlight incidence at ground level at the pasture. This could have interfered in the availability of breeding resources for the insect fauna, resulting in a delay of the decomposition process in those seasons and areas (Monteiro-Filho & Penereiro 1987; Campobasso *et al.* 2001; Rosa *et al.* 2009; Faria *et al.* 2018). The species *B.* (*A.*) *acridiophagoides*, *B.* (*A.*) *caridei*, *O. occulta*, *N. orbitalis*, *R. effrenata* and *S.* (*N.*) *polistensis* were not listed in previous studies of the Diptera fauna of the Cerrado biome and/or for the state of Minas Gerais (for details, see Mello-Patiu *et al.* 2014). Specimens of *Oxysarcodexia mineirensis* Souza & Paseto collected in this study were used for the original species description in a paper previous published (Souza & Paseto 2015) apart from the present study. Faria *et al.* (2018) also collected the species *B.* (*A.*) *caridei*, *N. orbitalis*, *O. mineirensis* and *R. effrenata* in an experiment carried out at the same experimental farm, in 2010.

Sarcophagidae reared from the carcasses. Association of *P.* (*P.*) *intermutans* with carcasses in natural areas of Cerrado at the same studied region is already known (Rosa *et al.* 2009; Faria *et al.* 2013). This species is commonly found breeding on carcasses at anthropic and natural environments in Brazil (Souza & Linhares 1997; Carvalho *et al.* 2000; Barros *et al.* 2008; Barbosa *et al.* 2009). Rosa *et al.* (2009) recorded the emergence of *P.* (*P.*) *intermutans*, *P.* (*S.*) *lambens* and *P.* (*S.*)

trivittata at grazing areas and Faria *et al.* (2013), at the same experimental area, recorded the emergence of *P.* (*E.*) *collusor*, *P.* (*P.*) *intermutans* and *P.* (*S.*) *lambens*. Species of *Oxysarcodexia* breeding in carcasses are not common, so the five specimens reported here could have been incorrectly screened and were, in fact, adults attracted to the carcass.

Vertebrate Actions. Action of a scavenger on the carcasses can accelerate the decomposition process, and they can reduce the availability of substrate and the number of attracted insects. Although variations occur in the form of vertebrate actions, the carcasses are always moved, the skeletons dismembered and the size of the carcasses reduced (Willey & Snyder 1989).

General considerations. The present study demonstrates the high diversity of Sarcophagidae attracted by midsized pig carcasses, pattern already observed in other studies. *Peckia* (*P.*) *intermutans* reared in pig carcasses and the large number of Sarcophagidae species was specific regarding the environment, season or decomposing stage. The new record of occurrence of Sarcophagidae species at the Experimental Farm of Glória, Minas Gerais, Brazil, is an indicator of the high ecological relevance to develop similar studies in other Cerrado areas.

ACKNOWLEDGMENTS

We would like to thank the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for the scholarship granted to MLP; Cátia Antunes de Mello-Patiu for her assistance on the identification of Sarcophagidae species; Carina Mara de Souza, Marcela Aquiyama Alonso and Vinícius da Costa-Silva for their comments about this manuscript.

REFERENCES

Amorim, DS, VC Silva & MPI Balbi, 2002. Estado do conhecimento dos Diptera neotropicais. Principais coleções brasileiras de Diptera: histórico taxonômico e situação atual, pp. 29-36. *In:* Costa C, SA Vanin, JM Lobo & A Melic (Eds.) Proyecto de Red Iberoamericana de Biogeografía y Entomología Sistemática, Editora Zaragoza: Sociedad Entomológica Aragonesa (SEA) & Cyted, Ribeirão Preto, São Paulo.

Barbosa, RR, CA Mello-Patiu, RP Mello & MMC Queiroz, 2009. New records of calyptrate dipterans (Fanniidae, Muscidae and Sarcophagidae) associated with the decomposition of domestic pigs in Brazil. Memórias do Instituto Oswaldo Cruz, 104: 923-926. DOI: https://doi.org/10.1590/s0074-02762009000600018.

Barros, RM, CA Mello-Patiu & JR Pujol-Luz, 2008. Sarcophagidae (Insecta, Diptera) associados à decomposição de carcaças de *Sus scrofa* Linnaeus (Suidae) em área de Cerrado do Distrito Federal, Brasil. Revista Brasileira de Entomologia, 52: 606-609. DOI: https://doi.org/10.1590/s0085-56262008000400011.

Brown, VB, 2005. Malaise trap catches and the crisis in Neotropical Dipterology. American Entomologist, 51: 180-183. DOI: https://doi.org/10.1093/ae/51.3.180.

Campobasso, CPG, D Vella & F Introna, 2001. Factors affecting decomposition and Diptera colonization. Forensic Science International, 120: 18-27. DOI: https://doi.org/10.1016/s0379-0738(01)00411-x.

Carvalho, CJB & CA Mello-Patiu, 2008. Key to the adults of the most common forensic species of Diptera in South America. Revista Brasileira de Entomologia, 52: 390-406. DOI: https://doi.org/10.1590/s0085-56262008000300012.

Carvalho, LML & AX Linhares, 2001. Seasonality of insect succession and pig carcass decomposition in a natural forest area in southeastern Brazil. Journal of Forensic Science, 46: 604-608. DOI: https://doi.org/10.1520/jfs15011j.

Carvalho, LML, PJ Thyssen, AX Linhares & FAB Palhares, 2000. A checklist of arthropods associated with pig carrion and human corpses in Southeastern Brazil. Memórias do Instituto Oswaldo Cruz, 95: 135-138. DOI: https://doi.org/10.1590/s0074-02762000000100023.

Cruz, TM & SD Vasconcelos, 2006. Entomofauna de solo associada à decomposição de carcaça de suíno em um fragmento de mata atlântica de Pernambuco, Brasil. Biociências, 14: 193-201.

d'Almeida, JM, 1987. Substratos para criação de dípteros caliptratos em área rural do estado do Rio de Janeiro. Arquivos da Universidade Federal Rural do Rio de Janeiro, 9: 13-22.

d'Almeida, JM, 1988. Substratos utilizados para criação de dípteros caliptratos em uma área urbana do município do Rio de Janeiro. Memórias do Instituto Oswaldo Cruz, 83: 201-206. DOI: https://doi.org/10.1590/s0074-02761988000200009.

d'Almeida, JM, 1989. Substratos utilizados para criação de dípteros caliptratos no jardim zoológico do Rio de Janeiro (Rio-Zoo). Memórias do Instituto Oswaldo Cruz, 84: 257-264. DOI: https://doi.org/10.1590/s0074-02761989000200016.

d'Almeida, JM, 1994. Ovipositional substrates used by Calyptrate Diptera in Tijuca Forest, Rio de Janeiro. Memórias do Instituto Oswaldo Cruz, 89: 261-264. DOI: https://doi.org/10.1590/s0074-02761994000200027.

Denno, RF & WR Cothran, 1976. Competitive interactions and ecological strategies of Sarcophagid and Calliphorid flies inhabiting rabit carrion. Annals of the Entomological Society of America, 69: 109-113. DOI: https://doi.org/10.1093/aesa/69.1.109.

Dias, ES, DP Neves & HS Lopes, 1984. Estudo sobre a fauna de Sarcophagidae (Diptera) de Belo Horizonte - Minas Gerais. I - Levantamento Taxonômico e Sinantrópico. Memórias do Instituto Oswaldo Cruz, 79: 83-90. DOI: https://doi.org/10.1590/s0074-02761984000100010.

Faria, LS, ML Paseto, FT Franco, VC Perdigão, G Capel & J Mendes, 2013. Insects Breeding in Pig Carrion in Two Environments of a Rural Area of the State of Minas Gerais, Brazil. Neotropical Entomology, 42: 216-222. DOI: https://doi.org/10.1007/s13744-012-0099-8.

Faria, LS, ML Paseto, MS Couri, CA Mello-Patiu & J Mendes, 2018. Insects Associated with Pig Carrion in Two Environments of the Brazilian Savanna. Neotropical Entomology, 47: 181-198. DOI: https://doi.org/10.1007/s13744-017-0518-y.

Haridasan, M & GM Araujo, 2005. Perfil nutricional de espécies lenhosas de duas florestas semidecíduas em Uberlândia, MG. Revista Brasileira de Botânica, 28: 295-303. DOI: https://doi.org/10.1590/s0100-84042005000200010.

Jirón, LF & VM Cartín, 1981. Insect succession in the decomposition of a mammal in Costa Rica. Journal of the New York Entomological Society, 89: 158-165.

Klink, CA & RB Machado, 2005. A conservação do Cerrado brasileiro. Megadiversidade, 1: 147-155.

Leandro, MJF & JM d'Almeida, 2005. Levantamento de Calliphoridae, Fanniidae, Muscidae e Sarcophagidae em um fragmento de mata na Ilha do Governador, Rio de Janeiro, Brasil. Iheringia Série Zoologia, 95: 377-381. DOI: https://doi.org/10.1590/s0073-47212005000400006.

Lopes, HS, 1973. Collecting and rearing Sarcophagid flies (Diptera) in Brazil during forty years. Anais Academia Brasileira de Ciências, 45: 279-291.

Loureiro, MS, VC Oliveira & JM d'Almeida, 2005. Desenvolvimento pós-embrionário de *Pattonella intermutans* (Thompson) (Diptera: Sarcophagidae) em diferentes dietas. Revista Brasileira de Entomologia, 49: 127-129. DOI: https://doi.org/10.1590/s0085-56262005000100014.

Mello-Patiu, CA, WF Soares & KP Silva, 2009. Espécies de Sarcophagidae (Insecta: Diptera) registradas no Estado do Rio de Janeiro. Arquivos do Museu Nacional do Rio de Janeiro, 67: 173-188.

Mello-Patiu, CA, ML Paseto, LS Faria, J Mendes & AX Linhares, 2014. Sarchophagid flies (Insecta, Diptera) from pig carcasses in Minas Gerais, Brazil, with nine new records from the Cerrado, a threatened Neotropical biome. Revista Brasileira

de Entomologia, 58: 142-146. DOI: https://doi.org/10.1590/s0085-56262014000200005.
Mello-Patiu, CA, 2016. Family Sarcophagidae. Zootaxa, 4122: 884-903. DOI: https://doi.org/10.11646/zootaxa.4122.1.75.
Myers, N, RA Mittermeier, CG Mittermeier, GAB da Fonseca & J Kent, 2000. Biodiversity hotspots for conservation priorities. Nature, 403: 853-858.
Monteiro-Filho, ELA & JL Penereiro, 1987. Estudo da decomposição e sucessão sobre uma carcaça animal numa área do estado de São Paulo, Brasil. Revista Brasileira de Biologia, 47: 289-295.
Nassu, MP, PJ Thyssen & AX Linhares, 2014. Developmental rate of immatures of two fly species of forensic importance: *Sarcophaga* (*Liopygia*) *ruficornis* and *Microcerella halli* (Diptera: Sarcophagidae). Parasitology Research, 113: 217-222. DOI: https://doi.org/10.1007/s00436-013-3646-2.
Oliveira-da-Silva, A, R Ale-Rocha & JA Rafael, 2006. Bionomia dos estágios imaturos de duas espécies de *Peckia* (Diptera, Sarcophagidae) em suíno em decomposição em área de floresta no norte do Brasil. Revista Brasileira de Entomologia, 50: 524-527. DOI: https://doi.org/10.1590/s0085-56262006000400013.
Pape, T, 1996. Catalogue of Sarcophagidae of the World (Insecta, Diptera). Memoirs on Entomology International, 8: 1-558.
Pape, T, D Bickel & R Meier, 2009. Diptera diversity: status, challenges and tools. Koninklijke Brill NV, 459 p.
Pape, T, V Blagoderov & MB Mostovski, 2011. Order Diptera Linnaeus, 1758. Animal biodiversity: An outline of higher-level classification and survey of taxonomic richness. Zootaxa, 3148: 222-229. DOI: https://doi.org/10.11646/zootaxa.3148.1.9.
Ratter, JA, JF Ribeiro & S Bridgewater, 1997. The Brazilian Cerrado vegetation and threats to its biodiversity. Annals of Botany, 80: 223-230. DOI: https://doi.org/10.1006/anbo.1997.0469.
Rodrigues, WC, 2015. DivEs - Diversidade de Espécies - Software e Guia do Usuário. Seropédica: Entomologistas do Brasil. Available on: <http://dives.ebras.bio.br>.
Rosa, R, SC Lima & WL Assunção, 1991. Abordagem preliminar das condições climáticas de Uberlândia (MG). Revista Sociedade & Natureza, 3: 91-108.
Rosa, TA, MLY Babata, CM Souza, D Sousa, CA Mello-Patiu & J Mendes, 2009. Dípteros de interesse forense em dois perfis de vegetação de Cerrado em Uberlândia, MG. Neotropical Entomology, 38: 859-866.
Rosa, TA, MLY Babata, CM Souza, D Sousa, CA Mello-Patiu, FZV Mello & J Mendes, 2011. Arthropods associated with pig carrion in two vegetation profiles of Cerrado in the State of Minas Gerais, Brazil. Revista Brasileira de Entomologia, 55: 424-434. DOI: https://doi.org/10.1590/s0085-56262011005000045.
SAS Institute, 2006. S.A.S. user's guide: Statistics, Version 6.12. Cary, NC.
Silva, EM & WL Assunção, 2004. O clima na cidade de Uberlândia, Minas Gerais. Revista Sociedade & Natureza, 16: 91-107.
Shewell, GE, 1987. Sarcophagidae. pp. 1159-1186. *In:* McAlpine JF, BV Peterson, GE Shewell, HJ Teskey, JR Vockeroth & Wood DM (Eds.). Manual of Neartic Diptera vol. II. Agriculture Canada, Quebec, Canada.
Souza, AM & AX Linhares, 1997. Diptera and Coleoptera of potential forensic importance in southeastern Brazil: relative abundance and seasonality. Medical and Veterinary Entomology, 11: 8-12. DOI: https://doi.org/10.1111/j.1365-2915.1997.tb00284.x.
Souza, CM & ML Paseto, 2015. Description of a Neotropical New Species of *Oxysarcodexia* Townsend, 1917 (Diptera: Sarcophagidae). EntomoBrasilis, 8: 222-225. https://doi.org/10.12741/ebrasilis.v8i3.524.
Teskey, HJ, 1981. Morphology and Terminology - Larvae. pp. 74-88. *In*: McAlpine JF, BV Peterson, GE Shewell, HJ Teskey, JR Vockeroth & Wood DM (Eds.). Manual of Neartic Diptera vol. I Research Branch, Agriculture Canada, Quebec, Canada, Monograph 27, 674p.
Vairo, KP, CA Mello-Patiu & CJB Carvalho, 2011. Pictorial identification key for species of Sarcophagidae (Diptera) of potential forensic importance in southern Brazil. Revista Brasileira de Entomologia, 55: 333-347. DOI: https://doi.org/10.1590/s0085-56262011005000033.
Vairo, KP, MO Moura & CA Mello Patiu, 2015. Comparative morphology and identification key for females of nine Sarcophagidae species (Diptera) with forensic importance in Southern Brazil. Revista Brasileira de Entomologia, 59: 177-187. DOI: https://doi.org/10.1016/j.rbe.2015.06.003.
Willey, P & LM Snyder, 1989. Canid modification of human remains: implications for time-since-death estimations. Journal of Forensic Science, 34: 894-901. DOI: https://doi.org/10.1520/jfs12718j.
Xavier, AS, RR Barbosa, CG Barbosa & MMC Queiroz, 2015. Bionomy of two flies of sanitary and forensic importance: *Peckia* (*Sarcodexia*) *lambens* (Wiedemann) and *Oxysarcodexia amorosa* (Schiner) (Diptera, Sarcophagidae). Revista Brasileira de Entomologia, 59: 229-233. DOI: https://doi.org/10.1016/j.rbe.2015.06.002.

****

Suggestion citation:

Paseto, ML, LS de Faria, J Mendes & AX Linhares, 2019. Diversity of Sarcophagidae (Insecta, Diptera) associated with decomposing carcasses in a rural area of the State of Minas Gerais, Brazil. EntomoBrasilis, 12 (3): 118-125.
Available on: doi:10.12741/ebrasilis.v12i3.842