Arthropods associated with pig carrion in two vegetation profiles of Cerrado in the State of Minas Gerais, Brazil

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ABSTRACT. Arthropods associated with pig carrion in two vegetation profiles of Cerrado in the State of Minas Gerais, Brazil. Forensic Entomology research has been concentrated in only a few localities of the "Cerrado" vegetation, the Brazilian Savannah. The present study had, as its objective, an examination of the diversity of arthropod fauna associated with the carcasses of *Sus scrofa* (Linnaeus) in this biome. The study was conducted during the dry and humid periods in two Cerrado vegetation profiles of the State of Minas Gerais. The decaying process was slower and greater quantities of arthropods were collected during the dry period. Insects represented 99% of 161,116 arthropods collected. The majority of these were Diptera (80.2%) and Coleoptera (8.8%). The entomofauna belong to 85 families and at least 212 species. Diptera were represented by 31 families and at least 132 species. Sarcophagidae (Diptera) and Scarabaeidae (Coleoptera) were the richest groups. *Oxysarcodexia* (Sarcophagidae) presented the largest number of attracted species, however none of these species bred in the carcasses. The Coleoptera collected belong to at least 50 species of 21 families. Among these species, *Dermestes maculatus* and *Necrobia rufipes* were observed breeding in the carcasses. This study showed species with potential importance for estimating the postmortem interval (PMI), indicative of seasonal and environmental type located.

KEYWORDS. Coleoptera; Diptera; ecological succession; insect diversity.

RESUMO. Artrópodes associados a carcaças de suínos em dois perfis de vegetação de Cerrado no Estado de Minas Gerais, Brasil. Estudos de entomologia forense em área de Cerrado ainda são escassos no Brasil. Este trabalho teve como objetivo estudar a riqueza da artropodofauna associada a carcaças de suínos domésticos em decomposição. O estudo foi conduzido em dois perfis de Cerrado, Cerrado senso stricto e Campo sujo, durante dois períodos do ano, seco e úmido, em Uberlândia, MG, Brasil. Insetos representaram 99% dos 161.116 artrópodes coletados, sendo representados majoritariamente por dípteros (80,2%) e coleópteros (8,8%). A entomofauna era pertencente a 85 famílias e pelo menos 212 espécies. Os dípteros foram representados por 31 famílias e pelo menos 132 espécies. Os Sarcophagidae (Diptera) e Scarabaeidae (Coleoptera) foram os grupos com maior riqueza de espécies. *Oxysarcodexia* (Sarcophagidae) apresentou o maior número de espécies atraídas. Os coleópteros coletados pertenciam a pelo menos 21 famílias e 50 espécies, dentre as quais *Dermestes maculatus* e *Necrobia rufipes* foram observadas criando-se nas carcaças. Este estudo apresenta várias espécies com potencial importância para estimar o Intervalo Pós-Morte (IPM), e indicativas de sazonalidade e de ambiente localizado.

PALAVRAS-CHAVE. Coleoptera; Diptera; diversidade entomológica; sucessão entomológica.

The importance of entomofauna in the decomposition of animal carcasses is well known. While a vast number of insects use these substrates as food sources for their immature and/or adults forms, others use them as habitats for trophic interaction with other species (Hanski 1987). Adequate knowledge of a natural area also requires studies of the fauna associated with carrion (Turchetto & Vanin 2004). The potential of the insects as forensic indicators has stimulated detailed research regarding the role of fauna in carcass decomposition in various regions and countries (Carvalho & Linhares 2001; Centeno *et al.* 2002; Oliveira-Costa & Mello-Patiu 2004; Kimberly *et al.* 2005; Velásquez 2008). These studies have reported great diversity in the entomofauna found in animal carcasses during the decomposition process and the preference of species for specific stages of decomposition, types of environments and seasons (Campobasso *et al* 2001; Turchetto & Vanin 2004; Archer *et al.* 2005). Species that present such peculiarities are useful as forensic indicators in their respective study regions.

There is increasing interest in Medico-legal Forensic Entomology in Brazil and, as a result, the number of papers published in this area has increased (Carvalho *et al.* 2000; Carvalho & Linhares 2001; Oliveira-Costa & Mello-Patiu 2004; Carvalho *et al.* 2004; Thyssen *et al.* 2005; Barros *et al.*

2008; Barbosa *et al.* 2009). Brazil, a country of continental dimensions, presents notable variation in climate and vegetation among its regions. Studies of forensic entomology in the Cerrado are rare and restricted to only a few localities in this country (Marchiori *et al.* 2000; Barros *et al.* 2008).

In a recent study, Rosa *et al.* (2009) presented detailed information regarding the Diptera found in pig carcasses in this type of vegetation, in Uberlândia, State of Minas Gerais. The present work presents the diversity of entomofauna associated with pig carcasses in two Cerrado profiles in this same region, during the humid and dry seasons.

MATERIAL AND METHODS

The experiments were conducted in a natural area of Cerrado (518,98319 S; 048,29723 W), situated seven kilometers south of the urban perimeter of the city of Uberlândia, State of Minas Gerais, Brazil. The study was conducted during two periods of the year: first in the dry period of 2005 and the second in the humid period of 2006 and in two vegetation profiles, "Campo sujo" and "Cerrado *stricto sensu"*. "Campo sujo" presents predominantly herbaceous, sub-shrub, and sparse shrub and arboreal vegetation. "Cerrado *stricto sensu*" is composed predominantly of shrubs and trees with contorted forms, three to five meters in height (Ribeiro *et al.* 1983). In each period, four carcasses of domestic pigs (*Sus scrofa* Linnaeus) weighing 10 ± 0.5 kg were exposed, two in each of the vegetation profiles, 150 meters from each other. The distance between sites in each of the two vegetation profiles was approximately two kilometers. Removable trays two cm deep containing sawdust were placed on the bottom of the cages to retain ambulatory and immature insects. A pyramidal support of iron bars covered with a thin cotton fabric for the capture of winged insects attracted to the carcass was installed above the cages. A thermo-hygrometer was located in each area to obtain daily temperature and humidity readings during the decomposition process. Precipitation levels were obtained from the weather station of the Federal University of Uberlândia, located 10 and 12 km from the study areas.

The sawdust in the trays were replaced daily and taken to the laboratory for analysis. Winged insects that had been captured were also collected daily, using collector flasks and insect nets. The sawdust with immature specimens (post-feeding larvae) was maintained in the laboratory until adult emergence. The decomposition process was divided according to the classification of Bornemisszà (1957): 1) initial decay, 2) putrefaction, 3) black putrefaction, 4) butyric fermentation and 5) dry decay. Details of the procedures adopted are described in Rosa *et al.* (2009).

RESULTS

Decomposition in the first phase of the experiment lasted 68 days, from July 22 to September 28, 2005. This period had average daily temperatures of 24.87°C (±3.3°C), relative humidity of 52.7% (±6.1%) and a total precipitation of 50.63 mm^3, characterizing the dry period. The second phase was undertaken from January 27 to March 4, 2006, totaling 37 days. This period had average temperatures of 25.7°C (±2.6°C), relative humidity of 60.2% (±5.3%) and a total of 302 mm^3 of precipitation, thus characterizing a warmer and more humid period.

The first two stages of decay had respective durations of one and three days in both periods of the year. The third stage was five days in duration during the dry period and three days in the humid one. The fourth and fifth stages of decay presented durations of 18 and 41 days during the dry period and 13 and 18 days in the humid period (data from Rosa *et al.* 2009).

Carcasses were visited mainly by Calliphoridae, Sarcophagidae, Muscidae and Fanniidae during the first three stages of decay. As the decaying process advanced (fourth and fifth stages), these dipterans were replaced by Stratiomyidae (Diptera), Dermestidae and Cleridae (Coleoptera).

Both areas presented a great diversity of insects during the two study periods. A total of 161,116 arthropods were collected and almost all of them (99%) were insects belonging to 85 families and at least 212 species. Diptera and Coleoptera represented respectively 80.2% and 8.8% of all collected entomofauna. Many other groups of insects were also collected. Heteroptera, Hymenoptera and Lepidoptera were most representative among the other groups (Table I).

Diptera were represented by 31 families and at least 132 species. The Sarcophagidae were notable due to their diversity of species, representing 67.1% of total insects collected and 38% of species. Coleoptera were the second in species diversity with 8.7% of relative frequency and 28% of all attracted species. Scarabaeidae and Staphylinidae were notable due to their great diversity among the coleopterans (Table I). Two Coleoptera species used the carcasses as breeding substrate (Table I). Data on the Diptera reared in the carcasses are presented in Rosa *et al.* (2009).

Oxysarcodexia (Diptera, Sarcophagidae) demonstrated the greatest diversity of species attracted to the carcasses (Table I). *Chrysomya albiceps* Wiedemann was the most abundant among Calliphoridae (Table I). *Cochliomyia macellaria* and *Chrysomya putoria* Wiedemann were other Calliphoridae that presented abundance in the carcasses (Table I). *Ophyra aenescens* Wiedemann was the Muscidae most observed and was collected during the two periods of the year. *Musca domestica* Linnaeus and *Stomoxys calcitrans* Linnaeus also were collected during both periods (Table I). In addition to the significant participation of Diptera species of the above mentioned families in the carcass decomposition, the less frequent presence of Fanniidae, Stratiomyidae and Phoridae (Diptera) was also observed (Table I).

The study registered the occurrence of Sarcophagidae *Blaesoxipha (Acantodotheca) minensis* Lopes & Downs, *Helicobia morionella* Aldrich, *Oxysarcodexia culmiforceps* Aldrich and *Tricharaea (Sarcophagula) ramirezi* Lopes, in

Table I. Absolute (AF) and relative (%) frequencies of arthropods attracted to pig carrion (*Sus scrofa* L.) during dry period of 2005 and the humid period of 2006 in Uberlândia, State of Minas Gerais. * Species reared from the carcasses (from Rosa *et al.* 2009).

Taxa	Dry period		Humid period		Total	
	AF	%	AF	%	AF	%
Diptera						
Sarcophagidae						
Argoravinia rufiventris (Wiedemann, 1830)	21	0.03	5	0.07	26	0.03
Blaesoxipha (Acantodotheca) lanei (Lopes, 1938)	1,297	1.62	233	3.41	1,530	1.76
Blaesoxipha (Acantodotheca) minensis (Lopes & Downs, 1951)	25	0.03	0	0.00	25	0.03
Dexosarcophaga carvalhoi (Lopes, 1980)	5,234	6.55	238	3.48	5,47	6.31
Dexosarcophaga paulistana (Lopes, 1982)	1	0.00	0	0.00	1	0.00
Dexosarcophaga spp.	229	0.29	165	2.42	394	0.45
Dexosarcophaga transita (Townsend, 1917)	403	0.50	5	0.07	408	0.47
Helicobia aurescens (Townsend, 1927)	126	0.16	47	0.69	173	0.20
Helicobia borgmeieri Lopes, 1939	3	0.01	0	0.00	3	0.00
Helicobia morionella (Aldrich, 1930)	35	0.04	0	0.00	35	0.04
Helicobia pilifera Lopes, 1939	67	0.08	6	0.09	73	0.08
Helicobia rapax (Walker, 1842)	161	0.20	26	0.38	187	0.22
Microcerella erythropyza (Lopes, 1936)	19	0.02	0	0.00	19	0.02
Oxysarcodexia admixta (Lopes, 1933)	138	0.17	3	0.04	141	0.16
Oxysarcodexia amorosa (Skiner,1868)	3	0.00	0	0.00	3	0.00
Oxysarcodexia angrensis (Lopes,1933)	333	0.42	8	0.12	341	0.39
Oxysarcodexia aura (Hall, 1937)	667	0.83	5	0.07	672	0.78
Oxysarcodexia avuncula (Lopes, 1932)	11,588	14.50	305	4.47	11,893	13.70
Oxysarcodexia carvalhoi Lopes, 1946	29	0.07	4	0.06	33	0.04
Oxysarcodexia culmiforceps Dodge, 1966	10	0.01	0	0.00	10	0.01
Oxysarcodexia diana (Lopes, 1933)	891	1.12	40	0.59	931	1.07
Oxysarcodexia eberti Lopes & Tibana, 1987	30	0.04	2	0.03	32	0.04
Oxysarcodexia fluminensis Lopes, 1946	253	0.32	12	0.18	265	0.31
Oxysarcodexia modesta Lopes, 1946	1	0.00	0	0.00	1	0.00
Oxysarcodexia paulistanensis (Mattos, 1919)	32	0.04	1	0.02	33	0.04
Oxysarcodexia riograndensis Lopes, 1946	5	0.01	0	0.00	5	0.01
Oxysarcodexia simplicoides (Lopes, 1933)	388	0.48	41	0.60	429	0.49
Oxysarcodexia spp.	17	0.02	3	0.04	20	0.02
Oxysarcodexia terminalis (Wiedemann, 1830)	1	0.00	0	0.00	1	0.0
Oxysarcodexia thornax (Walker, 1849)	37,557	46.98	2,972	43.51	40,529	46.71
Oxysarcodexia xanthosoma (Aldrich, 1916)	3	0.01	0	0.00	3	0.00
Peckia (Euboettcheria) anguilla (Curran & Walley, 1934)	132	0.17	24	0.35	156	0.18
Peckia (Euboettcheria) australis (Townsend, 1927)	2	0.01	0	0.00	2	0.00
Peckia (Euboettcheria) collusor (Curran & Walley, 1934)	264	0.33	25	0.37	289	0.33
Peckia (Euboettcheria) florencioi (Prado & Fonseca, 1932)	89	0.11	21	0.31	110	0.13
Peckia (Pattonella) intermutans (Walker, 1861) *	35	0.04	10	0.15	45	0.05
Peckia (Peckia) chrysostoma (Wiedemann, 1830)	80	0.10	5	0.07	85	0.10
Peckia (Peckia) pexata (Wulp, 1895)	73	0.09	2	0.03	75	0.09
Peckia (Squamatodes) ingens (Walker, 1849)	6	0.01	2	0.03	8	0.01
Peckia (Squamatodes) trivittata (Curran, 1927) *	197	0.25	98	1.44	295	0.34
Ravinia advena (Walker, 1853)	360	0.45	52	0.76	412	0.48
Ravinia belforti (Prado & Fonseca 1932)	1,910	2.39	95	1.39	2,005	2.31
Sarcodexia lambens (Wiedemann, 1830) *	1,035	1.29	331	4.85	1,366	1.57
Sarconeiva fimbriata (Aldrich, 1916)	1	0.00	0	0.00	1	0.00
Sarcophaga (Lipoptilocnema) crispula (Lopes,1938)	124	0.16	2	0.03	126	0.15

Continue

Table I. Continued.

Taxa	Dry period		Humid period		Total	
	AF	%	AF	%	AF	%
Titanogrypa (Cucullomyia) larvicida (Lopes, 1935)	81	0.10	5	0.07	86	0.10
Tricharaea (Sarcophagula) occidua (Fabricius, 1794)	4,602	5.76	1,606	3.51	6,208	7.16
Tricharaea (Sarcophagula) ramirezi (Lopes, 1990)	28	0.04	0	0.00	28	0.03
Sarcophagidae spp.	11,348	14.20	431	6.31	11,779	13.60
Total Sarcophagidae	79,934	100.00	6,830	100.00	86,764	100.00
Muscidae						
Atherigona orientalis (Schiner, 1868)	1,007	16.74	35	2.17	1,042	13.65
Biopyrellia bipuncta (Wiedemann, 1830)	855	14.21	1	0.06	856	11.22
Brontaea debilis (Williston, 1896)	130	2.16	5	0.31	135	1.77
Brontaea spp.	0	0.00	3	0.19	3	0.04
Cyrtoneurina sp.	0	0.00	11	0.68	11	0.14
Cyrtoneuropsis conspersa (Stein, 1911)	1	0.02	0	0.00	1	0.01
Cyrtoneuropsis rescita (Walker, 1861).	453	7.53	241	14.91	694	9.09
Graphomya maculata (Scopoli, 1763)	29	0.48	6	0.37	35	0.46
Myospila sp.	2	0.03	0	0.00	2	0.03
Morellia ochricornis (Wiedemann, 1830)	35	0.58	1	0.06	36	0.47
Musca domestica (Linnaeus, 1758)*	1,693	28.14	234	14.48	1,927	25.25
Ophyra chalcogaster (Wiedemann, 1824)	12	0.20	1	0.06	13	0.17
Ophyra aenescens (Wiedemann, 1830)*	1,517	0.25	1,020	0.63	2,537	0.33
Pseudoptilolepis nigripoda (Snyder, 1949)	0	0.00	14	0.87	14	0.18
Sarcopromusca pruna (Shannon & Del Ponte, 1926)	268	4.45	5	0.31	273	3.58
Stomoxys calcitrans (Linnaeus, 1758) *	12	0.20	39	2.41	51	0.67
Synthesiomyia nudiseta (Wulp, 1883)	2	0.03	0	0.00	2	0.03
Total Muscidae	6,016	100.00	1,616	100.00	7,632	100.00
Calliphoridae						
Chloroprocta idiodea (Townsend, 1935)	0	0.00	2	0.10	2	0.03
Chrysomya albiceps (Wiedemann, 1819)*	4,351	72.99	1,452	71.25	5,803	72.55
Chrysomya megacephala (Fabricius, 1794)	12	0.20	53	2.60	65	0.81
Chrysomya putoria (Wiedemann, 1818)*	480	8.05	55	2.70	535	6.69
Cochliomyia hominivorax (Coquerel, 1858)	6	0.10	0	0.00	6	0.08
Cochliomyia macellaria (Fabricius, 1775)	1,013	16.99	404	19.82	1,417	17.72
Hemilucilia segmentaria (Fabricius, 1805)*	9	0.15	15	0.74	24	0.30
Lucilia cuprina (Wiedemann, 1830)	1	0.02	1	0.05	2	0.03
Lucilia eximia (Wiedemann, 1819)*	76	1.28	52	2.55	128	1.60
Lucilia sericata (Meigen, 1826)	13	0.22	4	0.20	17	0.21
Total Calliphoridae	5,961	100.00	2,038	100.00	7,999	100.00
Fanniidae						
Fannia (subgroup *pusio*)*	49	9.65	61	12.18	110	10.90
Fannia pusio (Wiedemann, 1830)*	314	61.81	346	69.06	660	65.41
Fannia snyderi (Seago, 1954)	90	17.72	13	2.59	103	10.21
Fannia sp.	55	10.83	81	16.17	136	13.48
Total Fanniidae	508	100.00	501	100.00	1,009	100.00
Phoridae *	13	0.01	1	0.01	14	0.01
Stratiomyidae						
Hermetia illuscens (Linnaeus, 1758)*	38	0.03	15	0.08	53	0.04
Other Diptera	17,951	16.26	7,831	41.58	25,769	19.94
Total Diptera	110,408	100.00	18,832	100.00	129,240	100.00

Continue

Table I. Continued.

Taxa	Dry period		Humid period		Total	
	AF	%	AF	%	AF	%
Coleoptera						
Cleridae						
Necrobia rufipes (De Geer, 1775)*	2,185	100.00	136	100.00	2,321	100.00
Dermestidae						
Dermestes maculatus (DeGeer, 1774)*	4,610	100.00	264	100.00	4,874	100.00
Staphylinidae						
Aleochara sp.	22	1.76	18	3.16	40	2.20
Atheta sp.	37	2.96	40	7.03	77	4.23
Cryptobium sp.	1	0.08	0	0.00	1	0.06
Dybelonetes hibridus (Erichson, 1840)	9	0.72	9	1.58	18	0.99
Eulissus calybaeus (Mannerheim, 1830)	1	0.08	2	0.35	3	0.17
Heterothops spp.	10	0.80	6	1.05	16	0.88
Neophyrus sp.	2	0.16	1	0.18	3	0.17
Oxytellus sp.	1	0.08	0	0.00	1	0.06
Philonthus flavolimbatus (Erichson, 1840)	723	57.75	40	59.75	1,063	58.37
Philonthus spp.	417	33.31	132	23.20	549	30.15
Other Staphylinidae	29	2.32	21	3.69	50	2.75
Total Staphylinidae	1,252	100.00	569	100.00	1,821	100.00
Histeridae						
Euspilotus spp.	1,156	88.11	946	85.30	2,102	86.82
Histeridae spp.	156	11.89	163	14.70	319	13.18
Total Histeridae	1,312	100.00	1,109	100.00	2,421	100.00
Scarabaeidae						
Ataenius aequalis Harold, 1880	48	12.28	53	16.83	101	14.31
Ataenius sp.	6	1.54	3	0.95	9	1.27
Ateuchus vividus (Germar, 1824)	26	6.65	42	13.33	68	9.63
Canthidium sp.	2	0.51	0	0.00	2	0.28
Canthon virens (Mannerheim, 1829)	12	3.07	8	2.54	20	2.83
Coprophanaeus ensifer (Germar, 1824)	0	0.00	2	0.64	2	0.28
Deltochilum (*Deltohyboma*) sp.	33	8.44	18	5.71	51	7.22
Dichotomius nisus (Olivier, 1789)	1	0.25	0	0.00	1	0.14
Dichotomius opacipennis (Luederwaldt, 1931)	0	0.00	1	0.32	1	0.14
Eurysternus aeneus Génier, 2009	2	0.51	12	3.81	14	1.98
Labarrus pseudolividus (Balthasar, 1941)	0	0.00	1	0.32	1	0.14
Ontherus appendiculattus (Mannerheim, 1829)	109	7.88	32	10.16	141	19.97
Onthophagus hirculus (Mannerheim, 1829)	89	22.76	42	13.33	131	18.55
Trichillum externepunctatum Preudhomme de Borre, 1880	55	14.07	98	31.11	153	21.67
Scarabaeidae spp.	8	2.05	3	0.95	11	1.56
Total Scarabaeidae	391	100.00	315	100.00	706	100.00
Geotrupidae						
Bolbapium striatopunctatum (Castelnau, 1840)	2	100.00	0	0.00	2	100.00
Silphidae						
Oxyletrum discicolle (Brullé)	2	100.00	1	100.00	3	100.00
Trogidae						
Omorgus suberosus (Fabricius, 1775)	3	100.00	2	100.00	5	100.00
Other Coleoptera	1,111	13.42	844	14.47	1,955	13.86
Total Coleoptera	8,276	100.00	5,832	100.00	14,108	100.00

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Table I. Continued.

Taxa	Dry period		Humid period		Total	
	AF	%	AF	%	AF	%
Other Arthropoda						
Hemiptera	9,318	100.00	532	100.00	9,850	100.00
Hymenoptera	3,682	100.00	659	100.00	4,341	100.00
Lepidoptera	841	100.00	2,338	100.00	3,179	100.00
Blattodea	1	0.00	5	0.02	6	0.01
Dermaptera	0	0.00	2	0.01	2	0.00
Homoptera	1	0.00	1	0.00	2	0.00
Isoptera	47	0.04	20	0.07	67	0.04
Odonata	69	0.05	15	0.05	84	0.05
Orthoptera	159	0.12	32	0.11	191	0.12
Acari	13	0.01	11	0.04	24	0.02
Araneida	21	0.02	1	0.00	22	0.01
Total	132,836	100.00	28,280	100.00	161,116	100.00

considerable abundance but only in the dry period of the year. On the other hand, *Cyrtoneurina* sp., *Pseudoptiloleps nigripoda* Snyder (Muscidae) and Micropezidae were observed exclusively in the humid period. Specimens of *Microcerella erythropyga* Lopes (Diptera, Sarcophagidae) were collected only at the "Campo sujo" vegetation profile (Table II).

The Coleoptera collected belong to at least 50 species of 21 families. Only *Dermestes maculatus* De Geer (Dermestidae) and *Necrobia rufipes* De Geer (Cleridae), however, were observed breeding in the carcasses. Some Coleoptera and representatives of other orders, showed preference for specific areas and periods of the year (Tables I and II). *Dermestes maculatus* was found in the carcasses in the second and third stages, between the third and sixth day of the postmortem interval (PMI), and their larvae were encountered on the trays under the carcasses from the sixth day of PMI (third stage) during the humid period. Adults of *Necrobia rufipes* were found in the carcasses from the sixth to the tenth days of PMI in both humid and dry periods. There were some adults that had emerged from larvae collected on the eleventh day of PMI, in the dry period. Both of the above species presented higher numbers of larvae during stage five of the dry period and a significant reduction in the numbers of attracted and reared adults during the humid period of the year.

Among the Scarabeidae, the following species were dominant: *Trichillum externepunctatum* Predhomme de Borre *Onthophagus hirculus* (Mannerheim), *Ontherus appendiculatus* (Mannerheim) and *Ataenius aequalis* Harold. All of these were collected during both periods of the year in both areas (Tables I and II). *Coprophanaeus ensifer* (Germar) (Scarabaeidae) was collected from the thirteenth day of PMI, only in the "Cerrado *stricto sensu*", during the humid period. Nevertheless, orifices resembling those produced by this species were observed on the soil surface beside the cages in both areas of collection.

DISCUSSION

Climatic conditions registered during the experiments were consistent with those predicted for the area: there was a dry, cool period from May to September and a rainy, hot period from October to April (Rosa *et al.* 1991). The greater quantity of arthropods collected in the dry period, mainly representatives of the orders Diptera and Coleoptera, seems to be related to a reduction in the rapidity of the decaying process in the carcasses during this period. The low moisture and pluviosity would have promoted more rapid dehydration, restricting colonization by the breeding fauna to a shorter period of time. On the other hand, the carcasses functioned as sources of attraction to adult insects for a longer time during the dry period (Carvalho & Linhares 2001; Rosa *et al.* 2009).

The results highlight a great diversity of Sarcophagidae in the study area. Barros *et al.* (2008) also found great diversity among these Diptera attracted to pig carrion in Cerrado vegetation in the region of Brasília, 435 km from the city of Uberlândia. The genus *Oxysarcodexia* (Sarcophagidae) was the most diverse of the family (Table I). Similar results were also produced by Barbosa *et al.* (2009) in Rio de Janeiro. According to Lopes (1973), species of *Oxysarcodexia* prefer feces as breeding media. The presence of these flies in decaying carcasses indicates that they are using carrion as a source of protein for development of their ovocites and/or as mating sites (Archer & Elgar 2003).

Chrysomya albiceps (Wiedemann) was the most abundant species among the Calliphoridae. Rosa *et al.* 2009 also found this species to be the most abundant among the breeding Diptera in pig carcass in this area. Many studies carried out in Brazil have found this species to be a very important forensic indicator (Souza & Linhares 1997; Carvalho & Linhares 2001; Barbosa *et al.* 2010), including research con-

Table II. Absolute (AF) and relative (%) frequencies of arthropods attracted to pig carrion (*Sus scrofa* L.) in two vegetation profiles of Cerrado, "Campo sujo" and "Cerrado stricto sensu", during the dry and the humid periods of the year in Uberlândia, State of Minas Gerais.

Taxa	Campo sujo		Cerrado stricto sensu		Total	
	AF	%	AF	%	AF	%
Diptera						
Sarcophagidae						
Argoravinia rufiventris	13	0.03	13	0.04	26	0.03
Blaesoxipha (A.) lanei	811	1.56	719	2.08	1,530	1.76
Blaesoxipha (A.) minensis	16	0.03	9	0.03	25	0.03
Dexosarcophaga carvalhoi	3,283	6.30	2,189	6.32	5,472	6.31
Dexosarcophaga paulistana	1	0.00	0	0.00	1	0.00
Dexosarcophaga spp.	256	0.49	138	0.40	394	0.45
Dexosarcophaga transita	218	0.42	190	0.55	408	0.47
Helicobia aurescens	7	0.19	76	0.22	173	0.20
Helicobia borgmeieri	3	0.01	0	0.00	3	0.00
Helicobia morionella	16	0.03	19	0.06	35	0.04
Helicobia pilifera	29	0.06	44	0.13	73	0.08
Helicobia rapax	114	0.22	73	0.21	187	0.22
Microcerella erythropyza	19	0.04	0	0.00	19	0.02
Oxysarcodexia admixta	72	0.14	69	0.20	141	0.16
Oxysarcodexia amorosa	0	0.00	3	0.01	3	0.00
Oxysarcodexia angrensis	121	0.23	220	0.63	341	0.39
Oxysarcodexia aura	446	0.86	226	0.65	672	0.76
Oxysarcodexia avuncula	6,502	12.47	5,391	15.56	11,893	13.71
Oxysarcodexia carvalhoi	1	0.00	32	0.09	33	0.04
Oxysarcodexia culminiforceps	5	0.01	5	0.01	10	0.01
Oxysarcodexia diana	492	0.94	439	1.27	931	1.07
Oxysarcodexia eberti	26	0.05	6	0.02	32	0.04
Oxysarcodexia fluminensis	132	0.25	133	0.38	265	0.31
Oxysarcodexia modesta	1	0.00	0	0.00	1	0.00
Oxysarcodexia paulistanensis	30	0.06	3	0.01	33	0.04
Oxysarcodexia riograndensis	5	0.01	0	0.00	5	0.01
Oxysarcodexia simplicoides	253	0.48	176	0.51	429	0.49
Oxysarcodexia spp.	4	0.01	16	0.05	20	0.02
Oxysarcodexia terminalis	1	0.00	0	0.00	1	0.00
Oxysarcodexia thornax	25,761	49.42	14,768	42.63	40,529	46.71
Oxysarcodexia xanthosoma	0	0.00	3	0.01	3	0.00
Peckia (Euboettcheria) anguilla	104	0.20	52	0.15	156	0.18
Peckia (Euboettcheria) australis	0	0.00	2	0.01	2	0.00
Peckia (Euboettcheria) collusor	114	0.22	175	0.51	289	0.33
Peckia (Euboettcheria) florencioi	48	0.09	62	0.18	110	0.13
Peckia (Pattonella) intermutans	40	0.08	5	0.01	45	0.05
Peckia (Peckia) chrysostoma	57	0.11	28	0.08	85	0.10
Peckia (Peckia) pexata	64	0.12	11	0.03	75	0.09
Peckia (Squamatodes) ingens	7	0.01	1	0.00	8	0.01
Peckia (Squamatodes) trivitatta	200	0.38	95	0.27	295	0.34
Ravinia advena	327	0.63	85	0.25	412	0.47
Ravinia belforti	1,068	2.05	937	2.70	2,005	2.31
Sarcodexia lambens	527	1.01	839	2.42	1,37	1.57
Sarconeiva fimbriata	1	0.00	0	0.00	1	0.00
Sarcophaga (L.) crispula	87	0.17	39	0.11	126	0.15
Titanogrypa (C.) larvicida	80	0.15	6	0.02	86	0.10

Continue

Table II. Continued.

Taxa	Campo sujo		Cerrado stricto sensu		Total	
	AF	%	AF	%	AF	%
Tricharaea (S.) occidua	3,358	6.44	2,850	8.23	6,208	7.15
Tricharaea (S.) ramirezi	15	0.03	13	0.04	28	0.03
Sarcophagidae spp.	7,297	14.00	4,482	12.94	11,779	13.58
Total Sarcophagidae	52,122	100.00	34,642	100.00	86,764	100.00
Muscidae						
Atherigona orientalis	226	4.76	816	28.28	1,042	13.65
Biopyrellia bipuncta	259	5.46	597	20.69	856	11.22
Brontaea debilis	116	2.44	19	0.66	135	1.77
Brontaea spp.	1	0.02	2	0.07	3	0.04
Cyrtoneurina sp.	5	0.11	6	0.21	11	0.14
Cyrtoneuropsis conspersa	1	0.02	0	0.00	1	0.01
Cyrtoneuropsis rescita	479	10.09	215	7.45	694	9.09
Graphomya maculata	27	0.57	8	0.28	35	0.46
Myospila sp.	2	0.04	0	0.00	2	0.03
Morellia ochricornis	15	0.32	21	0.73	36	0.47
Musca domestica	1,417	29.85	510	17.68	1,927	25.25
Ophyra aenescens	1,970	41.50	567	19.65	2,537	33.24
Ophyra chalcogaster	2	0.04	11	0.38	13	0.17
Pseudoptilolepis nigripoda	6	0.13	8	0.28	14	0.18
Sarcopromusca pruna	175	3.69	98	3.40	273	3.58
Stomoxys calcitrans	44	0.93	7	0.24	51	0.67
Synthesiomyia nudiseta		0.04	0	0.00	2	0.03
Total Muscidae	4,747	100.00	2,885	100.00	7,632	100.00
Calliphoridae						
Chloroprocta idiodea	0	0.00	2	0.06	2	0.03
Chrysomya albiceps	3,467	71.62	2,336	73.97	5,803	72.55
Chrysomya megacephala	23	0.48	42	1.33	65	0.81
Chrysomya putoria	259	5.35	276	8.74	535	6.69
Cochliomyia hominivorax	6	0.12	0	0.00	6	0.08
Cochliomyia macellaria	1,000	20.66	417	13.21	1,417	17.72
Hemilucilia segmentaria	19	0.39	5	0.16	24	0.30
Lucilia cuprina	1	0.02	1	0.03	2	0.03
Lucilia eximia	61	1.26	67	2.12	128	1.60
Lucilia sericata	5	0.10	12	0.40	17	0.21
Total Calliphoridae	4,841	100.00	3,158	100.00	7,999	100.00
Fanniidae						
Fannia (subgroup *pusio*)	84	12.37	26	7.88	110	10.90
Fannia pusio	418	61.56	242	73.33	660	65.41
Fannia snyderi	80	11.78	23	6.97	103	10.21
Fannia sp.	97	14.29	39	11.82	136	13.48
Total Fanniidae	679	100.00	330	100.00	1,009	100.00
Phoridae	3	0.00	11	0.02	14	0.01
Hermetia illuscens	38	0.05	15	0.03	53	0.04
Other Diptera	15,640	20.03	10,129	19.79	25,769	19.94
Total Diptera	78,070	100.00	51,170	100.00	129,240	100.00
Coleoptera						
Staphylinidae						
Aleochara sp.	16	1.46	24	3.30	40	2.20

Continue

Table II. Continued.

Taxa	Campo sujo		Cerrado *stricto sensu*		Total	
	AF	%	AF	%	AF	%
Atheta sp.	35	3.20	42	5.78	77	4.23
Cryptobium sp.	1	0.09	0	0.00	1	0.06
Dybelonetes hibridus	9	0.82	9	1.24	18	0.99
Eulissus calybaeus	1	0.09	2	0.27	3	0.17
Heterothops sp.	10	0.91	6	0.83	16	0.88
Neophyrus sp.	2	0.18	1	0.14	3	0.17
Oxytellus sp.	1	0.09	0	0.00	1	0.06
Philonthus flavolimbatus	595	54.39	468	64.37	1,063	58.37
Philonthus spp.	398	36.38	151	20.77	549	30.15
Staphylinidae sp.	26	2.38	24	3.30	50	2.75
Total Staphylinidae	1,094	100.00	727	100.00	1,821	100.00
Dermestidae						
Dermestes maculatus	2,129	100.00	2,745	100.00	4,874	100.00
Cleridae						
Necrobia rufipes	879	100.00	1,442	100.00	2,321	100.00
Histeridae						
Euspilotus spp.	1,038	87.74	1,064	85.95	2,102	86.82
Histeridae spp.	145	12.26	174	14.06	319	13.18
Total Histeridae	1,183	100.00	1,238	100.00	2,421	100.00
Scarabaeidae						
Ataenius aequalis	48	11.77	53	17.78	101	14.31
Ataenius sp.	5	1.22	4	1.34	9	1.27
Ateuchus vividus	21	5.15	47	15.77	68	9.63
Canthidium sp.	2	0.49	0	0.00	2	0.28
Canthon virens	18	4.41	2	0.67	20	2.83
Coprophanaeus ensifer	0	0.00	2	0.67	2	0.28
Deltochilum (Deltohyboma) sp.	20	4.90	31	10.40	51	7.22
Dichotomius nisus	1	0.25	0	0.00	1	0.14
Dichotomius opacipennis	0	0.00	1	0.34	1	0.14
Eurysternus aff. *hirtellus*	1	0.25	13	4.36	14	1.98
Labarrus pseudolividus	0	0.00	1	0.34	1	0.14
Ontherus appendiculattus	122	29.90	19	6.38	141	19.97
Onthophagus hirculus	107	26.23	24	8.05	131	18.56
Trichillum externepunctatum	55	13.48	98	32.89	153	21.67
Scarabaeidae spp.	8	1.96	3	1.01	11	1.56
Total Scarabaeidae	408	100.00	298	100.00	706	100.00
Bolboceratidae						
Bolbapium striatopunctatum	2	100.00	0	0.00	2	100.00
Silphidae						
Oxyletrum disciolle	1	100.00	2	100.00	3	100.00
Trogidae						
Omorgus suberosus	3	100.00	2	100.00	5	100.00
Other Coleoptera	820	12.58	1,135	14.96	1,955	13.86
Total Coleoptera	6,519	100.00	7,589	100.00	14,108	100.00
Other Arthropoda						
Hemiptera	5,496	5.85	4,354	6.48	9,850	6.11
Hymenoptera	2,495	2.56	1,846	2.75	4,341	2.69

Continue

Table II. Continued.

Taxa	Campo sujo		Cerrado *stricto sensu*		Total	
	AF	%	AF	%	AF	%
Lepidoptera	1,234	1.31	1,945	2.90	3,179	1.97
Blattodea	2	0.00	4	0.01	6	0.00
Dermaptera	2	0.00	0	0.00	2	0.00
Homoptera	1	0.00	1	0.00	2	0.00
Isoptera	0	0.000	67	0.100	67	0.04
Odonata	25	0.03	59	0.09	84	0.05
Orthoptera	87	0.09	104	0.16	19	0.12
Acari	11	0.01	13	0.02	24	0.02
Araneida	10	0.01	12	0.02	22	0.01
Total	93,952	100.00	67,164	100.00	161,116	100.00

ducted in areas of the Cerrado (Marchiori *et al.* 2000; Rosa *et al.* 2009). *Cochliomyia macellaria* Fabricius was the second most numerous species among the Calliphoridae attracted to the carrion. This result was also observed by Souza & Linhares (1997) in the State of São Paulo. The introduction of *Chrysomya* species on the American Continent has interfered with the distribution of *C. macellaria* in many areas (Boumgartner & Greenberg 1984). Nevertheless, recent research developed in Rio de Janeiro e Rio Grande do Norte has documented the collection of immature individuals and adults of this species in human cadavers, suggesting a reduced impact of exotic species upon it in those localities (Oliveira-Costa & Mello-Patiu 2004; Andrade *et al.* 2005).

Coleoptera, mainly Staphylinidae and Scarabaeidae, presented a different seasonal distribution from Diptera and manifested greater diversity of species during the humid period. Campobasso *et al.* (2001) identified temperature as an important factor affecting the quantity and diversity of insects associated with decaying carcasses. Temperature and humidity appeared to be the principal factors responsible for the seasonal variations of Coleoptera, mostly Staphylinidae and Scarabaeidae, in the present study. Staphylinidae and Histeridae occurred from the second to the fifth stages of decay. They are predators on the immature insects growing in the carcasses during the process of decomposition.

Dermestidae are pests that feed on dry organic materials (Schroeder *et al.* 2002). Carcasses in the final stages of decay can be used by them as a food source for the adults and immature stages (Souza & Linhares 1997; Schroeder *et al.* 2002; Carvalho *et al.* 2004; Velásquez 2008). They remove the remains of muscles and tendons (Hefti *et al.* 1980). *Omorgus suberosus* (Fabricius) (Trogidae) is another species that feeds on dry organic remains rich in nitrogen, such as animal carcasses and bird excrement (FZVM, pers. obs.). *Necrobia rufipes* (De Geer) has also been encountered colonizing partially or totally dry human cadavers and animal carcasses in Brazil (Souza & Linhares 1997; Carvalho *et al.* 2004; Almeida & Mise 2009). The decrease in the numbers of *D. maculatus* during the humid period is probably related to the concomitant decrease in the duration of the final stages of the decaying process during this period. The greater humidity also reduces the attractiveness of the carcasses for these Coleoptera.

Studies conducted by Marchiori *et al.* (2000) in an area of Cerrado close to the town of Itumbiara, in the State of Goiás, identified *T. externepunctatum* as the most abundant Scarabaeidae in decaying carcasses. This specie, as do the majority of the dominant Scarabaeidae in this study, breeds in the excrement of herbivorous mammals and its presence in the carcasses is related to feeding but without nidification activity. Its larvae, as well as those of *Ataenius aequalis*, breed directly in their food source (López-Alarcón *et al.* 2009). Carvalho *et al.* (2000) encountered *Coprophanaeus ensifer* (Germar) associated with carcasses in a forested area in the State of São Paulo and described it as an important PMI and localization indicator. *Coprophanaeus ensifer* and *Deltochilum (Deltohyboma)* sp. were the Scarabaeidae strictly or mostly necrophagous encountered in the present study (FZVM, per. obs.). The trays placed in the bottoms of the cages containing the carcasses may have interfered with the underground nidification of these species and also the nidification of other Scarabaeinae (Halffter & Edmonds 1982).

It is possible, however, that the trays were not deep enough to retain all the ambulatory Arthrododa species and post-feeding larvae. As a result, part of them may not have been properly sampled. Although many of the species registered here are potential indicators of seasonality, the possibility of using the majority of them that do not breed in carcasses as indicators is restricted when compared with those species that also breed in the substrate. On the other hand, the results presented, associated with those that can be obtained from the anthropic environments – areas of urban and agricultural and cattle-raising activities – may identify some the species registered here as indicators of specific natural areas.

The occurrence of an entomological succession throughout the decaying process of the carcasses was clearly observed. Despite the constant presence of insects, some species/groups occurred in the carcasses only in certain decaying stages. The present study demonstrates a great diversity of entomofauna associated with carrion in an ecosystem rarely studied until now. Considering the Cerrado as a biome with great biodiversity and high rates of endemism but largely unknown (Ribeiro *et al.* 1983), the information presented is significant from an ecological point of view and also for medico-legal forensic entomology.

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