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Sarchophagid flies (Insecta, Diptera) from pig carcasses in Minas Gerais, Brazil, with nine new records from the Cerrado, a threatened Neotropical biome

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ABSTRACT. Sarchophagid flies (Insecta, Diptera) from pig carcasses in Minas Gerais, Brazil, with nine new records from the Cerrado, a threatened Neotropical biome. The diversity of the Sarcophagidae fauna of the Cerrado biome, also know as the Brazilian Savanna, is still underestimated. In this research we collected flies in the state of Minas Gerais, Brazil, during a Forensic Entomology experiment. Samples were collected throughout the decomposition process of domestic pig (*Sus scrofa* Linnaeus) carcasses, and the experiments were conducted in areas of pasture and semideciduous forest. A total of 85,694 adult flesh flies belonging to 57 species were collected from all carcasses. New records for nine species of Sarcophaginae are provided, including the first record of *Blaesoxipha* (*Acridiophaga*) *caridei* (Brèthes, 1906) to Brazil, and new occurrences of the following species for the Cerrado and/or for the state of Minas Gerais: *Blaesoxipha* (*Acanthodotheca*) *acridiophagoides* (Lopes & Downs, 1951)*, Malacophagomyia filamenta* (Dodge, 1964), *Nephochaetopteryx orbitalis* (Curran & Walley, 1934), *Nephochaetopteryx cyaneiventris* Lopes, 1936, *Nephochaetopteryx pallidiventris* Townsend, 1934*, Oxysarcodexia occulta* Lopes, 1946, *Ravinia effrenata* (Walker, 1861) and *Sarcophaga* (*Neobellieria*) *polistensis* (Hall, 1933).

KEYWORDS. Biodiversity; flesh flies; necrophagous flies; Sarcophagidae; savanna.

Sarcophagidae (flesh-flies), a very diverse family of Calyptratae Diptera, include more than 3,000 described species (Pape *et al*. 2011). Flesh-flies are distributed in all biogeographic areas, being more diverse in tropical and subtropical climates (Shewell 1987; Pape 1996). The Neotropical fauna of Sarcophagidae, although quite rich (with approximately 800 species described), is incipiently known (Pape 1996; Amorim *et al.* 2002; Brown 2005).

Flesh-fly females are ovoviviparous multilarviparous, meaning that they deposit many first instar larvae directly on the substrate (Meier *et al*. 1999). Adults are 5 to 20 mm long and have the following characteristics: dull gray in color with three longitudinal black stripes on mesonotum, abdomen checkered or spotted, a row of meral setae, and subscutellum undeveloped (Carvalho & Mello-Patiu 2008). Currently, three subfamilies are recognized: Miltogramminae, Paramacronychiinae and Sarcophaginae, the latter being the most abundant and the most diverse in the Neotropical Region. Species of Sarcophaginae are generally of medium size and display a great diversity of habits. Nevertheless, most species have carrion-feeding larvae and scavenging adults, and some are relevant to forensics (Pape 1996; Carvalho & Mello-Patiu 2008; Brown *et al*. 2009; Mello-Patiu *et al*. 2009).

Sarcophagidae is one of the four Diptera families that are considered important to Forensic Entomology, the other three being Calliphoridae, Muscidae and Fanniidae. Species in these four families have been the subject of a number of forensic studies (Payne 1965; Smith 1986; Greenberg 1991; Oliveira-Costa *et al.* 2001; Pujol-Luz *et al*. 2008; Barbosa *et al.* 2009, 2010; Rosa *et al*. 2009, 2011; Faria *et al*. 2013).

Flesh-flies associated with carcasses have not been as extensively studied as species of other Calyptrate families, for instance Calliphoridae or Muscidae, particularly in the Neotropics. In Brazil, forensic studies focusing on sarcophagids usually only provide a list of species found visiting carcasses exposed at different locations or environments (Dias *et al*. 1984; Souza & Linhares 1997; Leandro & d' Almeida 2005; Cruz & Vasconcelos 2006; Barros *et al*. 2008; Rosa *et al*. 2009; Barbosa *et al*. 2009). Certainly, the great species richness of the Neotropical region, and the difficulties involved in the identification of females and larvae have hindered the publication of more robust analyses of Sarcophagidae succession on carrion. Still, data on the necrophagous fauna have contributed to enhance the knowledge on the taxonomy and biogeography of Neotropical flesh flies.

In the present study we aimed to contribute to the knowledge of the biodiversity of Sarcophagidae in the Cerrado, also known as the Brazilian savanna. The Cerrado is the second largest biome in the Neotropics. In spite of the fact that it covers 22% of Brazil's territory, it has been relatively neglected by science, and is now fragmented and modified (Myers *et al*. 2000; Klink & Machado 2005).

MATERIAL AND METHODS

The experiment was conducted in two areas of the *Fazenda Experimental do Glória*, an experimental cattle farm of the *Universidade Federal de Uberlândia* (UFU), in Uberlândia, State of Minas Gerais, Brazil. The farm, situated two kilometers south of an urban area (18°57'S; 48°12'W) (Haridasan & Araújo 2005), has 685 ha. The pasture area is composed of grasslands, and is reached by intense sunlight at the ground level. The second area is a fragment of mesophytic semideciduous forest, with some trees over five meters tall and a low incidence of direct sunlight at the ground level (Ratter *et al*. 1997). The region presents two defined seasons: a dry and colder season from April to September (winter) and a rainy and warmer season (summer) from October to March. The annual rainfall and daily temperature average are 1,750 mm and 22.5°C, respectively (Rosa *et al*. 1991).

Two replicates were conducted in each of the two seasons (see above). Summer collecting was undertaken from February to March, 2010 and 2013. In the winter, collecting took place from July to September, 2010 and 2012. Eight carcasses of domestic pig (*Sus scrofa* Linnaeus, 1758), previously killed in a commercial slaughterhouse and weighing approximately 10 ± 1 kg, were used in all experiments. Each carcass was placed inside a metal cage (80 x 60 x 40 cm) and carried to the site where it was exposed. The cage was covered with a metal frame with pyramidal dimensions of 1.80 m high and 1.40 m wide and a thin and transparent nylon fabric, in order to retain the winged insects. The insects had access to the carcass through a 30 cm aperture 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).

Trapped adult flesh flies were collected, pinned, and males had their terminalia exposed to allow identification. They were then classified to genus with the aid of identification keys (Carvalho & Mello-Patiu 2008; Vairo *et al*. 2011) and by comparison with material from the reference collection of the Laboratory of Entomology, Institute of Biomedical Sciences/UFU (Uberlândia). Species identifications were performed by comparison with material deposited at the Entomological Collection of the *Museu Nacional*/UFRJ (Rio de Janeiro).

RESULTS AND DISCUSSION

A total of 85,694 adult flesh flies belonging to 57 species were collected from all carcasses (Table I). One of the species, *Blaesoxipha* (*Acridiophaga*) *caridei* (Brèthes, 1906), is a new record for Brazil, and eight are new records for the Brazilian Cerrado and/or for the state of Minas Gerais: *Blaesoxipha* (*Acanthodotheca*) *acridiophagoides* (Lopes & Downs, 1951), *Malacophagomyia filamenta* (Dodge, 1964), *Nephochaetopteryx orbitalis* (Curran & Walley, 1934), *Nephochaetopteryx cyaneiventris* Lopes, 1936, *Nephochaetopteryx pallidiventris* Townsend, 1934, *Oxysarcodexia*

Table I. List of the species of Sarcophagidae collected from the Cerrado of the Fazenda Experimental do Glória, Universidade Federal de Uberlândia (Minas Gerais, Brazil) in 2010, 2012 and 2013.

Blaesoxipha (*Acanthodotheca*) *acridiophagoides* (Lopes & Downs, 1951)
Blaesoxipha (*Acanthodotheca*) *lanei* (Lopes, 1938)
Blaesoxipha (*Acanthodotheca*) *minensis* (Lopes & Downs, 1951)
Blaesoxipha (*Acridiophaga*) *caridei* (Brèthes, 1906)
Blaesoxipha (*Gigantotheca*) *plinthopyga* (Wiedemann, 1830)
Dexosarcophaga ampullula (Engel, 1931)
Dexosarcophaga carvalhoi (Lopes, 1980)
Dexosarcophaga paulistana (Lopes, 1982)
Dexosarcophaga transita Townsend, 1917
Helicobia aurescens (Townsend, 1927)
Helicobia borgmeieri Lopes, 1939
Helicobia morionella (Aldrich, 1930)
Helicobia rapax (Walker, 1849)
Malacophagomyia filamenta (Dodge, 1964)
Microcerella erythropyga (Lopes, 1936)
Nephochaetopteryx cyaneiventris Lopes, 1936
Nephochaetopteryx orbitalis (Curran & Walley, 1934)
Nephochaetopteryx pallidiventris Townsend, 1934
Oxysarcodexia admixta (Lopes, 1933)
Oxysarcodexia angrensis (Lopes, 1933)
Oxysarcodexia aura (Hall, 1937)
Oxysarcodexia avuncula (Lopes, 1933)
Oxysarcodexia carvalhoi Lopes, 1946
Oxysarcodexia culmiforceps Dodge, 1966
Oxysarcodexia diana (Lopes, 1933)
Oxysarcodexia fluminensis Lopes, 1946
Oxysarcodexia major Lopes, 1946
Oxysarcodexia meridionalis (Engel, 1931)
Oxysarcodexia occulta Lopes, 1946
Oxysarcodexia parva Lopes, 1946
Oxysarcodexia paulistanensis (Mattos, 1919)
Oxysarcodexia riograndensis Lopes, 1946
Oxysarcodexia simplicoides (Lopes, 1933)
Oxysarcodexia terminalis (Wiedemann, 1830)
Oxysarcodexia thornax (Walker, 1849)
Oxysarcodexia sp.
Peckia (*Euboettcheria*) *anguilla* (Curran & Walley, 1934)
Peckia (*Euboettcheria*) *collusor* (Curran & Walley, 1934)
Peckia (*Euboettcheria*) *florencioi* (Mattos, 1919)
Peckia (*Pattonella*) *intermutans* (Walker, 1861)
Peckia (*Peckia*) *chrysostoma* (Wiedemann, 1830)
Peckia (*Peckia*) *pexata* (Wulp, 1895)
Peckia (*Squamatodes*) *ingens* (Walker, 1849)
Peckia (*Squamatodes*) *trivittata* (Curran, 1927)
Ravinia advena (Walker, 1853)
Ravinia belforti (Prado & Fonseca, 1932)
Ravinia effrenata (Walker, 1861)
Sarcodexia lambens (Wiedemann, 1830)
Sarcophaga (*Lipoptilocnema*) *crispina* (Lopes, 1938)
Sarcophaga (*Lipoptilocnema*) *crispula* (Lopes, 1938)
Sarcophaga (*Lipoptilocnema*) sp.
Sarcophaga (*Neobellieria*) *polistensis* (Hall, 1933)
Titanogrypa (*Cucullomyia*) *larvicida* (Lopes, 1935)
Titanogrypa (*Sarconeiva*) *fimbriata* (Aldrich, 1916)
Tricharaea (*Sarcophagula*) *occidua* (Fabricius, 1794)
Lepidodexia (*Harpagopyga*) sp.
Tricharaea (*Sarothromyia*) sp.

occulta Lopes, 1946, *Ravinia effrenata* (Walker, 1861) and *Sarcophaga* (*Neobellieria*) *polistensis* (Hall, 1933). There are also two possible new species among the material collected. The frequency and abundance of these nine species throughout the seasons and by collecting site (pasture or forest) are summarized in Table II.

Seven specimens of *B*. (*Acridiophaga*) *caridei*, a parasite of Orthoptera, Acridoidea and Lepidoptera, were collected, all in the pasture area (Table II). According to Pape (1994), this species is distributed in the Nearctic and Neotropical regions, occurring in most of the American Continent, from Canada to Chile. Nevertheless, it had not been previously recorded from Brazil. The lack of records of this species for the country may well be the result of misidentifications, because it is difficult to segregate it from other species that belong in the *angustifrons-aculeata-caridei* complex (Pape 1994). Our record from Brazil is, however, not surprising, since *B*. (*A*.) *caridei* is the only species in the *angustifrons-aculeata-caridei* complex distributed in South America.

Only a few specimens (less than four) of *B*. (*A*.) *acridiophagoides*, *M*. *filamenta*, *O*. *occulta* and *S*. (*N*.) *polistensis* were collected (Table II). This could mean that these species are accidental in carrion.

Among the new records, *B*. (*A*.) *acridiophagoides* is a beetle parasite, as most species of *Blaesoxipha* s. str. and *B*. (*Acanthodotheca*) (Pape 1994). This species, distributed in the Nearctic and Neotropical regions, had been previously recorded from the Brazilian localities of Nova Teutônia, in Seara municipality, state of Santa Catarina, and São Paulo city, state of São Paulo (Lopes 1990).

Malacophagomyia filamenta had been previously registered for the Neotropical region from Bolivia, Brazil and Suriname. Larvae of this species breed in carcasses of gastropod mollusks (Lopes 1966; Mulieri & Mello-Patiu 2013). In Brazil, *M*. *filamenta* had been recorded only from the states of Pará and Rio de Janeiro (Pape 1996), which correspond to localities in the Amazon rainforest and the Atlantic forest, respectively.

Nephochaetopteryx cyaneiventris had been previously recorded from the states of São Paulo, Rio de Janeiro, and Paraná in Brazil (Lopes 1936; Mello-Patiu *et al*. 2009; Vairo *et al*. 2011), and from Argentina (Mulieri *et al*. 2008, 2010). Vairo *et al*. (2011) registered it for the first time on pig carcass after conducting a forensic experiment in the state of Paraná. Our record of *N. cyaneiventris* is therefore the second one in pig carcass, the species being more abundant in the forest site. In Buenos Aires, Argentina, this species was collected only in forest, attracted by rotten cow liver and feces (Mulieri *et al*. 2008, 2010).

Nephochaetopteryx orbitalis has also Neotropical distribution, in Guyana and Brazil (Pape 1996), with Brazilian records in the states of Rio de Janeiro (Lopes 1936) and Pará (Carvalho-Filho 2012). In our data this species was collected only in forest (Table II), suggesting a preference for areas with lower sunlight, such as those found in the Amazon and Atlantic Forest. Similarly, *N. pallidiventris* also showed preference for forest rather than pasture (Table II). It had been recorded only from the Brazilian states of Pará and Rio de Janeiro, but recently Carvalho-Filho (2012) recorded it in the states of Amazonas and Ceará.

Besides Panama, Ecuador and Colombia, *Oxysarcodexia occulta* was listed for the following states of Brazil: Rio de Janeiro (Atlantic Forest biome), Ceará (Caatinga biome), and Roraima (Amazon biome) (Lopes & Tibana 1987, 1991). *Ravinia effrenata* occurs in the Nearctic region, from the U.S.A. to Mexico, and in the Neotropics, from the Bahamas to Peru (Pape 1996). In Brazil, it is known only for the state of Roraima (Lopes & Leite 1991). The species of *Ravinia* Robineau-Desvoidy, as well as those of *Oxysarcodexia* Townsend, are coprophagous according to Lopes (1973) and Pape (1996). This may explain why it was only collected in the pasture area in this work, (Table II). However, species of both *Ravinia* and *Oxysarcodexia* tend to be abundantly attracted by several types of substrate (dung, fish, mammal carcasses, etc.), demonstrating their high ecological plasticity.

Finally, *Sarcophaga* (*Neobellieria*) *polistensis* is distributed in the southern portion of the U.S.A. to Brazil and Argentina (Pape 1996). In Brazil, it occurs in the Atlantic and Amazon forests, but Giroux & Wheeler (2009) had also recorded it from an area of Cerrado in the state of Maranhão. Additionally, our results show that it also occurs in the state of Minas Gerais. Larvae of *S*. (*N*.) *polistensis* are parasites of *Polistes* spp. nests (Hymenoptera, Vespidae).

Table II. Abundance and seasonal frequency of nine newly recorded Sarcophagidae species attracted by pig carcasses at the Fazenda Experimental do Glória, Universidade Federal de Uberlândia (Minas Gerais, Brazil) in 2010, 2012 and 2013 (p = pasture; f = forest; G = grand total).

Species	Winter 2010		Summer 2010		Winter 2012		Summer 2013		Total		
	p	f	p	f	p	f	p	f	p	f	G
Blaesoxipha (*Acanthodotheca*) *acridiophagoides*	0	0	0	0	0	0	0	1	0	1	1
Blaesoxipha (*Acridiophaga*) *caridei*	1	0	0	0	6	0	0	0	7	0	7
Malacophagomyia filamenta	1	0	0	0	0	0	0	0	1	0	1
Nephochaetopteryx cyaneiventris	5	2	2	20	0	0	0	0	7	22	29
Nephochaetopteryx orbitalis	0	20	0	3	0	5	0	0	0	28	28
Nephochaetopteryx pallidiventris	1	3	0	7	0	0	0	0	1	10	1
Oxysarcodexia occulta	0	0	0	0	0	1	0	0	0	1	1
Ravinia effrenata	2	0	2	1	7	1	7	0	18	2	20
Sarcophaga (*Neobelieria*) *polistensis*	0	0	0	0	0	1	2	0	2	1	3

In conclusion, our results show that species previously known from tropical forest biomes, as the Amazon Rainforest and Atlantic Forest, also occur in the Cerrado, corroborating the hypothesis of Amorim (2009). Having a wide range of fito-physiognomic profiles and sharing species with the neighboring forest biomes certainly contributes for the extraordinary faunal richness of the Cerrado. Therefore, studies on arthropod diversity in different profiles of the Cerrado, preserved or impacted by humans, have proved to be of great importance for systematics and ecology, besides forensics. Studies on Sarcophagidae in these different areas could contribute to the identification of bioindicator species, and to the knowledge of the real species richness in this threatened biome.

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