



Scavengers flesh flies (Diptera, Sarcophagidae) from two phytophysiognomies in the state of Maranhão, Northeastern of Brazil

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Abstract: Flesh flies (Sarcophagidae) have been found in a wide range of natural and anthropogenic environments, from forests to deserts. The state of Maranhão, located in Northeastern Brazil, has a diverse phytogeography, but few faunistic studies have been conducted in this area. Therefore, the objective of this study was to inventory species of Sarcophagidae and compare abundance patterns between the Cerrado (savanna-like vegetation) and riparian forests in the municipality of Codó, state of Maranhão. Twelve sampling events were carried out from the second half of 2015 to the first half of 2017. This resulted in 3,220 specimens, 27.15% of which were males, from nine genera and 27 species. A total of 491 specimens (16 species) were collected in the Cerrado, and 383 specimens (21 species) in the riparian forest. *Peckia* (Sarcodexia) *lambens* (Wiedemann) was the most abundant species (56,18% of the specimens sampled), followed by *Peckia* (*Peckia*) *pexata* (Wulp) (13%); *Peckia* (*Euboettcheria*) *collusor* (Curran & Walley) (13%), and *Peckia* (*Peckia*) *chrysostoma* Wiedemann (10%). Only *P. (E.) collusor* was found in greater abundance in the Cerrado. *Oxysarcodexia angrensis* (Lopes), *Peckia* (*Peckia*) *enderleini* (Engel), and *Retrocitomyia andina* Lopes are all new records to Maranhão and the entire Northeast Region of Brazil. *Titanogrypa* (*Cuculomyia*) *albuquerquei* (Lopes) is also a new to Maranhão.

Keywords: Calypttratae, cerrado; insects; inventory; Oestroidea; riparian forest.

Moscas necrófagas (Diptera, Sarcophagidae) de duas fitofisionomias no estado do Maranhão, Nordeste do Brasil

Resumo: As moscas Sarcophagidae podem ser encontradas em vários tipos de ambientes, naturais ou antropizados, desde florestas até desertos. O estado brasileiro do Maranhão, localizado na Região Nordeste, possui uma grande variedade de áreas fitogeográficas, mas poucos estudos faunísticos tem sido realizados nesta região. Portanto, o objetivo deste estudo foi inventariar as espécies de sarcófagídeos e comparar os seus padrões de abundância entre as áreas de cerrado (vegetação tipo savana) e de mata ciliar do município de Codó, estado do Maranhão. Foram realizadas 12 coletas, do segundo semestre de 2015 ao primeiro semestre de 2017. Foram coletados 3.220 espécimes, dos quais 27,15% são machos, representados por nove gêneros e 27 espécies. No cerrado foram coletados 491 espécimes (16 espécies), na mata ciliar foram coletados 383 espécimes (21 espécies). As espécies mais abundantes foram *Peckia* (Sarcodexia) *lambens* (Wiedemann) (56,18% dos indivíduos amostrados), *Peckia* (*Peckia*) *pexata* (Wulp) (13%), *Peckia* (*Euboettcheria*) *collusor* (Curran & Walley) (13%) e *Peckia* (*Peckia*) *chrysostoma* Wiedemann (10%). Apenas *P. (E.) collusor* foi significativamente mais abundante na área de cerrado. *Oxysarcodexia angrensis* (Lopes), *Peckia* (*Peckia*) *enderleini* (Engel) e *Retrocitomyia andina* Lopes são novos registros para a Região Nordeste do Brasil e *Titanogrypa* (*Cuculomyia*) *albuquerquei* (Lopes) é novo registro para o estado do Maranhão.

Palavras-chave: Calypttradas; cerrado; insetos; inventario; Oestroidea; floresta ripária.

Introduction

Sarcophagidae, or flesh flies, is one of the most diverse families of Calypttratae flies, with over 3,100 species divided into three subfamilies: Miltogramminae, Paramacronychiinae, and Sarcophaginae (Pape et al. 2011, Piwczynski et al. 2017). The Neotropical Region harbors one of the most diverse Sarcophagidae faunas, with over 800 species, many of which belong to the subfamily Sarcophaginae (Pape 1996, Pape & Dahlem 2010). There is only one species of Paramacronychiinae, which is found in the Galapagos Islands, and only a few species Miltogramminae are known to exist in this region (Pape 1996). In Brazil, which has one of the most diverse fauna of Sarcophagidae, the Sarcophaginae account for 94% of the species (Mello-Patiu 2020).

In the larval stage, flesh flies have the most diverse feeding habits among all Calypttratae fly families (Dahlem 1991, Pape & Dahlem 2010). Most larvae of Miltogramminae are kleptoparasites in solitary hymenopteran nests; however, there are also scavenger species (Piwczynski et al. 2017). The larvae of the Paramacronychiinae and Sarcophaginae can be saprophagous, coprophagous, kleptoparasites in hymenopteran nests, predators of other insects' eggs, parasitoids of other arthropods, and vertebrate parasites (Shewell 1987, Dahlem 1991, Pape & Dahlem 2010).

The larvae of several Sarcophaginae species are scavengers, meaning they feed on decomposing tissues of dead animals, including humans (Pape & Dahlem 2010). Adults can be found on or near carcasses, which serve as a food source, breeding site, and substrate for immature development. This is why flesh flies are considered to be one of the most important indicators in forensic studies (Guo et al. 2014, Sharma et al. 2015, Fakoornziba et al. 2017, Pavaraj et al. 2018, Jang et al. 2019, Oliveira et al. 2019, Vairo & Moura 2021). Furthermore, Sarcophaginae are an ideal taxonomic group for ecological studies because they can be easily collected in a variety of environments using traps containing decomposing organic matter (Sousa et al. 2016).

Flesh flies are found on all continents and in a wide range of terrestrial environments, from deserts to various types of forests (Shewell 1987). While some species can be found in several different habitats, others are restricted to a few specific locations (Carvalho-Filho et al. 2017, Camargo et al. 2018). Several Sarcophagidae species prefer open and sunny environments, such as pastures and forest clearings, and some of them have successfully colonized urban areas (Mulieri et al. 2011, Sousa et al. 2011, 2016, Vasconcelos et al. 2014).

Brazil is the largest country in South America; hence, it is home to a diverse range of habitats and plant communities, some of which are endemic, such as the Caatinga, an arid ecoregion in Northeastern Brazil (Silva et al. 2017, Tabarelli et al. 2018). The Cerrado, which is similar to African savannas and has direct contact with other biomes, is one of Brazil's most common vegetation types (Viera et al. 2019, Dutra & Silva 2020). The Cerrado has a diverse phytophysiology, ranging from more open vegetation types, such as "*campo limpo*", "*campo sujo*", and "*cerrado sensu stricto*", to more dense vegetation types, such as riparian forests surrounding streams, rivers, and lakes (Werneck 2011, Araújo et al. 2016, Rios et al. 2016, Silva et al. 2017, Eloy et al. 2019, Zuin 2020). The vegetation is denser in the riparian forest, with small and large trees growing close together under compact canopies (Castro et al. 2012, Kuntschik et al. 2014). Because riparian forests are an intermediate environment between the open Cerrado and more highly forested areas, species from both habitats can be found there (Silva et al. 2017, Dufek et al. 2020a). As a result, these environments

are critical for the preservation of biodiversity, as well as serving as ecological corridors between many types of habitats (Silva et al. 2017).

Many studies on the Sarcophagidae fauna of the Cerrado have been conducted in various regions of Brazil, particularly in the Central-West and Southeast areas (Rosa et al. 2011, Mello-Patiu et al. 2014, Paseto et al. 2019, Toma et al. 2020). Sousa et al. (2016) carried out a comprehensive research on the scavenger Sarcophagidae fauna in several types of phytophysiology, including the Cerrado in the northeastern Brazilian state of Maranhão. However, none of these studies addressed the fauna of the riparian forest. Therefore, the goal of this study is to inventory the scavenger Sarcophagidae species and compare their abundance patterns in "*cerrado sensu stricto*" and riparian forest areas in the eastern portion of the state of Maranhão, in a transition zone between the Cerrado and the Caatinga biomes.

Material and Methods

1. Study area

This study was carried out in the municipality of Codó (04°28'57,54800" S; 43°55'03,84603" W), located in the eastern portion of the state of Maranhão, Northeastern Brazil, in an area of "*cerrado sensu stricto*", on the villages of Roncador and Mirindiba, at the margins of the BR316 road, in areas of riparian forests surrounding the rivers Saco and Codozinho, both tributaries of the Itapecuru river (IBGE, 2019a) (Figure 1). The municipality has a land area of 4,361 km² (IBGE, 2019), with the Cerrado as its main phytogeographic domain, with different phytophysiology depending on the region's ground topography "*campo cerrado*", "*cerrado sensu stricto*" and "*cerradão*" (Feitosa & Almeida 2002, Correia-Filho 2011, Lopes Sobrinho et al. 2014). Furthermore, the region also harbors riparian forests, gallery forests, and babassu forest, which are overshadowed by the babassu palm tree (*Attalea speciosa* Mart. ex Spreng) (Correia-Filho 2011). The climate of the region is subhumid and semiarid, with total annual precipitation ranging between 1200 and 2000 mm. The wet season lasts from December to May, and the dry season from June to November. The annual average temperature varies between 26°C and 27°C, and the average relative humidity fluctuates between 65% and 85% (Correia-Filho 2011).

2. Data collection

We carried out 12 sampling events, two in the second half of 2015, three in 2016, and seven in the first half of 2017. The Sarcophagidae were captured using fly traps similar to those described by Almeida et al. (2003) and baited with 50 g of bovine lungs. To kill all captured insects, we placed pyrethroid (k-othrine) insecticide-impregnated tape inside the collector bag. Traps were attached to tree branches 1.2 meters above ground. The minimum distance between traps was one kilometer, and each trap was left in the field for 48 hours. We set up 60 traps in total, 30 in Cerrado areas and 30 in riparian forest areas. In each sampling event, we set up five traps per area.

The Sarcophagidae were separated, labeled, identified, and counted at the Federal University of Maranhão (UFMA), Codó Campus, state of Maranhão, Brazil. Because the main characteristics used to identify the species are based on the male terminalia, only males were identified at species level. The following studies were used for identification: Lopes (1956, 1976), Guimarães (2004), Carvalho & Mello-Patiu (2008), Vairo et al. (2011, 2015), Buenaventura & Pape (2013), Mulieri et al. (2016), Mello-Patiu & Salazar-

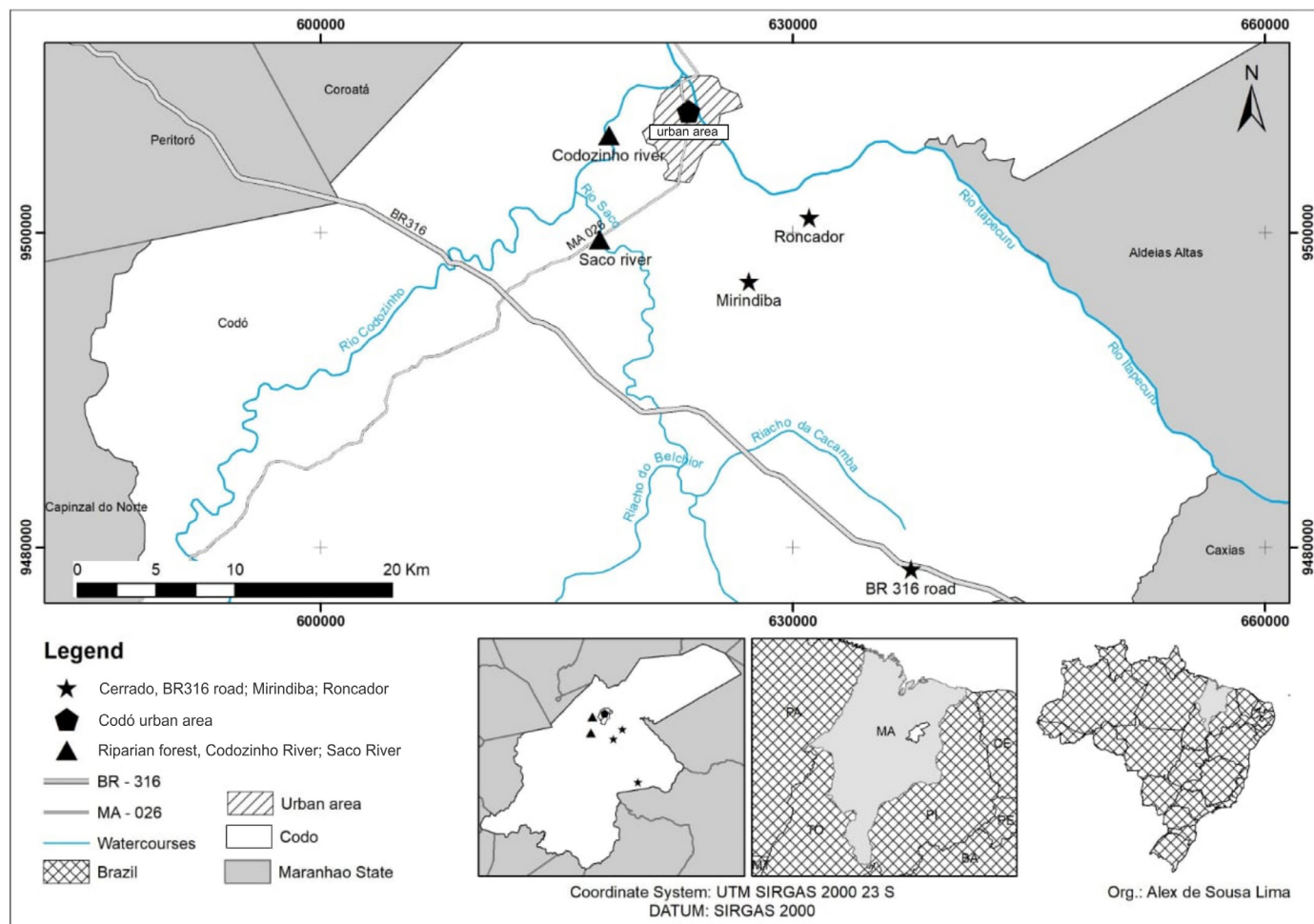


Figure 1. Location of the study area in the municipality of Codó, state of Maranhão, Brazil. Source: IBGE, 2019b (Modified by A.S. Lima).

Souza (2016), and Souza et al. (2020). We also compared our samples to specimens identified in the entomological collection of the Museu Paraense Emílio Goeldi (MPEG) in Belém, state of Pará, Brazil. All specimens were either deposited in the Coleção Zoológica do Maranhão (CZMA) of the State University of Maranhão (UEMA), at the Caxias Campus, or in the MPEG.

3. Data analysis

The abundance of each species was used as a continuous dependent variable, and the different habitat types as categorical independent variables (two levels: Cerrado and riparian forest). Each trap in each sampled area served as our sample unit. Before comparing the abundance values for the most representative species (more than 40 sampled specimens) of both habitat types, we tested the premises of variance homogeneity (Levene test) and normality (Shapiro test). Because the premises were not met, we log-transformed the response variables and tested for the same premises; if they were met, we performed ANOVA for one factor. In this case, however, the chart was created using data from the non log-transformed response variable in order to avoid the loss of biological effects of species abundance. When the premises were not satisfied even after transformation, we used data from the non-log-transformed response variable to perform the non-parametric Kruskal-Wallis test (Zar 2008). Using the R software, we performed statistical analysis and created charts (R Core Team 2020). When p-values were ≤ 0.05 , we considered the results significant.

Results and Discussion

We collected a total of 3,220 sarcophagid specimens, of which 2,346 (72.85%) were female and 874 (27.15%) were male (Table 1). Females were more abundant in carcasses and traps containing decomposing animal tissue because they use these substrates as larviposition sites and as a protein source for egg development (Ferraz 1992, Archer & Elgar 2003, Bänziger & Pape 2004). Thus, including females in the analyses can improve the reliability of the results regarding ecological and forensic issues. However, because there are few taxonomic tools that would allow us to identify female individuals, such as taxonomic keys and taxonomic descriptions, the majority of ecological and forensic studies on flesh flies only identify males to the genus or species level.

The males sampled belong to nine genera and 27 species, three of which (*Oxysarcodexia angrensis* (Lopes, 1933), *Peckia* (*Peckia*) *enderleini* (Engel, 1931), and *Retrocitomyia andina* (Lopes, 1985))

Table 1. Abundance of Sarcophagidae by genus in the study areas (cerrado and riparian forest), in the municipality of Codó, MA, Brazil.

	COLLECTION AREA		TOTAL
	Cerrado	Riparian forest	
Females	1.593	753	2.346
Males	491	383	874
TOTAL	2.084	1.136	3.220

are new records for the Northeast Region, and one (*Titanogrypa* (*Cuculomyia*) *albuquerquei* (Lopes, 1976)) is a new record for the state of Maranhão (Table 2). *Peckia* (*P.*) *enderleini* has been found primarily in the southern South America (Argentina, Paraguay, Bolivia, and Brazil (states of Mato Grosso, Mato Grosso do Sul, Rio Grande do Sul, and São Paulo)) (Buenaventura & Pape 2013, Toma et al. 2020). Therefore, this is the most northern-located record for this species in the continent. This species was also one of the most abundant among the scavenger sarcophagids sampled with traps containing bovine liver in a Cerrado area of the state of Mato Grosso do Sul (Toma et al. 2020), indicating a preference for this habitat type. However, we only found one specimen in the current study, which could be attributed to the type of bait used or to environmental conditions, as the Cerrado areas of Maranhão are drier than those in the state of Mato Grosso do Sul.

Retrocitomyia andina has been recorded in Bolivia and Peru (Mello-Patiu & Salazar-Souza 2016), but it was recently found in Amazonian

grasslands in Brazil (Souza 2018). These grasslands are dry habitats, similar to Cerrado areas, implying that this species may be associated with these types of habitats, as has been observed for other *Retrocitomyia* species (e.g., *Retrocitomyia mizuguchiana* Tibana & Xerez, 1985).

Oxysarcodexia angrensis is found in a wide distribution, ranging from Central America (Costa Rica and Panama) to Southeast Brazil (São Paulo), but it had yet to be recorded in the Brazilian Northeast Region. *Titanogrypa* (*C.*) *albuquerquei* had previously been recorded in the Bahamas, Cuba, and Brazil, but only in the Brazilian state of Piauí (Pape 1996). As a result, Maranhão is the second Brazilian state where this species has been recorded. The presence of new records indicates that the Sarcophagidae fauna in Brazil's Northeast Region is diverse but still understudied, as previously highlighted by other authors (Barbosa et al. 2015, Sousa et al. 2015).

Peckia (eight species) and *Oxysarcodexia* (eight species) were the genera with highest species richness. These were also the most abundant genera, with 801 (91.64%) *Peckia* and 46 (5.26%) *Oxysarcodexia* specimens

Table 2. Composition and abundance of Sarcophagidae species collected in the cerrado and riparian forest in the municipality of Codó, MA, Brazil. * First record for Northern Region. ** First record for state of Maranhão.

SPECIES	COLLECTION AREA		TOTAL
	Cerrado	Riparian forest	
<i>Blaesoxipha</i> (<i>Gigantotheca</i>) <i>stallengi</i> (Lahille, 1907)	1	0	1
<i>Helicobia morionella</i> (Aldrich, 1930)	1	0	1
<i>Lipoptilocnema misella</i> (Lopes, 1938)	0	1	1
<i>Oxysarcodexia amorosa</i> (Schiner, 1868)	0	1	1
<i>Oxysarcodexia angrensis</i> (Lopes, 1933)*	1	0	1
<i>Oxysarcodexia avuncula</i> (Lopes, 1933)	0	1	1
<i>Oxysarcodexia fringidea</i> (Curran & Walley, 1934)	0	2	2
<i>Oxysarcodexia modesta</i> Lopes, 1946	1	4	5
<i>Oxysarcodexia thornax</i> (Walker, 1849)	1	29	30
<i>Oxysarcodexia timida</i> Aldrich, 1916	2	4	6
<i>Peckia</i> (<i>Euboettcheria</i>) <i>anguilla</i> (Curran & Walley, 1934)	3	0	3
<i>Peckia</i> (<i>Euboettcheria</i>) <i>collusor</i> (Curran & Walley, 1934)	91	22	113
<i>Peckia</i> (<i>Peckia</i>) <i>chrysostoma</i> (Wiedemann, 1830)	9	77	86
<i>Peckia</i> (<i>Peckia</i>) <i>enderleini</i> (Engel, 1931)*	0	1	1
<i>Peckia</i> (<i>Peckia</i>) <i>pexata</i> (Wulp, 1895)	72	42	114
<i>Peckia</i> (<i>Peckia</i>) <i>uncinata</i> (Hall, 1933)	0	2	2
<i>Peckia</i> (<i>Sarcodexia</i>) <i>lambens</i> (Wiedemann, 1830)	300	181	481
<i>Peckia</i> (<i>Squamatodes</i>) <i>ingens</i> (Walker, 1849)	0	1	1
<i>Peckiamyia abnormalis</i> (Hall, 1937)	1	0	1
<i>Ravinia belforti</i> (Prado & Fonseca, 1932)	1	0	1
<i>Ravinia effrenata</i> (Walker, 1861)	1	1	2
<i>Retrocitomyia andina</i> Lopes, 1985*	0	4	4
<i>Retrocitomyia mizuguchiana</i> Tibana & Xerez, 1985	5	4	9
<i>Retrocitomyia retrocita</i> (Hall, 1933)	0	1	1
<i>Titanogrypa</i> (<i>Airypel</i>) <i>cryptopyga</i> Lopes, 1956	0	1	1
<i>Titanogrypa</i> (<i>Cuculomyia</i>) <i>albuquerquei</i> (Lopes, 1976)**	1	1	2
<i>Titanogrypa</i> (<i>Cuculomyia</i>) <i>luculenta</i> (Lopes, 1938)	0	3	3
TOTAL	491	383	874

(Table 2). Likewise, they were the most diverse genera in studies conducted in other Cerrado areas in the state of Maranhão (Sousa et al., 2015, 2016), the Central-West (Mello-Patiu et al. 2017, Toma et al. 2020), and Southeast regions of Brazil (Rosa et al. 2011, Mello-Patiu et al. 2014), as well as for other biomes, such as the Amazon Rainforest (Sousa et al. 2011) and the Atlantic Forest (Leandro & D'Almeida 2005, Barbosa et al. 2014, Lopes et al. 2018). *Peckia* and *Oxysarcodexia* are two of South America's most species-rich genera (Buenaventura & Pape 2013, Souza et al. 2020), and many of its species have scavenger larvae (Pape & Dahlem 2010). They are among the most important genera in terms of forensic and ecological studies in the Neotropical Region due to their abundance, diversity, and scavenger habit.

The low abundance of *Oxysarcodexia* may be related to habitat type, as some species in this genus prefer forested environments (Valverde-Castro et al. 2017). Certain species sampled in this study were also found to be in low abundance in previous studies conducted in Cerrado areas using decomposing animal organic matter (Rosa et al. 2011, Toma et al. 2020). Furthermore, because some *Oxysarcodexia* species are coprophagous (Pape & Dahlem 2010), the type of bait used may have influenced our results.

Peckia (Sarcodexia) lambens (Wiedemann, 1830) was the most abundant species found (56,18% specimens sampled), followed by *Peckia (Peckia) pexata* (Wulp, 1895) (13%), *Peckia (Euboettcheria) collusor* (Curran & Walley, 1934) (13%), and *Peckia (Peckia) chrysostoma* (Wiedemann, 1830) (10%). The remaining species account for 9% of all sampled specimens (Table 2). *Peckia (S.) lambens* is native to the southern United States of America (USA), several Caribbean islands, nearly all of South America, and has been introduced to the Cook Islands and French Polynesia. This widespread distribution is most likely due to the species' high ecological plasticity, which allowed it to colonize a wide range of environments, including heavily populated ones (Camargo et al. 2018, Sousa et al. 2020); furthermore, its larvae consume a variety of food sources. They can be insect parasitoids, predators of dying scorpions and insects, cause myiasis in birds and mammals, and scavengers of dead vertebrates and invertebrates. As a result, this is one of the most abundant species used in ecological and forensic studies (Alves et al. 2014a, b, Vasconcelos et al. 2015, Sousa et al. 2016, Souza & Zuben 2016, Dufek et al. 2020a). There was no difference in abundance between open habitats and riparian forests in Cerrado areas, as expected for a species with high ecological plasticity ($\chi^2 = 0.0611$, $df = 1$, $p = 0.434$, Kruskal-Wallis nonparametric test) (Figure 2).

Even though *P. (P.) pexata* has a wide distribution, ranging from Texas to Argentina, and can be found in both forested and open habitats (Ferreira 1979, Linhares 1981, Couri et al. 2000, Sousa et al. 2011, 2016, Valverde-Castro et al. 2017, Dufek et al. 2020b), it is not commonly seen in primary forests (Camargo et al. 2018). Hence, it may be associated with open and dry environments, such as the Cerrado and grasslands (Barros et al. 2008, Carvalho-Filho et al. 2018, Toma et al. 2020). Nevertheless, it was abundant in both open habitats and riparian forests in the studied area, with no significant differences between them (One-way ANOVA: $F_{(1, 58)} = 2.370$, $p = 0.129$) (Figure 3).

Peckia (E.) collusor is a generalist species that can be found in a variety of habitats, including urban forests (Linhares 1981, D'Almeida 1984, Dias et al. 1984, Yepes-Gaurisas et al. 2013), open vegetation, and urban areas (Sousa et al. 2011, 2016, Mello-Patiu et al. 2014). Nevertheless, the difference in abundance between open areas and the riparian forest was significant in our study ($\chi^2 = 4.769$, $df = 1$, $p = 0.029$, Kruskal-Wallis nonparametric test) (Figure 4). Sousa et al. (2016) and Valverde-Castro et al. (2017) also sampled fewer specimens of this species in forested habitats than in open habitats.

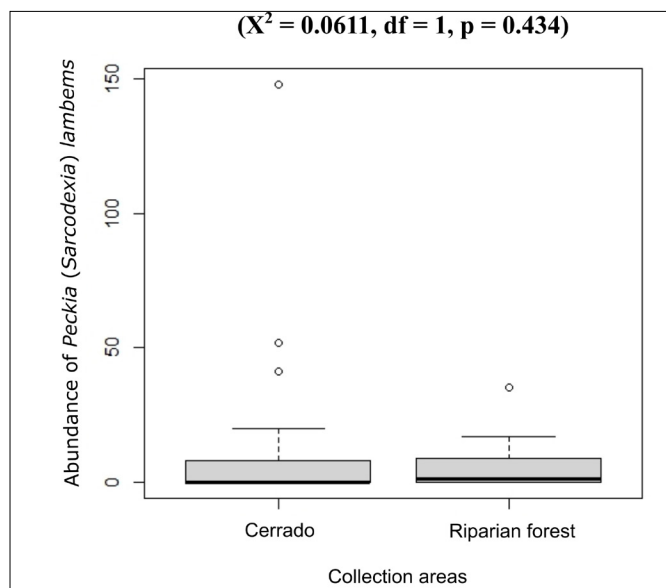


Figure 2. Relationship between the abundance of *Peckia (Sarcodexia) lambens* and the collection areas habitats (Cerrado and Riparian forest), in Codó municipality, Maranhão. Medians of the abundances between the two habitat types were not significantly different ($p > 0.05$; the Kruskal-Wallis two-tailed test). Data: — = median; □ 25%-75% ▮ Min-Max ; ° = Outlier.

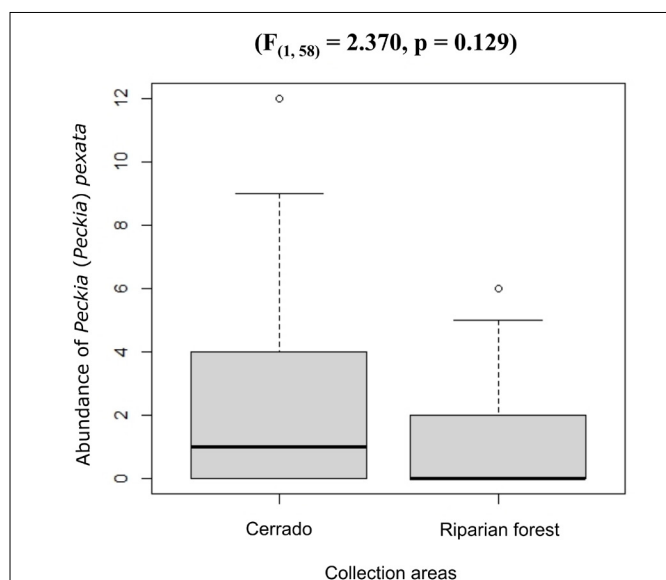


Figure 3. Relationship between the abundance of *Peckia (Peckia) pexata* and the collection areas habitats (Cerrado and Riparian forest), in Codó municipality, Maranhão. Means of the abundances between the two habitat types were not significantly different ($p > 0.05$; ANOVA one-way test). Data: — = means; □ 25%-75% ▮ Min-Max ; ° = Outlier.

Peckia (P.) chrysostoma is a widely distributed species (found from Southern United States to Southern Brazil) and an important representative of the scavenger fauna in Brazil, where it can be found in a variety of habitats, including cities (Yepes-Gaurisas et al. 2013, Carmo & Vasconcelos 2016, Barbosa et al. 2017). Therefore, it is consistently one of the most abundant species in ecological and forensic studies in South America (Alves et al. 2014a, b, Sousa et al. 2016, Valverde-Castro et al. 2017). This species was abundant in both open and riparian habitats, with no significant differences between them ($\chi^2 = 0.073$, $df = 1$, $p = 0.788$, Kruskal-Wallis nonparametric test) (Figure 5).

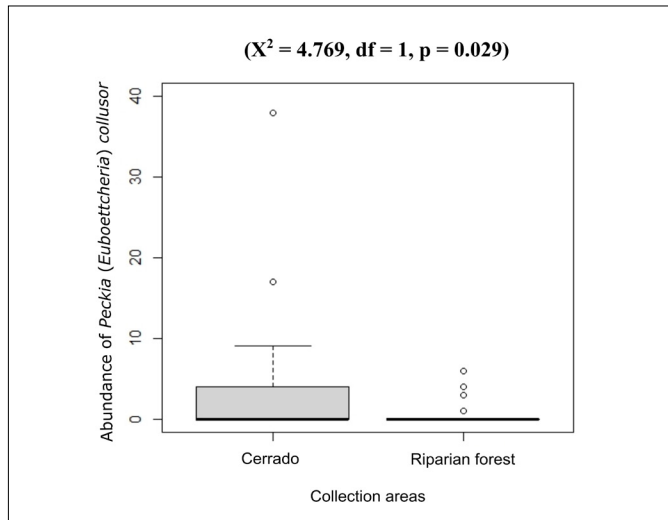


Figure 4. Relationship between the abundance of *Peckia* (*Euboettcheria*) *collusor* and the collection areas habitats (Cerrado and riparian Forest), in Codó municipality, Maranhão. Medians of the abundances between the two habitat types were significantly different ($p < 0.05$; Kruskal-Wallis two-tailed test). Dados: — = median; □ 25%-75% ▮ Min-Max ; ° = Outlier.

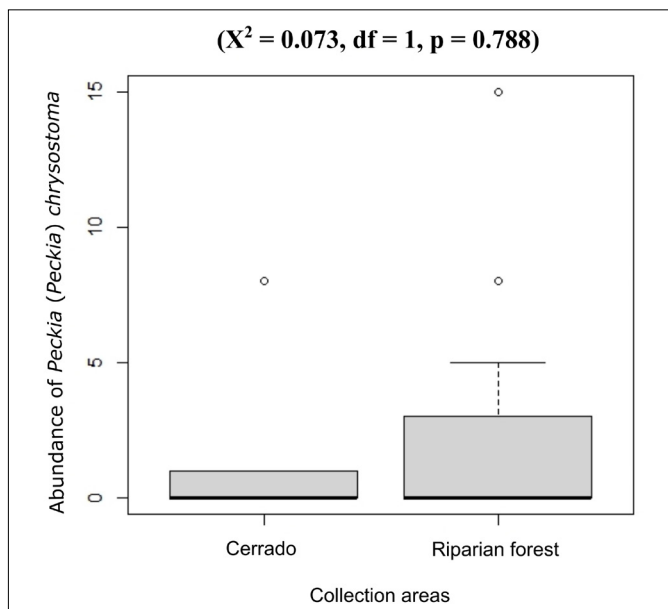


Figure 5. Relationship between the abundance of *Peckia* (*Peckia*) *chrysostoma* and the collection areas habitats (Cerrado and Riparian forest), in Codó municipality, Maranhão. Medians of the abundances between the two habitat types were not significantly different ($p > 0.05$; Kruskal-Wallis two-tailed test). Dados: — = median; □ 25%-75% ▮ Min-Max ; ° = Outlier.

Of the total number of specimens sampled, 2,084 were found in Cerrado areas and 1,136 in riparian forests. Flesh flies, both males and females, were more abundant in open areas of Cerrado. These findings are consistent with previous research, which found that species belonging to this family were more abundant in open environments (pastures, clearings, and savannas) than in adjacent forests (Sousa et al., 2011, 2016, Yepes-Gaurisais et al. 2013). The majority of the species of Sarcophagidae found in this study have a wide geographical distribution in both Brazil and South America, being present in various phytogeographic domains such as the Amazon Rainforest, Atlantic

Forest, Cerrado, and Caatinga (Alves et al. 2014a, b, Mello-Patiu et al. 2014, 2017, Sousa et al. 2016, Barbosa et al. 2017).

However, some of the species sampled, such as *Lipoptilocnema misella* (Lopes, 1938), *R. mizuguchiana*, and *Blaesoxipha (Gigantotheca) stallengi* (Lahille, 1907), are most likely associated with open and/or dry habitats. In a study conducted in different biomes of the state of Maranhão, *R. mizuguchiana* and *B. (G.) stallengi* were only sampled in savannas and swamps, which are open environments (Sousa et al. 2016). *Lipoptilocnema misella* was only identified in the Brazilian states of Goiás, Maranhão, Mato Grosso, and Minas Gerais (Mulieri et al. 2016, Sousa et al. 2016). Because this species, like many others in the same genus, is associated with Cerrado areas (Mulieri et al. 2016), it is absent in forensic studies and lists of scavenger flesh flies in the Amazon (Vairo et al. 2014, Ramos-Pastrana et al. 2018).

In Brazil, only two species of the subgenus *Squamatodes* are found: *Peckia (Squamatodes) ingens* (Walker, 1849) and *Peckia (Squamatodes) trivittata* (Curran, 1927), the former being more common in forested habitats and the latter in more open ones such as the Cerrado (Barros et al. 2008, Valverde-Castro et al. 2017, Camargo et al. 2018). This is most likely why the abundance of *P. (S.) ingens* was low in the studied area. Sousa et al. (2016), on the other hand, sampled 39 specimens in Cerrado areas and none in the Amazon rainforest in the state of Maranhão.

The species *L. misella*, *Oxysarcodexia amorosa* (Schiner, 1868), *Oxysarcodexia avuncula* (Lopes, 1933), *Oxysarcodexia fringidea* (Curran & Walley, 1934), *P. (P.) enderleini*, *Peckia (Peckia) uncinata* (Hall, 1933), *P. (S.) ingens*, *R. andina*, *Retrocitomyia retrocita* (Hall, 1933), *Titanogrypa (Cuculomyia) luculenta* (Lopes, 1938) and *Titanogrypa (Airypel) cryptopyga* (Lopes, 1956), were found only in the riparian forest, although in low abundance (less than 5 specimens) (Table 2). According to Macedo (1993), Castro et al. (2012), and Kuntschik et al. (2014), riparian forests have great ecological importance because of their faunistic, floristic, and microbiotic composition, thus playing an important role in forming corridors that promote gene flow. The presence of species of Sarcophagidae in riparian forests that were absent in open areas, as well as new species records, suggest that this vegetation type is also important for the conservation of the family's biodiversity in the Cerrado. Nonetheless, anthropogenic activities, particularly logging, cattle raising, and agriculture, are drastically altering riparian forests in the municipality of Codó, because these areas typically have fertile soils (Castro 2012, Kuntschik et al. 2014, Kutzmy et al. 2019).

Conclusions

We identified 27 species of scavenger Sarcophagidae in the studied areas, three of them were new records for the Northeast Region (*Oxysarcodexia angrensis*, *Peckia (Peckia) enderleini* and *Retrocitomyia andina*), and one for the state of Maranhão (*Titanogrypa (Cuculomyia) albuquerquei*). This highlights the importance and necessity of conducting more surveys in the region, especially in areas such as riparian forests, where the sarcophagid fauna has not yet been adequately sampled. The habitat type only significantly affected the abundance of *Peckia (Euboettcheria) collusor*, which was more abundant in open areas. *Peckia (Peckia) chrysostoma*, *P. (P.) pexata*, and *P. (S.) lambens* were generalists in the studied areas. This study contributes to the understanding of the spatial distribution of different Sarcophagidae species in "cerrado" *sensu stricto* and riparian forest areas, reducing the knowledge gap for this group in the Northeast Region of Brazil.

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Author Contributions

Raimundo Francisco Oliveira Nascimento: Substantial contribution in the concept and design of the study; Contribution to data collection; Contribution to data analysis and interpretation; Contribution to manuscript preparation; Contribution to critical revision, adding intellectual content.

José Orlando de Almeida Silva: Substantial contribution in the concept and design of the study; Contribution to data collection; Contribution to data analysis and interpretation; Contribution to manuscript preparation; Contribution to critical revision, adding intellectual content.

Fernando da Silva Carvalho-Filho: Contribution to data analysis and interpretation; Contribution to manuscript preparation; Contribution to critical revision, adding intellectual content.

Conflicts of Interest

There is no conflict of interest.

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