Distribution and Abundance of Necrophagous Flies (Diptera: Calliphoridae and Sarcophagidae) in Maranhão, Northeastern Brazil

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ABSTRACT. This study aimed at surveying the local calliphorid and sarcophagid species in Maranhão State (Brazil) to determine their distribution and abundance, as well as the distribution of exotic Chrysomya species. In total, 18,128 calliphorid specimens were collected, distributed in 7 genera and 14 species. The species Hemilucilia semidiaphana (Rondani, 1850) and Paralucilla paraeensis (Mello, 1969) were new state records. Chrysomya albiceps (Wiedemann, 1819) and Cochliomyia macellaria (F., 1775) were the most abundant species, and the exotic species of Chrysomya together contributed more than 50% of total blow fly abundance. The abundance distribution of the calliphorid community conformed to a log series model, characterized by a steep curve that reflects an assemblage with a high degree of dominance. For the Sarcophagidae, a total of 14,810 specimens were collected and distributed in 15 genera, 11 subgenera, and 52 species. Tricharaea (Sarcophagula) occidua (F., 1794) and Peckia (Sarcodexia) lambens (Wiedemann, 1830) were the most abundant species. The abundance distribution of the species followed a log normal model, with a gentler slope, consistent with a more uniform community. The cumulative species curve for the sarcophagids did not reach the asymptote. Forty-three sarcophagid species were new state records and 22 were new records for the Brazilian northeast, which emphasizes the need for a continued survey in this region.

Key Words: blow fly, flesh fly, insect sampling, neotropical region.

Flies of the families Calliphoridae and Sarcophagidae are ecologically and forensically important, due to the fact that the larvae of many species feed on dead organic matter, acting as decomposers and potential indicators of the postmortem interval (Rivers and Dahlem 2014). From a medical and sanitary viewpoint, the adults are potential vectors of diseases feed on dead organic matter, acting as decomposers and potential indicators of the postmortem interval (Rivers and Dahlem 2014). From a medical and sanitary viewpoint, the adults are potential vectors of pathogens (Greenberg 1971), while the larvae of some species parasitize humans and other vertebrates, causing myiasis, known as blowfly strike (Zumpt 1965, Hall and Wall 1995, Guimaraes and Papavero 1999).

There are 1,525 known calliphorid species belonging to 97 genera (Pape et al. 2011), of which 130 species are known to occur in the Neotropical Region (Carvalho and Mello-Patiu 2008) and 38 in Brazil (Mello 2003, Kosmann et al. 2013). During the 1970s, the composition of the calliphorid fauna of the Americas was affected by the invasion of three exotic species of the genus Chrysomya, originally from the Old World (Carreira 1978, Guimaraes et al. 1978, Linhares 1981, Paraluppi and Castellon 1994). Since this time, these species, Chrysomya albiceps (Wiedemann), C. megacephala (F., 1794), and C. putoria (Wiedemann, 1818), have become very abundant in Brazil and have come to predominate in both urban environments and forest fragments, where they have even displaced native species, such as Cochliomyia macellaria (F., 1775) and Lucilia eximia (Wiedemann, 1819) (Carreira 1979, 1983; Guimaraes et al. 1979; Paraluppi and Castellon 1994; Esposito 1997). A fourth species of Chrysomya, C. rufiacies (Macquart, 1843), has been discovered in Brazil, in the states of Maranhão (Silva et al. 2012a) and Rio de Janeiro (Ribeiro et al. 2013). However, Grella et al. (2015) concluded that the specimens identified as C. rufiacies represent a polymorphic form of the species C. albiceps and that C. rufiacies does not yet occur in Brazil.

The sarcophagids are a more diverse group, with a total of 3,094 species, distributed in 173 genera (Pape et al. 2011) and three subfamilies (Miltogrammatinae, Paramacronychiinae, and Sarcophaginae). Approximately 800 species are known to occur in the Neotropics, and 350 have been recorded in Brazil (Pape 1996, Amorim et al. 2002). The subfamily Sarcophaginae is the richest in species and the most diverse, in biological terms, with approximately 1,800 known species and 51 genera, which have been recorded in all biogeographic regions and are common in the New World (Shewell 1987, Pape 1996, Pape et al. 2006). Most species are most effectively identified based on the characteristics of the male genitalia (Carvalho and Mello-Patiu 2008).

Most of the available studies of the geographic distribution and occurrence of calliphorid and sarcophagid species in Brazil have focused on the southern and southeastern regions (Viana and Pinheiro 1998; Leandro and D’Almeida 2005; Furusawa and Cassino 2006; Ferraz et al. 2009, 2010b; Souza and Von Zuben 2012; Cabrini et al. 2013; Ribeiro et al. 2013), as well as the northern region (Carvalho and Couri 1991; Paraluppi and Castellon 1994; Paraluppi 1996; Couri et al. 2000; Esposito et al. 2009, 2010; Sousa et al. 2010, 2011), while few studies are available for the other Brazilian regions, as the midwest (Gomes et al. 2000, Barros et al. 2008, Corrêa et al. 2010, Koller et al. 2011) and the northeast (Vasconcelos and Araujo 2012, Silva et al. 2012b, Vasconcelos et al. 2013, Vasconcelos and Salgado 2014) and many areas have yet to be surveyed.

The Brazilian state of Maranhão not only covers a vast area but is also characterized by a remarkable diversity of habitats due to its location in the transition zone between the Amazon, Cerrado, and Caatinga biomes (Ab’Saber 1977, Muniz 2006), a scenario that has stimulated considerable interest from zoologists. Given the lack of data on the fauna of calliphorids and sarcophagids found in Maranhão, this study aimed to survey the local species and determine their distribution and abundance, as well as the distribution and abundance of the exotic Chrysomya species found in the state.
Materials and Methods

Study Area. The survey was conducted at 105 sites located in 19 municipalities distributed throughout the state of Maranhão (Table 1; Fig. 1), in northeastern Brazil, between the coordinates 01° 01’ to 10° 21’ S and 41° 48’ to 48° 40’ W. The specimens were collected in traps designed specifically for the capture of saprophagous dipterans, containing 50 g of cow’s lung as bait (Ferreira 1978). The traps were set at three to nine sites in each municipality in July–October 2009, August–October 2010, January, April, and October 2011, and February, May, and November 2012. Between 15 and 30 traps were set at each site, which was considered to be a sampling unit, and were replicated at a minimum distance of 2 km from one another.

The calliphorid specimens were identified using the taxonomic keys of Guimarães (1977), Dear (1985), Carvalho and Ribeiro (2000), Mello (2003), Carvalho and Mello-Patiu (2008), and Kosmann et al. (2013). The sarcophagid specimens were identified using the specific keys for the genera Oxysarcodexia (Lopes 1946, Lopes and Tibana 1987) and Peckia (Buenaustiana and Pape 2013), as well as other studies, which despite not presenting identification keys as such, do provide illustrations of the genitalia of some genera, that permit an accurate identification of the taxa (Lopes 1939, 1958, 1976, 1989; Tibana 1976, 1981; Lopes and Tibana 1982; Tibana and Xerez 1985; Guimarães 2004). This process was further refined by comparisons with voucher specimens deposited in the entomological collection of the Museu Paraense Emílio Goeldi (MPEG) in Belém, Pará (Brazil).

The specimens collected in this study were deposited in the MPEG entomological collection, in the Museu de Zoologia da Universidade Federal do Pará, also in Belém, and in the teaching collection of the Prof. Clésio Fonseca Laboratory of Zoology at the Universidade Estadual do Maranhão in Imperatriz, Maranhão (Brazil).

Data Analysis. The efficiency of the sampling of the calliphorid and sarcophagid species in the study area was verified using cumulative species curves derived from a first-order nonparametric Jackknife procedure (Colwell and Coddington 1994), with one thousand randomizations based on the number of study sites (Colwell 2013). The Jackknife 1 estimator is based on the richness of the rarest species, using the formula: $S_{Jackknife} = Sobs + L (n - 1/n)$, where $Sobs$ = the number of species observed overall, $L$ = the number of species found in a single sample, and $n$ = the number of samples (Palmer 1991, Colwell 2013). The estimates of species richness were calculated in EstimateS, version 9.0 (Colwell 2013).

The calliphorid and sarcophagid species were classified in three categories (common, intermediate, and rare), based on their occurrence at the study sites surveyed in Maranhão. The analysis of the records was based on indices of frequency and constancy (Silveira-Neto et al. 1976).

The Frequency Index (FI) is the proportion of individuals of a given species in relation to the total sample, $FI = n_i/N$, where $n_i$ = the number of specimens of species $i$ and $N$ = the total number of specimens collected. Based on the FI values, the species were classified as dominant (D) or nondominant (ND). Dominant species were those with a FI value higher than 1/$S$, where $S$ is species richness, i.e., the total number of species in the community.

The Constancy Index (CI) is the percentage of samples in which a given species was present, $CI = p*100/N$, where $p$ = the number of samples in which the species was recorded and $N$ = the total number of samples. This analysis considered the 105 study sites as individual samples. Based on their CI values, the species were classified as constant (CT), when present in more than 50% of the samples (CI > 0.50), accessory (AS) when present in 25–50% of the samples (CI = 0.25–0.50), and accidental (AC) when found in fewer than 25% of samples (CI < 0.25). The species were classified based on the combination of these two indices, as common (D+CT), intermediate (D+AS; D+AC; ND+CT; ND+AS), and rare (ND+AC).

The species were classified in decreasing order of abundance and these data were compared with four mathematical models of abundance distribution, i.e., geometric, log series, log-normal, and broken stick, to determine the best fit of the data collected. The fit was determined using Chi-square, considering $P < 0.05$ (Magurran 1988). These analyses were run in the program Species Diversity and Richness 3.0 (Henderson and Seaby 2002) and the graphs were produced in Past (Hammer et al. 2001).

Results

In total, 18,128 calliphorid specimens were collected during this study, representing 3 subfamilies (Chrysomyinae, Luciliinae, and Mesembrinellinae), 7 genera, and 14 species, 10 of which were chrysomyines. The species Hemicellia semidiaphana (Rondani, 1850) and Paralucilia paraensis (Mello, 1969) were recorded for the first time in the state of Maranhão (Table 2). C. albiceps and C. macellaria were

| Municipio          | Geographic coordinates | Mesoregion         | Study sites | Number of traps |
|--------------------|------------------------|--------------------|-------------|-----------------|
| Carolina           | 07° 12’ 58.8” S        | 47° 25’ 54.6” W   | South Maranhão 6 | 30              |
| Riachão            | 07° 25’ 40.1” S        | 46° 45’ 3.06” W   | South Maranhão 6 | 30              |
| Baía               | 07° 27’ 4.44” S        | 46° 24’ 57.02” W | South Maranhão 6 | 30              |
| Estreito           | 06° 33’ 39” S          | 47° 27’ 0.3” W    | South Maranhão 9 | 18              |
| Esperantinópolis   | 04° 55’ 09.02” S       | 44° 57’ 09.43” W | Central Maranhão 6 | 30              |
| Poção de Pedras    | 04° 49’ 10.95” S       | 44° 55’ 35.55” W | Central Maranhão 6 | 30              |
| Lago do Junco      | 04° 36’ 14.3” S        | 45° 01’ 03.44” W | Central Maranhão 6 | 30              |
| Caiari             | 03° 19’ 18.03” S       | 44° 52’ 13.06” W | North Maranhão 6 | 30              |
| Cajapó             | 03° 50’ 19.98” S       | 44° 40’ 42.72” W | North Maranhão 6 | 30              |
| Viana             | 03° 12’ 39.7” S        | 44° 56’ 59.3” W  | North Maranhão 6 | 30              |
| Cedral             | 01° 57’ 44.3” S        | 44° 30’ 41.6” W  | North Maranhão 6 | 30              |
| Guimarães          | 02° 05’ 20.3” S        | 44° 33’ 11.7” W  | North Maranhão 6 | 30              |
| Cândido Mendes     | 01° 25’ 54.39” S       | 45° 30’ 45.12” W | West Maranhão 3  | 15              |
| Turião             | 01° 31’ 07.4” S        | 45° 25’ 47.2” W  | West Maranhão 3  | 15              |
| Centro Novo do Maranhão | 03° 37’ 09.1” S       | 46° 43’ 22.6” W  | West Maranhão 9  | 45              |
| Bom Jardim         | 04° 00’ 53.04” S       | 46° 46’ 48.99” W | West Maranhão 3  | 15              |
| Cidélândia         | 05° 07’ 39.9” S        | 47° 45’ 37.0” W  | West Maranhão 3  | 15              |
| Vila Nova dos Martírios | 05° 11’ 09.4” S       | 47° 56’ 41.1” W  | West Maranhão 3  | 15              |
| Imperatriz         | 05° 31’ 33” S          | 47° 28’ 38” W    | West Maranhão 6  | 36              |
| Total              |                        |                    |             | 105             | 504             |
the most abundant species, and the exotic species of the genus Chrysomya together contributed more than 50% of total abundance.

The abundance distribution of the calliphorid community produced a best fit with the log series distribution (Fig. 2a: $\chi^2 = 12.185; P = 0.430; df = 12$). In contrast, the abundance values recorded for the species of this family did not adjust to the geometric (Fig. 2b: $\chi^2 = 995.511; P < 0.05; df = 14$), broken stick (Fig. 2c: $\chi^2 = 246.508; P < 0.05; df = 14$) or log normal (Fig. 2d: $\chi^2 = 6.191; P < 0.05; df = 12$) models.

The cumulative species curve based on the total sample of the calliphorids had reached the asymptote by the end of the study (Fig. 3), with sampling efficiency (observed species richness divided by estimated

![Fig. 1. Location of the municipalities surveyed in the different mesoregions of the Brazilian state of Maranhão between 2009 and 2012.](image)

| Species          | Frequency index | CI     | Category | New occurrence$^a$ |
|------------------|-----------------|--------|----------|--------------------|
| AA               | Fl %           | C      | O        | Cl %               | C |
| C. albiceps      | 7,326           | 40.41  | 7.14     | D                  | 101 | 96.19 | CT Common |
| Co. macellaria   | 4,787           | 26.41  | 7.14     | D                  | 99  | 94.29 | CT Common |
| C. megacephala   | 2,199           | 12.13  | 7.14     | D                  | 72  | 68.57 | CT Common |
| Ch. idioidea     | 1,910           | 10.54  | 7.14     | D                  | 65  | 61.90 | CT Common |
| L. eximia        | 1,065           | 5.87   | 7.14     | ND                 | 61  | 58.10 | CT Intermediate |
| C. putoria       | 363             | 2.00   | 7.14     | ND                 | 51  | 48.57 | AS Intermediate |
| M. bicolor      | 242             | 1.33   | 7.14     | ND                 | 14  | 13.33 | AC Rare |
| H. semidiaphana  | 190             | 1.05   | 7.14     | ND                 | 17  | 16.19 | AC Rare |
| P. paraensis     | 17              | 0.09   | 7.14     | ND                 | 8   | 7.62  | AC Rare |
| Co. hominivorax  | 11              | 0.06   | 7.14     | ND                 | 8   | 7.62  | AC Rare |
| L. sericata      | 10              | 0.06   | 7.14     | ND                 | 3   | 2.86  | AC Rare |
| H. segmentaria   | 6               | 0.03   | 7.14     | ND                 | 4   | 3.81  | AC Rare |
| H. benoisti      | 1               | 0.01   | 7.14     | ND                 | 1   | 0.95  | AC Rare |
| M. batesi        | 3               | 0.01   | 7.14     | ND                 | 1   | 0.95  | AC Rare |
| Total            | 18,128          | 100    | 2        |

AA, absolute abundance; Fl, Frequency Index; S, observed species richness; C, class; O, occurrence; D, dominant; ND, not dominant; CT, constant; AS, accessory; AC, accidental.

$^a$New occurrence of species in Maranhão.
Fig. 2. Models of the abundance distribution of calliphorid species in Maranhão: (a) log series, (b) geometric, (c) broken stick, and (d) log normal.

Fig. 3. Cumulative species richness curves (observed, Mao Tau, and estimated, Jackknife 1) for the calliphorids sampled in Maranhão, Brazil, 2009–2012.
richness) of 94%, which indicates that sampling effort was sufficient for the reliable measurement of the species richness of the Calliphoridae in the study area.

Based on the classification of the frequency and constancy of the different species, four calliphorids (28.5% of the total fauna) were considered to be common in Maranhão, two species (14.3%) were classified as intermediate, and eight (57.2%) as rare (Table 1). The species C. albiceps, Co. macellaria, C. megacephala, and Chloroprocata idioidea (Robineau-Desvoidy, 1830) were all considered to be common, given that they were both dominant and constant, being found at more than half of the sites surveyed.

The species L. eximia and C. putoria were classified as intermediate, due to the fact that they were not considered to be dominant. The rare group (non-dominant and accidental) included three species of the genus Hemilucilia: H. semidiaphana, H. segmentaria (F., 1805), and H. benoisti Séguy, 1925 and two of the genus Mesembrinella Giglio-Tos 1893: Mesembrinella bicolor (F., 1805) and Mesembrinella bateri (Aldrich, 1922).

In the case of the Sarcophagidae, a total of 14,810 specimens were collected, all of which were sarcophagines, distributed in 15 genera, 11 subgenera, and 52 species. Forty-three of these species had not previously been recorded in Maranhão and 22 were known to occur in the Brazilian northeast. Tricharaea (Sarcophagida) occidia (F., 1794) and Peckia (Sarcodexia) lambens (Wiedemann, 1830) were the most abundant species (Table 3).

The best fit for the abundance distribution of the sarcophagids was the log normal model (Fig. 4a: $\chi^2 = 2.289; P = 0.999; df = 13$), whereas the data were not consistent with the geometric (Fig. 4b: $\chi^2 = 24.864.8; P < 0.05; df = 50$), log series (Fig. 4c: $\chi^2 = 40.261; P < 0.05; df = 13$), or broken stick (Fig. 4d: $\chi^2 = 2.153; P < 0.05; df = 13$) models.

The cumulative species curve for the sarcophagids did not reach the asymptote and was still rising at the end of the study period (Fig. 5). However, sampling efficiency (observed species richness divided by estimated richness) was 78%, indicating that the sampling effort was sufficient for the measurement of the species richness of necrophagous sarcophagids in the study area.

Three sarcophagid species (6% of the total) were considered to be common, 5 (9%) intermediate, and the remaining 44 (85%) rare. The common species, T. (S.) occidia, Pe. (S.) lambens, and Pe. (Peckia) chrysostoma (Wiedemann, 1830) were both dominant and constant, being not only abundant but also recorded at a high proportion of the study sites (Table 2). Even though Oxysarcodexia intona (Curran and Walley, 1934) and O. thornax (Walker, 1849) were dominant species, they were classified as intermediate due to their accessory status, being recorded at between 25% and 50% of the study sites. Pe. (Squamatodes) ingens (Walker, 1849) and Pe. (Peckia) pexata (Wulp, 1895), both considered to be accessory, and Pe. (Eubotthercia) collusor (Curran and Walley 1934), which was constant, were all classified as intermediate species because they were not dominant.

**Discussion**

The known calliphorid fauna of Maranhão represents 35% of the total number of species predicted to occur in Brazil by Mello (2003) and Kosmann et al. (2013). The estimates of the species richness of the calliphorids (Jackknife 1 and Mao Tau) indicate that the sampling effort was sufficient for the inventory of the full diversity of necrophagous species present within the study area. The number of species recorded was similar to that found in other Brazilian states, such as Pará (Esposito et al. 2009, 17 species), Amazonas (Sousa et al. 2010, 16 species), Rio Grande do Sul (Viana and Pinheiro 1998, 13 species), São Paulo (Cabrini et al. 2013, 13 species), Roraima (Carvalho and Couri 1991, nine species), Mato Grosso (Esposito and Carvalho-Filho 2009, seven species), and Pernambuco (Vasconcelos and Salgado 2014, six species). In the state of Rio de Janeiro, however, Ferraz et al. (2010) recorded the highest species richness (26 species), equivalent to 68% of the total found in Brazil.

Low species richness of the calliphorid fauna was registered in other regions of South America, such as Argentina, where Centeno et al. (2004) recorded 12 species in Hudson, and Mariluis et al. (2008) and Patucci et al. (2011) recorded four and six species, respectively, in Patagonia. Beltran et al. (2012) recorded six species in Bogotá, Colombia.

Of the 14 calliphorid species collected in this study, 10 were chrysomyines, 59% of the 17 species of this subfamily known to occur in Brazil (Kosmann et al. 2013). Similarly, of the four species of Hemilucilia found in Brazil (Dear 1985, Kosmann et al. 2013), three (H. semidiaphana, H. segmentaria, and H. benoisti) were recorded in Maranhão. In contrast, only one of the four species of the genus Paralucilia known to occur in Brazil (P. paraensis) was collected in this study.

In the Neotropical region, the only calliphorid species that is an obligate parasite of live tissue (i.e., a source of primary myiiasis) is Co. hominivorax (Coquerel, 1858) (Guimarães et al. 1983, Dear 1985). Despite this habit, Co. hominivorax also been captured using this type of bait in a number of previous studies (Viana and Pinheiro 1998, Esposito et al. 2009, Ferraz et al. 2010, Sousa et al. 2010).

The subfamily Luciliinae was represented by only two species, of which, L. eximia is a common species in Brazil, being found in rural areas and forests (Ferreira 1978, Linhares 1981, Madeira et al. 1982, Sousa et al. 2010). Six species of the genus Lucilia are known to occur in Brazil (Carvalho and Ribeiro 2000, Kosmann et al. 2013, Whitworth 2014).

The subfamily Mesembrinellinae was represented by the species M. bicolor and M. bateri. The mesembrinelline flies are found exclusively in the Neotropics, where they are represented by 30 species, of which, 14 of which occur in Brazil (Guimarães 1977, Kosmann et al. 2013). These flies are found in natural habitats, such as dense, humid forests (Peris and Mariluis 1984).

The calliphorid fauna recorded in Maranhão was similar to that found in other Brazilian states, especially given that two of the four common species were exotic members of the genus Chrysomya (C. albiceps and C. megacephala), with a third member of this genus (C. putoria) being found among the intermediate species. However, C. albiceps predominated considerably over C. megacephala and C. putoria at most study sites.

The abundance distribution of the calliphorid community conformed to a log series model, characterized by a steep curve that reflects an assemblage with a high degree of dominance. The log series model (Fisher et al. 1943) implies that the communities are not independent and require high rates of immigration to maintain their high number of rare species (Preston 1948). In these communities characterized by a high degree of dominance and low levels of abundance in the majority of species, the model predicts a smaller number of species than that observed (Magurran 1988).

The predominance of C. albiceps in comparison with other Chrysomya species has been attributed to the feeding behavior of its larvae, which are predators of the immature stages of other dipterans (Mello et al. 1997), as well as their short development period, with the larvae incorporating the maximum possible quantity of food during the shortest possible period of time (Prado and Guimarães 1982).

The species Co. macellaria (common) and L. eximia (intermediate) are important components of the necrophilous fly fauna of South America, although the presence of Chrysomya species has been shown to interfere with their abundance. A number of studies have indicated that the exotic species C. albiceps may be responsible for the displacement or reduction in the abundance of the native species through competition (Guimarães et al. 1979, Prado and Guimarães 1982, D’Almeida and Fraga 2007). The species Ch. idioidea, which is also considered to be common, is also an important component of the...
calliphorid fauna and has been collected at a number of different sites in Brazil (Esposito et al. 2009, 2010; Ferraz et al. 2009; Sousa et al. 2010). The rare calliphorid species include two members of the genus *Hemileucilla* Brauer, 1985, which are typical of forest habitats (D’Almeida and Lopes 1983). The species *M. bicolor* and *M. batesi* and all the other mesembrinellines are considered to be asynanthropic, in contrast, due to the fact that they are found exclusively in forest and apparently do not breed in any of the decomposing substrates so common in anthropogenic environments (Guimarães 1977, Ferreira 1978). They were recorded in the Amazon forest zone in this study.

The number of sarcophagid species recorded in Maranhão represents only around 15% of the total number of species predicted for Brazil. The estimates of species richness (Jackknife 1 and Mao Tau) indicate that the sampling effort was not sufficient for a reliable estimate of sarcophagid species richness, based on the criteria of Tóti et al. (2000). However, the sampling efficiency of 78% indicates that a large proportion of the local species were recorded, at least the necrophagous species. Even so, given the large number of species known to occur in the Neotropical region, including Brazil (Pape 1996, Pape et al. 2000). However, the sampling efficiency of 78% indicates that a large proportion of the local species were recorded, at least the necrophagous species. Even so, given the large number of species known to occur in the Neotropical region, including Brazil (Pape 1996, Pape et al. 2011), and the fact that the members of this family occupy an ample diversity of habitats and are members of several different guilds (not all species are regular visitors of decomposing meat), it seems likely that

| Species                                      | Frequency index | CI Category | New occurrence (NO) |
|----------------------------------------------|-----------------|-------------|---------------------|
| *Sarcofahrtiopsis cuneata*                   |                 | D 43        |                     |
| *Ravinia effrenata*                          |                 | D 14,810    |                     |
| *Ravinia belforti*                           |                 |             |                     |
| *Villegasia almeidai*                        |                 |             |                     |
| *Lipoptilocnema subducta*                    |                 |             |                     |
| *Sarcophaga (Cucullomyia) larvicida*          |                 |             |                     |
| *Helicobia aurescens*                        |                 |             |                     |
| *Helicobia pilileura*                        |                 |             |                     |
| *O. vilosa*                                  |                 |             |                     |
| *Blaesoxipha (Gigantoxychia) stollangi*       |                 |             |                     |
| *Dexosarcophaga (Bezzisca) tupinamba*         |                 |             |                     |
| *Dexosarcophaga (Farrimyia) carvalhii*        |                 |             |                     |
| *Hemicalliphora filamenta*                   |                 |             |                     |
| *Dexosarcophaga hugoi*                       |                 |             |                     |
| *Helicobia borgmeieri*                       |                 |             |                     |
| *O. aurea*                                   |                 |             |                     |
| *Oxyrsarcoderexia sp1*                       |                 |             |                     |
| *Pe. (Euboctettchera) subducta*               |                 |             |                     |
| *Pe. (Patonella) pallidipilosa*              |                 |             |                     |
| *Peckianmyia abnormals*                      |                 |             |                     |
| *Retrocitomyia retrocita*                    |                 |             |                     |
| *Sarcophaga (Tritonmyia) crisupa*            |                 |             |                     |
| *Sarcophaga (Neobelliera) polistensis*        |                 |             |                     |
| *Titanorygna (Ainyppel) cryptopyga*           |                 |             |                     |
| *Titanorygna (Cocullomyia) luculent*          |                 |             |                     |

**Table 3. Composition and total abundance of the sarcophagid species found in the study area in Maranhão, Brazil, between 2009 and 2012**
Fig. 4. Models of the abundance distribution of saprophagid species in Maranhão: (a) log series, (b) geometric, (c) broken stick, and (d) log normal.

Fig. 5. Cumulative species richness curves (observed, Mao Tau, and estimated, Jackknife 1) for the sarcophagids sampled in Maranhão, Brazil, 2009–2012.
additional sampling within the study area will result in an increase in the number of sarcophagid species known to occur in Maranhão. The confirmation of new records of 43 species for Maranhão and 22 for the Brazilian Northeast reinforces the need for further surveys in this region. The sarcophagid fauna of the New World is more diverse than that of the Old World, in terms of the number of species and genera, and the Neotropical region is the most diverse of all (Shewell 1987, Peck 1996, Pe et al. 2011). Approximately 800 species have been recorded in the Neotropics, of which, 350 are known to occur in Brazil (Peck 1996, Amorim et al. 2002). Even so, it seems likely that these numbers will continue to grow as new surveys are conducted.

Considering that the common sarcophagid species, T. (S.) occida and Pe. (S.) lambens, predominate over all other species, including the other common species, Pe. (Peckia) chrysostoma, reinforces their importance as components of the necrophagous sarcophagid fauna of Maranhão. However, the abundance distribution of the species followed a log normal model, with a gentler slope, consistent with a more uniform community.

The species Pe. (S.) lambens was also the most abundant sarcophagid on Maracá Island in the Brazilian state of Roraima (Lopes and Tibana 1991) and in the Serra do Navio in Amâpi (Couri et al. 2000), whereas T. (S.) occida was the most abundant species at the sites surveyed in Argentina (Mulieri et al. 2008). These two species are able to adapt to a diversity of environments and have been recorded in both open habitats and forests (Mulieri et al. 2008, Sousa et al. 2011).

The sarcophagid species classified as intermediate included Pe. (E.) collasor and Pe. (S.) ingens, which are capable of adapting to an ample diversity of environments. For example, Pe. (E.) collasor has been collected in areas of forest (Linares 1981, D’Almeida 1984, Dias et al. 1984, Yepes-Gaurias et al. 2013) as well as more open habitats (Sousa et al. 2011). Similarly, Pe. (S.) ingens has been found in both forests (Vasconcelos et al. 2013) and more open areas, such as clearings (Sousa et al. 2011).

The large proportion of rare species (85% of the total) found in the sample reinforces the need for further surveys, which should increase the number of necrophagous sarcophagid species known to occur in the state of Maranhão.

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References Cited

Ab’saber, A. N. 1977. Os domínios morfoclimáticos na América do Sul. Geomorfologia 52: 1–21.

Amorim, D. S., V. C. Silva, and M.I.P.A. Balbi. 2002. Estado do Conhecimento dos Diptera Neotropicais, pp. 29–36. In C. Costa, S. A. Vanin, J. M. Lobo, and A. Melic (eds.), PRIBES. Sociedade Entomológica Aragoneza, Zaragoza, Spain.

Barros, R. M., C. A. Mello-Patiú, and J. R. Pujol-Luz. 2008. Sarcophagidae (Insecta, Diptera) no Campus do Valonguinho, Universidade Estadual do Rio de Janeiro. Arq. Univ. Fed. Rural do Rio de Janeiro 17: 101–110.

Centeno, N. D., A. Almorza, and C. Arnillas. 2004. Diversity of Calliphoridae (Diptera: Calliphoridae) na Região Metropolitana do Estado do Rio de Janeiro. Univ. Fed. Rural do Rio de Janeiro 17: 101–110.

Carvalho, C.J.B., and M. S. Couri. 1991. Muscidae, Fanniidae and Calliphoridae (Diptera) do Projeto Maracá, Roraima, Brasil. Acta Amaz. 21: 35–43.

Carvalho, C.J.B., and C. A. Mello-Patiú. 2008. Keys to the adults of the most common forensic species of Diptera in South America. Rev. Bras. Entomol. 52: 390–406.

Carvalho, C.J.B., and P. B. Ribeiro. 2000. Estimation of terrestrial biodiversity through extrapolation. Philos. Trans. R. Soc. Lond. B. Biol. Sci. 315: 101–118.

Correa, E. C., W. W. Koller, and A.T.M. Barros. 2010. Abundância relativa e sazonalidade de espécies de Chrysomya (Diptera: Calliphoridae) no Pantanal Sul Mato - Grosso, Brasil. Rev. Bras. Parasitol. Vet. 19: 85–88, 2010.

Couri, M. S., C.J.E. Lamas, C.C.C.A. Aires, C. A. Mello-Patiú, V. C. Maia, D. M. Pamplona, and P. Magano. 2000. Dipteros da Serra do Navio (Saudá, Brasil): Asilídeos, Bubolídeos, Calliphoridae, Micropezídeos, Muscídeos, Sarcófágidos, Stratómyídeos, Sphyridíos, Tabanídeos e Tachínídeos. Rev. Bras. Zool. 17: 91–100.

D’Almeida, J. M. 1984. Sinantropia de Sarcophagidae (Diptera) no Pantanal, Brazil. J. Anim. Ecol. 12: 42–58.

Dear, J. P. 1985. A revision of the new world Chrysomya (Diptera: Calliphoridae). Rev. Br. Entomol. 3: 109–169.

Dias, E. S., D. P. Neves, and H. S. Lopes. 1984. Estudos sobre a fauna de Sarcophagidae (Diptera) de Belo Horizonte, Minas Gerais. I. Levantamento taxonômico e sinantrópico. Mem. Inst. Oswaldo Cruz 79: 83 – 91.

Esposito, M. C. 1997. The exotic species of Chrysomya (Diptera, Calliphoridae) in the Amazonia: Why they don’t occur in the Ferreirina Perna Scientific Station, pp. 361–367. In P.L.B. Lisboa (ed.), Caxiuanã. CNPq-Museu Paraense Emílio Goeldi, Belém, Pará, Brazil.

Esposito, M. C., C. J. R. P. Sousa, and F. S. Carvalho-Filho. 2009. Nos animais da Tanguro Mato Grosso-Diversidade na Zona de Transição entre Floresta Amazônica e o Cerrado. Museu Paraense Emílio Goeldi, Belém, Pará, Brazil.

Esposito, M. C., J.R.P. Sousa, and F. S. Carvalho-Filho. 2009. Diversidade de Calliphoridae (Insecta, Diptera) em Ambientes de matas e próximos de habitações da Estação Científica Ferreira Perna (ECFPn), Melgaço/PA, and da cidade de Portel/PA, pp. 461–469. In P.L.B. Lisboa (ed.), Caxiuanã: Desafios para a Conservação de uma Floresta na Amazônia. Museu Paraense Emílio Goeldi, Belém, Pará, Brazil.

Esposito, M. C., J.R.P. Sousa, and F. S. Carvalho-Filho, 2010. Diversidade de Calliphoridae (Insecta, Diptera) em Ambientes de matas e próximos de habitações da Estação Científica Ferreira Perna (ECFPn), Melgaço/PA, and da cidade de Portel/PA. J. Anim. Ecol. 80: 55–63.

Ferreira, M.J.M. 1979. Sinantropia de dípteros muscópidos de Curitiba, Paraná. II. Sarcophagidae. Rev. Bras. Entomol. 23: 390–399.

Ferraz, A.C.P., B. Q. Gadelha, and V. M. Aguilar-Coelho. 2009. Análise faunística de Calliphoridae (Diptera) da Reserva Biológica do Tinguá, Nova Iguaçu, RJ, Brasil. Rev. Bras. Entomol. 53: 620–628.

Ferraz, A.C.P., B. Q. Gadelha, and V. M. Aguilar-Coelho. 2010. Effects of forest fragmentation on díptero fauna (Calliphoridae) at the Reserva Biológica do Tinguá, Nova Iguaçu, RJ. Braz. J. Biol. 70: 55–63.

Ferreira, M.J.M. 1978. Sinantropia de dípteros muscópidos de Curitiba, Paraná. I. Calliphoridae. Rev. Bras. Biol. 38: 445–454.

Ferreira, M.J.M. 1979. Sinantropia de dípteros muscópidos de Curitiba, Paraná. II. Sarcophagidae. Rev. Bras. Biol. 39: 773–781.

Ferreira, M.J.M. 1983. Sinantropia de Calliphoridae (Diptera) em Goiânia, Goiás. Rev. Bras. Biol. 43: 199–210.

Fisher, R. A., A. S. Corbet, and C. B. Williams.1943. The relation between the number of species and the number of individuals in a random sample of an animal population. J. Anim. Ecol. 12: 42–58.
Tibana, R., and R. Xerez. 1985. Uma nova espécie de Retrocitomyia Lopes, 1982, (Diptera, Sarcophagidae). Rev. Bras. Biol. 45: 485–488.

Toti, D. S., F. A. Coyle, and J. A. Miller. 2000. A Structured inventory of Appalachian grass bald and heath bald spider assemblages and a test of species richness estimator performance. J. Arachn. 28: 329–345.

Vasconcelos, S. D., and M.C.S. Araújo. 2012. Necrophagous species of Diptera and Coleoptera in northeastern Brazil: state of the art and challenges for the forensic entomologist. Rev. Bras. Entomol. 56: 7–14.

Vasconcelos, S. D., and R. L. Salgado. 2014. First record of six calliphoridae (diptera) species in a seasonally dry tropical forest in brazil: evidence for the establishment of invasive species. Fla. Entomol. 97: 814–816.

Vasconcelos, S. D., T. M. Cruz, R. L. Salgado, and P. J. Thyssen. 2013. Dipterans associated with a decomposing animal carcass in a rainforest fragment in Brazil: notes on the early arrival and colonization by necrophagous species. J. Insect Sci. 13: 145.

Viana, M. V., and L.A.F.V. Pinheiro. 1998. Conservação da biodiversidade em fragmentos florestais. Série Técnica IPEF 12: 25–42.

Whitworth, T. 2014. A revision of the Neotropical species of Lucilia Robineau-Desvoidy (Diptera: Calliphoridae). Zootaxa 3810: 1–76.

Yepes-Gaurisas, D., J. D. Sanchez-Rodriguez, C. A. Mello-Patiu, and E. M. Wolff. 2013. Synanthropy of Sarcophagidae (Diptera) in La Pintada, Antioquia-Colombia. Rev. Biol. Trop. 61: 1275–1287.

Zumpt, F. 1965. Myiasis in man and animals in the Old World, 267 p. Butterworths, London.

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