ISSN: 2447-3359

REVISTA DE GEOCIÊNCIAS DO NORDESTE

Northeast Geosciences Journal

v. 6, nº 2 (2020)

https://doi.org/10.21680/2447-3359v6n2ID19857

STUDY OF THE DIPTERAN FAUNA IN AN ENVIRONMENTAL PROTECTION AREA IN MARANHÃO STATE, BRAZIL

Luiza Daiana Araújo da Silva Formiga[1]; Janete dos Santos Oliveira[2]; Márcia Verônica Pereira Gonçalves[3]; Francilene Oliveira Lima[4]; Alana Ellen de Sousa Martins[5]; Judson Chaves Rodrigues[6]; Francisco Ideilson Lima Soares[7]; Jaqueline Oliveira Moreira[8]

[1]Doutora em Zootecnia, Centro de Estudos Superiores de Caxias, Universidade Estadual do Maranhão (UEMA), Caxias/MA, Brasil.
ORCID: https://orcid.org/0000-0001-5001-3297
Email: luizadaiana@hotmail.com

[2]Graduada em Ciências Biológicas Departamento de Química e Biologia, Universidade Estadual do Maranhão (UEMA), Caxias/MA, Brasil.
ORCID: https://orcid.org/0000-0002-2797-7319
Email: janethe.oliveira@hotmail.com

[3]Graduanda em Ciências Biológicas, Departamento de Química e Biologia, Universidade Estadual do Maranhão (UEMA), Caxias/MA, Brasil.
ORCID: https://orcid.org/0000-0001-7805-1463
Email: mv186343@gmail.com

[4]Graduada em Ciências Biológicas, Departamento de Química e Biologia, Universidade Estadual do Maranhão (UEMA), Caxias/MA, Brasil.
ORCID: https://orcid.org/0000-0001-9256-2462
Email: fran.oliveira353@gmail.com

[5]Graduanda em Ciências Biológicas, Departamento de Química e Biologia, Universidade Estadual do Maranhão (UEMA), Caxias/MA, Brasil.
ORCID: https://orcid.org/0000-0002-3543-8972
Email: a.lanasousa2009@hotmail.com

[6]Graduando em Ciências Biológicas, Departamento de Química e Biologia, Universidade Estadual do Maranhão (UEMA), Caxias/MA, Brasil.
ORCID: https://orcid.org/0000-0001-9236-2508
Email: judsoom.rodriguesz@gmail.com

[7]Graduado em Ciências Biológicas, Departamento de Química e Biologia, Universidade Estadual do Maranhão (UEMA), Caxias/MA, Brasil.
ORCID: https://orcid.org/0000-0002-6655-9048
Email: idesoares_lima@hotmail.com

[8]Graduada em Ciências Biológicas Departamento de Química e Biologia, Universidade Estadual do Maranhão (UEMA), Caxias/MA, Brasil.
ORCID: https://orcid.org/0000-0003-1955-0275
Email: jakelinne.oliveira07@gmail.com

Abstract

Information on dipteran fauna is of great importance for a thorough understanding of the biodiversity of a given area, as some dipterans can be used as bioindicators of environmental quality. This study aimed to survey members of the order Diptera in different environments of the Inhamum Environmental Protection Area, Caxias, Maranhão State, Brazil. Two sites were evaluated, a gallery forest site (1) and a Cerrado site (2). Six collections were performed between October 2017 and March 2018 using PROVID traps. At each site, six parallel transects spaced about 10 m apart were sampled at five equidistant points, totaling 60 sampling points (30 points per site). The final sample comprised 1,040 dipteran individuals, including 479 specimens distributed in 22 families collected from site 1 and 561 specimens distributed in 23 families collected from site 2. This survey of families belonging to the order Diptera in the Inhamum Environmental Protection Area revealed the richness of the studied sites. Richness estimation suggested that further investigation of the area may lead to the discovery of rare specimens.

Keywords: Abundance; Diversity; Dominance.

ESTUDO DA ENTOMOFAUNA DE DIPTERA EM ÁREA DE PROTEÇÃO AMBIENTAL NO MARANHÃO, BRASIL

Resumo

O conhecimento da dipterofauna de uma determinada área é de grande importância para conhecer a sua biodiversidade. Pois, alguns dípteros são considerados bioindicadores, demonstrando indícios da qualidade ambiental de uma região. O estudo teve como objetivo realizar um levantamento da ordem Diptera em diferentes ambientes na Área de Proteção Ambiental do

Inhamum, Caxias-MA. A área experimental foi dividida em Área 1 (Mata de galeria) e Área 2 (Cerrado). Foram realizadas seis coletas, entre os meses de outubro de 2017/março de 2018. Utilizando armadilhas Provid. Em cada área foram instalados seis transectos paralelos, com distância de aproximadamente 10 m entre si e em cada transecto foram marcadas cinco unidades amostrais equidistantes, onde foram amostrados 30 pontos em cada área, totalizando 60 pontos. O presente estudo obteve um total 1.040 espécimes da ordem Diptera nas duas áreas, sendo 479 espécimes e 22 famílias para a Área I e 561 espécimes e 23 famílias para Área II. O levantamento de famílias da ordem Diptera realizado na Área de Proteção Ambiental do Inhamum aponta a riqueza de espécimes existentes nas áreas destacadas por esse estudo e os estimadores de riqueza mostram que mais pesquisas precisam ser realizadas, pois, devem existir na região espécimes raros.

Palavras-chave: Abundância; Diversidade; Dominância.

ESTUDIO DE DIPTERA ENTOMOFAUNA EN UM ÁREA DE PROTECCIÓN AMBIENTAL EM MARANHÃO, BRASIL

Resumen

El conocimiento de la dipterofauna de un área dada es de gran importancia para conocer su biodiversidad. Algunos dipterans se consideran bioindicadores, que muestran evidencia de la calidad ambiental de una región. El estudio tuvo como objetivo llevar a cabo una encuesta del orden Diptera em diferentes entornos en el Área de Protección Ambiental de Inhamum, Caxias-MA. El área experimental se dividió em Área 1 (bosque de galería) y Área 2 (Cerrado). Seis colecciones se realizaron entre octubre de 2017/marzo de 2018. Uso de trampas Provid. En cada área, se instalaron seis transectos paralelos, con una distancia de aproximadamente 10 m entre sí y em cada transecto, se marcaron cinco unidades de muestra equidistantes, donde se tomaron muestras de 30 puntos em cada área, totalizando 60 puntos. El presente estudio obtuvo total de 1,040 especímenes del orden Diptera em las dos áreas, con 479 especímenes y 22 familias para el Área I y 561 especímenes y 23 familias para el Área II. La encuesta de familias del orden Diptera realizada em el Área de Protección Ambiental de Inhamum señala la riqueza de especímenes existentes en las áreas destacadas por este estudio y los estimadores de riqueza muestran que se necesita más investigación, ya que los especímenes raros deben existir em la región.

Palabras-clave: Abundancia; Diversidad; Dominación.

1. INTRODUCTION

Various studies have been conducted in Brazilian biomes to identify and analyze the diversity of species occurring in the country's ecosystems. However, many investigations have wrongfully neglected insects. This vast group of organisms contribute to essential ecosystem processes, such as organic matter decomposition, nutrient cycling, energy flow, pollination, seed dispersal, and regulation of populations of plants and animals. Insects are sensitive to disturbances in their environment and can therefore serve as bioindicators of environmental impacts (SILVA, 2009).

Insects are vitally important for biotic communities. They constitute the most dominant group of animals on Earth, accounting for 70% of all known species. The order Diptera, represented by flies and mosquitoes, comprises about 160,000 species distributed in 180 families, corresponding to 10–15% of global biodiversity (CARVALHO et al., 2012; THOMPSON, 2008). Diptera ranks fourth in diversity among orders of the class Insecta (PAPE et al., 2011). More than 60,000 species occur in Brazil, the vast majority of which have a fragile, small (sometimes tiny) body (GULLAN and CRANSTON, 2017).

Faunal studies, particularly those carried out in the Neotropical region, have an increasingly strategic character, given the rapid degradation of environments and its unknown effects on local biodiversity (LEWINSOHN and PRADO, 2005; AMORIM et al., 2002). In Brazil, most faunal inventories of dipterans have focused on specific families of medicinal (Culicidae, Psychodidae, Simuliidae, and Tabanidae) (PATERNO and MARCONDES, 2004; GALATI et al., 2010; DOS-SANTOS et al., 2010; BARROS, 2001), economic (Tephritidae, Drosophilidae, and Lonchaeidae) (HOCHMULLER et al., 2010), environmental (Cecidomyiidae, Chironomidae, and Syrphidae) (URSO-GUIMARÃES and SCARELI-SANTOS, 2006; TRIVINHO STRIXINO-STRIXINO, 2005; JORGE; MARIONI; MARIONI, 2007), and forensic (Calliphoridae, Sarcophagidae, and Muscidae) importance (MELLO et al., 2009; MELLO-PATIU et al., 2010; COURI and CARVALHO, 2005). More comprehensive studies on Diptera diversity were carried out in areas of the Atlantic Forest (SILVA et al., 2011) and Cerrado (OLIVEIRA et al., 2008).

Dipterans play an important ecological role, particularly as natural enemies, acting both as predators and parasitoids (CARVALHO et al., 2012). They are also quite useful as detritivores and decomposers, and some are known to attack weed species (GULLAN and CRANSTON, 2017). As highlighted by Ferraz (2014), studies on the ecology of dipterans in forest fragments are incipient. Investigation of the biodiversity of forest areas is fundamental for identification of species and/or families and their distribution patterns (biogeography). With this information at hand, it is possible to determine which organisms can serve as bioindicators and gain knowledge of the dispersion and adaptability of exotic species, contributing to the design of conservation policies. According to Triplehorn and Johnson (2011), it is impossible to count all insects in an environment, which is why field surveys are conducted to sample and estimate population numbers. Inventory and monitoring of species diversity and population levels is essential for understanding the biodiversity of an ecosystem, allowing the construction of a database on the degree of environmental integrity of the study region (FARIAS et al., 2014).

The Inhamum Environmental Protection Area (EPA), Caxias, Maranhão State, Brazil, is undergoing changes in biota as a result of anthropogenic activities. Currently, there is a knowledge gap generated by the lack of scientific surveys on dipteran families. Most articles focus on families of economic or health relevance. Information on the structure and composition of dipteran families in the Inhamum EPA can provide insight into the environmental stability of the area. This study aimed to perform a field survey of the order Diptera in different environments of Inhamum EPA.

2. METHODS

2.1. Location and Description of the Experimental area

Inhamum EPA (04°53′30′S 43°24′53′W) is located in Caxias, Maranhão State, on the right side of the BR 316 highway and about 4 km away from the urban perimeter (CONCEIÇÃO et al., 2010; NERES and CONCEIÇÃO, 2014). It covers an area of about 3,500 ha (AZEVEDO, 2012) (Figure 1).

The experimental area has dry subhumid climate, with two well-defined seasons, a rainy season from December to June and a dry season from July to November (ALBUQUERQUE, 2012). According to Araújo (2012), the region receives between 1,600 and 1,800 mm of regularly distributed rainfall, and the minimum, average, and maximum temperatures are usually high, with an annual average temperature above 24 °C.

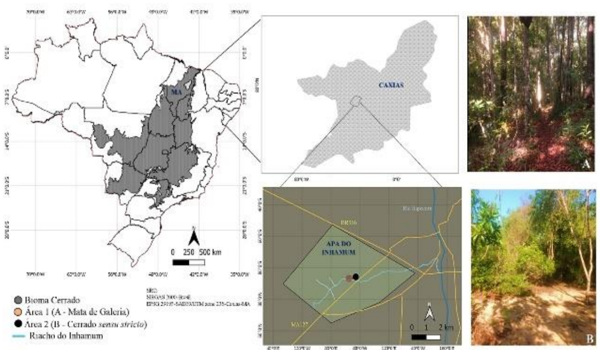

Figure 1 – Location map of the Inhamum Municipal Environmental Protection Area, Caxias, Maranhão State, Brazil, and phytophysiognomy of gallery forest (A) and Cerrado (B) sites. Source: prepared by the authors (2020).

As described by Barros (2012), the predominant soils are Red-Yellow Latosols, Red-Yellow Podzols, alluvial soils, and sandy soils. The region is covered mainly by grasses in flatlands and cerradão, chapada, and Cerrado (savanna) vegetation; there are also small areas of dense forest, which ensure the survival and serve as centers of biodiversity for many animals (ALBUQUERQUE, 2012). In addition to Cerrado, seasonal semideciduous forest phytophysiognomies also occur in Inhamum EPA, represented mainly by babassu palm forests. Some sections contain patches of Cerrado vegetation and gallery forests (CONCEIÇÃO et al., 2012).

Sample collections in Inhamum EPA were performed with approval from the Chico Mendes Institute for Biodiversity Conservation (ICMBio) and the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA) (authorization number 583781).

2.2. Experimental Sites

Two experimental sites were surveyed: site 1, a gallery forest with tall trees, partially closed canopy, and abundant shade; and site 2, characterized by the presence of typical Cerrado sensu stricto vegetation at the beginning of the access trail, which is close to a stream. Farther from the stream, there is a predominance of open vegetation, with low, twisted trees, shrubs, and grasses. This trail receives more sunlight and has sandy soil.

2.3. Sample Collection

Sample collection was performed using PROVID traps (GIRACCA et al., 2003; FORNAZIER et al., 2007), which consist of a 2 L PET bottle containing four holes (2 × 2 cm) at 20 cm height from the base. Bottles were filled with 200 mL of a 5% detergent solution and five drops of formaldehyde p.a.

At each site, six parallel transects spaced about 10 m apart were sampled at five equidistant points (10 × 10 m), totaling 60 sampling points (30 points per site). PROVID traps were installed with holes at ground level and left in the field for 4 days (96 h) (DRESCHER et al., 2007). After this period, traps were removed, labeled according to sampling point and date, and transported to the Laboratory of Soil Fauna (LAFS) of the Maranhão State University. Contents were washed, filtered through a 0.25 mm sieve, and transferred to plastic pots containing 70% ethyl alcohol. Specimens were screened, counted, and identified using the taxonomic identification key proposed by Triplehorn and Jonnson (2011). Samplings were carried out monthly from October 2017 to March 2018.

Rainfall data for the collection period were obtained from the National Institute of Meteorology (Inmet).

2.4. Faunal Indices and Data Analysis

Data were recorded on a Microsoft Excel spreadsheet and then subjected to faunistic analysis for determination of frequency, constancy, and dominance. The most predominant families (those with the highest faunistic indices) were identified (SILVEIRA NETO et al., 1995). Indices were calculated using the ANAFAU software (MORAES et al., 2003). Discrepancies were evaluated by graphic residual analysis (ATKINSON, 1985) for identification of super dominant, super abundant, and super frequent families.

Family frequency (f) was determined as the percentage of individuals of a given family in the total sample. Families were categorized into the following classes on the basis of 95% confidence intervals (CI) of frequency: infrequent (f < 95% CI lower limit), frequent (f within the 95% CI), and very frequent (f > 95% CI upper limit).

Constancy was calculated as the mean percentage of occurrence in collections and categorized as constant (families found in more than 50% of collections), accessory (families found in 25 to 50% of collections), or accidental (families found in less than 25% of collections), according to the classification of Bodenheiner (1955) as reported by Silveira Neto et al. (1976).

Dominance is defined as the ability of a family to modify, for their own benefit, the impact of the environment, possibly leading to the appearance or disappearance of other organisms

(SILVEIRA NETO et al., 1976). Families were classified as dominant (frequency higher than the dominance index) or nondominant (frequency lower than the dominance index). Family abundance was defined as the total number of specimens of a given family.

Diversity was assessed by the Shannon diversity index (*H′*), which ranges from 0 to 5. Low *H′* values indicate a greater dominance of some families at the expense of others (BEGON et al., 1996). *H′* was calculated by the equation $H' = -\Sigma p_i \log p_i$, with $p_i = n_i/N$, where n_i is the abundance of taxon *i* and *N* is the abundance of all taxa in the sample.

Pielou's evenness index (*J*), which ranges from 0 to 1, was used to assess the equality of distribution of families in the dipteran community (BEGON et al., 1996). It was defined by the equation $J = H'/\log S$, where *H′* is the Shannon diversity index and *S* the total number of specimens.

Family richness estimators were calculated in the R environment by using the Chao1, Jackknife1, and Jackknife2 procedures of the packages BiodiversityR and Vegan. Family accumulation curves were constructed from 1,000 random permutations generated by the specaccum function in the vegan package in R (R CORE TEAM, 2016).

3. RESULTS AND DISCUSSION

3.1. Abundance, Frequency, Constancy, and Dominance

A total of 1,040 specimens distributed in 27 families were sampled, 479 specimens and 22 families at site 1 (gallery forest) and 561 specimens and 23 families at site 2 (Cerrado sensu stricto) (Table 1).

The following families were found exclusively at site 1: Heleomyzidae, Sciomyzidae, Sphaeroceridae, and Tipulidae. At site 2, the exclusive families were Fanniidae, Micropezidae, Oestridae, and Tachinidae (Table 1).

Table 1 - Abundance (A), frequency (F), constancy (C), and dominance (D) of dipteran families sampled at sites 1 (gallery forest) and 2 (Cerrado sensu stricto) of the Inhamum Environmental Protection Area, Caxias, Maranhão State, Brazil. Source: prepared by the authors (2018).

Family	**Site 1**					**Site 2**				
	A	**%**	**F**	**C**	**D**	**A**	**%**	**F**	**C**	**D**
Agromyzidae	13	2.71	Frequent	Constant	Nondominant	1	0.18	Infrequent	Accidental	Nondominant
Bibionidae	1	0.21	Infrequent	Accidental	Nondominant	1	0.18	Infrequent	Accidental	Nondominant
Bombyliidae	2	0.42	Infrequent	Accidental	Nondominant	8	1.43	Infrequent	Constant	Nondominant
Calliphoridae	2	0.42	Infrequent	Accessory	Nondominant	16	2.85	Frequent	Constant	Nondominant
Cecidomyiidae	66	13.78	Very frequent	Constant	Dominant	43	7.66	Very frequent	Constant	Dominant
Ceratopogonidae	30	6.26	Frequent	Constant	Dominant	32	5.70	Very frequent	Constant	Dominant
Chironomidae	14	2.92	Frequent	Constant	Nondominant	3	0.53	Infrequent	Constant	Nondominant
Chloropidae	13	2.71	Frequent	Accessory	Nondominant	96	17.11	Very frequent	Constant	Dominant
Dolichopodidae	38	7.93	Very frequent	Constant	Dominant	88	15.69	Very frequent	Constant	Dominant
Drosophilidae	132	27.56	Very frequent	Constant	Dominant	31	5.53	Very frequent	Constant	Dominant
Empididae	6	1.25	Infrequent	Constant	Nondominant	4	0.71	Infrequent	Accessory	Nondominant
Ephydridae	4	0.84	Infrequent	Accessory	Nondominant	19	3.39	Infrequent	Constant	Nondominant
Fanniidae	-	-	-	-	-	1	0.18	Infrequent	Accidental	Nondominant
Heleomyzidae	2	0.42	Infrequent	Accidental	Nondominant	-	-	-	-	-
Hippoboscidae	8	1.67	Infrequent	Constant	Nondominant	10	1.78	Infrequent	Constant	Nondominant
Micropezidae	-	-	-	-	-	1	0.18	Infrequent	Accidental	Nondominant
Milichiidae	29	6.05	Frequent	Constant	Dominant	18	3.21	Frequent	Constant	Nondominant
Muscidae	-	-	-		-	2	0.36	Infrequent	Accidental	Nondominant
Mycetophilidae	21	4.38	Frequent	Constant	Nondominant	6	1.07	Infrequent	Constant	Nondominant
Oestridae	-	-	-	-	-	4	0.71	Infrequent	Constant	Nondominant
Phoridae	64	13.36	Very frequent	Constant	Dominant	89	15.86	Very frequent	Constant	Dominant
Sciaridae	16	3.34	Frequent	Constant	Nondominant	79	14.08	Very frequent	Constant	Dominant
Sciomyzidae	1	0.21	Infrequent	Accidental	Nondominant	-	-	-	-	-

Sphaeroceridae	7	1.46	Infrequent	Accidental	Nondominant	-	-	-	-	-
Tachinidae	-	-	-	-	-	3	0.53	Infrequent	Accessory	Nondominant
Tephritidae	8	1.67	Infrequent	Constant	Nondominant	6	1.07	Infrequent	Accidental	Nondominant
Tipulidae	2	0.42	Infrequent	Accidental	Nondominant	-	-	-		-
TOTAL	**479**	**100.0**				**561**	**100.0**			

The family with the greatest abundance at site 1 was Drosophilidae, with 132 specimens (27.56%), followed by Cecidomyiidae, with 66 specimens (13.78%), and Phoridae, with 64 specimens (13.36%). Site 1 is characterized by a more humid environment and presence of yeasts on trees, possibly explaining the greater abundance of Drosophilidae. According to Carson (1971), drosophilids are primary consumers of microorganisms, mainly yeasts, associated with early stages of fruit decomposition. These insects are highly abundant, easy to capture in nature, and highly sensitive to changes in the environment (WINK et al., 2009). Drosophilids are more abundant and diverse in forest edges and closed areas (lower canopy) protected from rain and wind with intermediate light incidence (GADELHA et al., 2009. GIANNOTTI et al., 2010).

The most abundant families at site 2 were Chloropidae (96 specimens, 17.15%), Phoridae, (89 specimens, 15.86%), Dolichopodidae (88 specimens, 15.69%), and Sciaridae (79 specimens, 14.08%). The abundance of these families might be related to the phytophysiognomy of the environment. Barbosa et al. (2005) found that some dipteran families share a preference for open habitats modified by human activity, as is the case of site 2. Other factors, such as stage of leaflitter decomposition, can also influence the abundance of certain families, such as Phoridae. According to Triplehorn and Johnson (2015), it is common to find adult individuals close to decaying vegetation, as they have a preference for highly decomposed material (GREENBERG and WEELS, 1998). The results for site 2 corroborate this finding, as the site was rich in litter at advanced stages of decomposition.

It is known that the frequency of families does not depend on their diversity. At site 1, the families Phoridae, Dolichopodidae, Drosophilidae, and Cecidomyiidae were the most frequent. At site 2, the following families were classified as very frequent: Cecidomyiidae, Ceratopogonidae, Chloropidae, Dolichopodidae, Drosophilidae, Phoridae, and Sciaridae (Table 1). Tauhyl and Guimarães (2012) stated that dipterans vary greatly in feeding habits and habitat. This diversification favors dispersion. As reported by Silva et al. (2011), dipterans can be sampled throughout the year, explaining the presence of some families in all collections and, consequently, their high frequency.

Constancy analysis showed that Agromyzidae, Cecidomyiidae, Ceratopogonidae, Chironomidae, Dolichopodidae, Drosophilidae, Empididae, Hippoboscidae, Milichiidae, Mycetophilidae, Phoridae, Sciaridae, and Tephritidae were constant at site 1. At site 2, Bombyliidae, Cecidomyiidae, Ceratopogonidae, Chironomidae, Chloropidae, Dolichopodidae, Drosophilidae, Ephydridae, Hippoboscidae, Milichiidae, Mycetophilidae, Oestridae, Phoridae, and Sciaridae were classified as constant. These findings might be associated with the feeding habits of these families and their preference for decaying vegetation. The sampling method consisted in the use of traps at ground level, where plant litter accumulates, favoring the collection of these individuals.

Families present in four or more collections were classified as dominant: Ceratopogonidae, Cecidomyiidae, Dolichopodidae, Drosophilidae, Milichiidae, and Phoridae at site 1 and Cecidomyiidae, Ceratopogonidae, Chloropidae, Dolichopodidae, Drosophilidae, Phoridae, Sciaridae, Dolichopodidae, Drosophilidae, Hippoboscidae, Milichiidae, Mycetophilidae, and Phoridae at site 2 (Table 1). The other families were classified as nondominant, infrequent, accessory, or accidental, as they showed low dominance, frequency, and constancy values at both sites (Table 1).

3.2. Effect of Rainfall on Dipteran Abundance

The variation in abundance as a function of daily rainfall from October 2017 to March 2018 is depicted in Figure 2. Specimen number fluctuated over time. In general, it was observed that after every rainfall pulse, the number of specimens increased. However, in months with high rainfall, the number of specimens decreased. Abundance was lower in the dry period than in the rainy period (Figure 2).

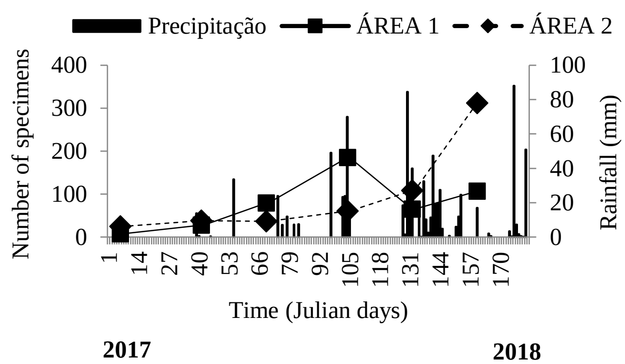

Figure 2 - Distribution of dipteran specimens collected from October 2017 to March 2018 as a function of rainfall at sites 1 (gallery forest) and 2 (Cerrado sensu stricto) of the Inhamum Environmental Protection Area, Caxias, Maranhão State, Brazil. Source: prepared by the authors (2018).

The high variability in the abundance of individuals over time is evidence of their high sensitivity to changes in the physicochemical and biological characteristics of the habitat. Dipterans can be sampled throughout the year and have a short life cycle, which contributes to the rapid response of species to environmental changes (DAMBROZ et al., 2007). Such a high variation was expected because, generally, more specimens are collected during the rainy season and fewer are collected in the dry season, as observed here and in the study of Torres and Madi-Ravazzi (2006). Tauhyl and Guimarães (2012) highlighted that variations in abundance usually accompany variations in rainfall intensity.

3.3. Shannon (*H′*) and Pielou (*J*) Indices

At site 1, the lowest diversity and evenness indices were observed for Drosophilidae (*H′* = 0.6; *J* = 0.2), Cecidomyiidae (*H′* = 0.9; *J* = 0.3), and Phoridae (*H′* = 0.9; *J* = 0.3) (Figure 3a). Families with the highest diversity and evenness were Bibionidae (*H′* = 2.7; *J* = 1.0) and Sciomyzidae (*H′* = 2.7; *J* = 1.0) (Figure 3a). The indices revealed that some families have a higher number of individuals distributed in a few species, i.e., a greater abundance but a lower diversity, and vice versa.

At site 2, the lowest diversity and evenness were observed for Chloropidae (*H′* = 0.8; *J* = 0.3), Phoridae (*H′* = 0.8; *J* = 0.3), Dolichopodidae (*H′* = 0.8; *J* = 0.3), and Sciaridae (*H′* = 0.9; *J* = 0.3) (Figure 3B). These families had a high number of individuals distributed in a few species. Agromyzidae (*H′* = 2.7; *J* = 1.0), Bibionidae (*H′* = 2.7; *J* = 1.0), Fanniidae (*H′* = 2.7; *J* = 1.0), and Micropezidae (*H′* = 2.7; *J* = 1.0) had the highest diversity and evenness (Figure 3B).

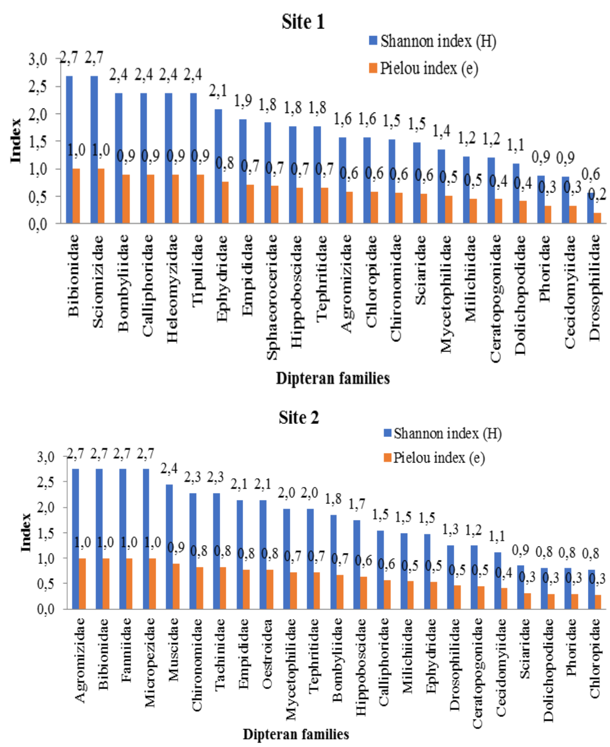

Figure 3 - Shannon (H′) and Pielou (J) indices for dipterans sampled at sites 1 (gallery forest, A) and 2 (Cerrado sensu stricto, B) of the Inhamum Environmental Protection Area, Caxias, Maranhão State, Brazil. Source: prepared by the authors (2018).

3.4. Richness and Accumulation Curve

Richness estimators and indices calculated for sites 1 and 2 are shown in Table 2. The observed richness of sites 1 and 2 was 22 and 23 families, respectively. The values predicted by estimators ranged from 27 (Chao1 and Jackknife1) to 29 (Jackknife2) for site 1 and from 28 (Chao1 and Jackknife1) to 30 (Jackknife2) for site 2.

Table 2: Richness estimators and indices for sites 1 (gallery forest) and 2 (Cerrado sensu stricto) of the Inhamum Environmental Protection Area, Caxias, Maranhão State, Brazil. Source: elaborated by the authors.

Richness estimators and indices	Site 1	Site 2
Observed richness	22	23
Chao	27	28
Jackknife1	27	28
Jackknife2	29	30

It is well known that the observed richness is lower than the expected richness (GOTELLI, 2009). Accumulation curves for the study sites indicated that saturation was not achieved, as the asymptote was not reached (Figure 4). Thus, the sampling effort was not sufficient to fully quantify the dipteran community, showing that it is possible to collect samples with greater richness in the study sites.

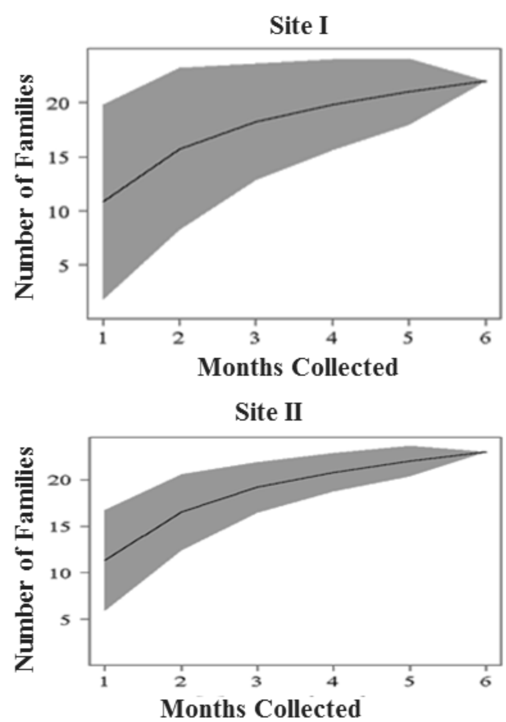

Figure 4 - Accumulation curves of dipteran family richness at sites 1 (gallery forest) and 2 (Cerrado sensu stricto) of the Inhamum Environmental Protection Area, Caxias, Maranhão State, Brazil.

4. FINAL CONSIDERATIONS

The present survey of dipteran families occurring in Inhamum EPA revealed high specimen richness. Some families were exclusive to the Cerrado sensu stricto site (Heleomyzidae, Sciomyzidae, Sphaeroceridae, and Tipulidae) and others to the gallery forest site (Fanniidae, Micropezidae, Muscidae, Oestridae, and Tachinidae), which explains the high diversity of families and plant heterogeneity. The highest family abundance was observed in the Cerrado sensu stricto site in periods of lower rainfall. This environment provided good conditions for the survival of specimens that prefer high leaf density and a greater number of breeding and feeding sites. Other families were more abundant in the gallery forest site but were also highly represented in the Cerrado sensu stricto site.

Richness estimators suggested the existence of rare or moderately common species in the study area, necessitating thorough surveys using other sampling methods.

5. REFERENCES

ALBUQUERQUE, A. Riacho Pontes e a Área de Proteção Ambiental Municipal do Inhamum, Caxias/MA. In: BARROS, M. C. et al. (Org.). *Biodiversidade na Área de Proteção Ambiental do Inhamum*. São Luís: UEMA, 2012. p. 22-25.

AMORIM, D. S.; SILVA, V. C.; BALBI, M. I. P. A. Estado do conhecimento dos dípteros neotropicais. Provecto de RedIberoamericana de Biogeografía y Entomología Sistemática, n. 2, p. 29-36, 2002.

ARAÚJO, W. S.; ESPÍRITO-SANTO FILHO K. Edge effect benefits galling insects in the Brazilian Amazon. *Biodiversity and Conservation*, n. 21, p. 2991-2997, 2012.

ATKINSON, A. C. Plots, transformations, and regression. New York, Oxford University Press. p. 282, 1985.

AZEVEDO, C. P.; SILVA, J. N. M.; SOUZA, C. R.; SANQUETTA, C. R. Eficiência de tratamentos silviculturais por anelamento na Floresta do Jari, Amapá. *Floresta*, v. 42, n. 2, p. 315-324, 2012.

BARBOSA, M. G. B.; HENRIQUES, A. L.; RAFAEL, J. A.; FONSECA, C. R. V. Diversidade e similaridade entre habitats em relação às espécies de Tabanidae (Insecta: Diptera) de uma floresta tropical de terra firme (Reserva Adolpho Ducke) na Amazônia Central, Brasil. *Amazoniana*, v. 18, n. 3/4, p. 251-266, 2005.

BARROS, A. T. M. Seasonality and Relative Abundance of Tabanidae (Diptera) Captured on Horses in the Pantanal, Brazil. Memoria's do Institute Oswaldo Cruz**,** v. 96, n. 7, p. 917-923, 2001.

BARROS, M. C. Biodiversidade na Área de Proteção Ambiental Municipal do Inhamum**,** São Luís: UEMA, p. 142, 2012.

BEGON, M.; HARPER, J. L.; TOWNSEND, C. R. Ecology: individuals, populations and communities**.** 3. ed. Oxford: Blackwell Science, p. 1068, 1996.

CARSON, H. L. The ecology of Drosophila breeding sites. Harold L. Lyon Arboretum Lecture 2. Universityof Hawaii. p. 27, 1971.

CARVALHO, C. J. B.; RAFAEL, J. A.; MELO, G. A. R.; CASARI, S. A.; CONSTANTINO, R. (Ed). Diptera. In: Rafael J.A., Melo G.A.R., Carvalho C.J.B., Casaria S.A. & Constantino R. *Insetos do Brasil: diversidade e taxonomia*. Ribeirão Preto: Holos, 2012. p. 700-743.

CONCEIÇÃO, G. M.; RODRIGUES, M. Pteridófitas do parque estadual do Mirador, Maranhão, Brasil. *Cadernos de Geociências*, n. 7, p. 47, 2010.

CONCEIÇÃO, G. M.; VARÃO, L. F.; CUNHA, I. P. R.; BRITO, E. S.; PERALTA, D. F. Melastomataceae da Área de Proteção Ambiental Municipal do Inhamum, Caxias, Maranhão. *Revista de Biologia e Farmácia*. v. 4, n. 2, p. 83-88, 2012.

COURI, M. S.; CARVALHO, C. J. B. Diptera Muscidae do Estado do Rio de Janeiro (Brasil). *Biota Neotropica***.** v. 5, n. 2, p. 205 – 222, 2005.

DAMBROZ, J.; MEDEIRO, E. P.; COELHO, R. T.; LOCCA, F. A. S. Entomofauna da fazenda Iracema na estação seca, município de Claudia-MT. In: CONGRESSO DE ECOLOGIA DO BRASIL, 8, 2007, Caxambu. Anais... Caxambu: SEB, 2007.

DOS SANTOS, R. B.; LOPES, J.; SANTOS, K. B. Distribuição espacial e variação temporal da composição de espécies de borrachudos (Diptera: Simuliidae) em uma microbacia situada no Norte do Paraná. *Neotropical Entomology***.** v. 39, n. 2, p. 289-298, 2010.

DRESCHER, M. S.; ELTZ, F. L. F.; ROVEDDER, A. P. M.; DORNELES, F. O. Mesofauna como bioindicador para avaliar a eficiência da revegetação com *Lupinus albescens* em solo arenizado do sudoeste do Rio Grande do Sul. In: XXXI Congresso Brasileiro de Ciência do Solo, 2007, Gramado. Anais... Gramado, SBCS, 2007. CD-ROM.

FARIAS, A. L. E. M.; CARVALHO, A. S.; PINHEIRO, A. R. F.; COSTA, A. S. S. Levantamento preliminar da diversidade de insetos existentes em área de caatinga no município de Ipanguaçu, RN. In: Congresso de Iniciação Científica do IFRN, IX. Anais... Ipanguaçu, RN, CONGIC, 2014.

FERRAZ, D. R. *Atratividade de iscas de origem animal para dípteros muscóides em área de cerrado do sudeste brasileiro, com ênfase na família Calliphoridae***.** Dissertação (Mestrado em Biologia Anima). Programa de Pós-Graduação em Biodiversidade Animal, Universidade Estadual de Campinas-SP, 2014.

FORNAZIER, R.; GATIBONI, L. C.; WILDNER, L. P.; BIANZI, D.; TODERO, C. Modificações na fauna edáfica durante a decomposição da fitomassa de *Crotalaria juncea L*. In: XXXI CONGRESSO BRASILEIRO DE CIÊNCIA DO SOLO, Gramado. Anais... Gramado, SBCS, 2007. CD-ROM.

GADELHA Q. B.; FERRAZ P. C. A.; COELHO A. M. V. A importância dos mesembrinelíneos (díptera: calliphoridae) e seu potencial como indicadores de preservação ambiental. *Oecologia Brasiliensis***.** v. 13, n. 4, p. 661-665, 2009.

GALATI, E. A. B.; MARASSA, A. M.; ANDRADE-GONÇALVES, R. N.; CONSALES, C. A.; BUENO, E. F. M. Phlebotomines (Diptera, Psychodidae) in the Ribeira Valley Speleological Province – 1. Parque Estadual Intervales, stateof São Paulo, Brazil. *Revista Brasileira de Entomologia*, v. 54, n. 2, p. 311-321, 2010.

GIANNOTTI, E; SOUZA, A. R.; PREZOTO, F. Diversidade e ecologia comportamental de insetos. In: GOMES, L. *Entomologia forense: novas tendências e tecnologias nas ciências criminais***.** 1ª Ed. Rio de Janeiro. Technical Books Editora, 2010. p. 122-132.

GIRACCA, E. M. N.; ANTONIOLLI, Z. I.; ELTZ, F. L. F.; BENEDETTI, E.; LASTA, E.; VENTURINI, S.F.; VENTURINI, E. F.; BENEDETTI, T. Levantamento da meso e macrofauna do solo na microbacia do Arroio Lino, Agudo/RS. *Revista Brasileira de Agrociência*, v. 9, n. 3, p. 257-261, 2003.

GOTELLI, N. J. *Ecologia*. 4 ed. Londrina: Editora Planta, 2009. p. 288.

GREENBERG, B.; WEELS, J. D. Forensic use of Megaselia abdita and M. scalaris (Phoridae: Diptera): case studies, development rates, and eggs structure. *Journal of Medical Entomology*, v.35, n. 3, p. 205-209, 1998.

GULLAN P. J.; CRANSTON, P. S. *Insetos: Fundamentos da Entomologia***.** 5ª ed. Rio de Janeiro, 2017.

HOCHMULLER, C. J. C.; LOPES-DA SILVA, M.; VALENTE, V. L. S.; SCHMITZ, H. J. The drosophilid fauna (Diptera, Drosophilidae) of the transition between the Pampa and Atlantic Forest Biomes in the state of Rio Grande do Sul, southern Brazil: first records. *Papéis Avulsos de Zoologia*, 2010.

JORGE, C. M.; MARINONI, L.; MARINONI, R. C. Diversidade de Syrphidae (Diptera) em cinco áreas com situações florísticas distintas no Parque Estadual Vila Velha em Ponta Grossa, Paraná. Iheringia, *Série Zoologia*. Porto Alegre, v. 97, n. 4, p. 452-460, 2007.

LEWINSOHN, T. M.; PRADO, P. I. *Biodiversidade brasileira: síntese do estado atual do* conhecimento. Contexto press. *p. 176, 2005.*

MELLO, R. S.; QUEIROZ, M. M. C.; AGUIAR-COELHO, V. M. Calliphoridfly (Diptera, Calliphoridae) attraction to different color edtraps in theTinguaBiological Reserve**,** Rio de Janeiro, Brazil**.** Iheringia, **Série Zoologia**. Porto Alegre, v. 99, n. 4, Dec. 2009.

MELLO-PATIU, C. A. Sarcophagidae in *Catálogo Taxonômico da Fauna do Brasil*. PNUD. 2010.

MORAES, R. C. B.; HADDAD, M. L.; SILVEIRA NETO, S.; REYES, A. E. L. Software para análise faunística. In: SIMPÓSIO DE ENCONTRO BIOLÓGICO, 8., 2003, São Pedro. Anais... São Pedro: Sinpobiol, p. 195, 2003.

NERES, L. P.; CONCEIÇÃO, G. M. Florística e fitossociologia da Área de Proteção Ambiental municipal do Inhamum, Caxias, Maranhão, Brasil. *Cadernos de Geociências*, v. 7, n. 2, p. 122-130, 2010.

OLIVEIRA, R. C.; FONSECA, A. R.; SILVA, C. G. Fauna de dípteros em uma área de cerrado no município de Divinópolis, estado de Minas Gerais. *Revista Trópica – Ciências Agrárias e Biológicas*, v. 2, n. 2, p. 3-7, 2008.

PAPE, T.; BLAGODERO, V. V.; MOSTOVSKI M. B. Order DIPTERA Linnaeus, 1758. In: *Zhang, Z-Q. (Ed.). Animal biodivesity: An outline of higher-level classification and survey of taxonomic richness***.** Zootaxa. n. 3148 p. 222-229. 2011.

PATERNO, U.; MARCONDES, C. B. Mosquitos anrtopofílicos de atividade matutina em Mata Atlântica, Florianópolis, SC. *Revista Saúde Pública***.** v. 38, n. 1, p. 133-135, 2004.

R CORE TEAM. A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. 2016.

SILVA, MUNIZ. M. *Diversidade de insetos em diferentes ambientes florestais no município de Cotriguaçu, estado de Mato Grosso*. Dissertação (Mestrado em Ciências Florestais e Ambientais) – Faculdade de Engenharia Florestal, Universidade Federal do Mato Grosso, Cuiabá, 2009.

SILVA, N. A. P.; FRIZZAS, M. R.; OLIVEIRA, C. M. Seasonality in insect abundance in the “Cerrado” of Goiás State, Brazil. *Revista Brasileira de Entomologia*, v. 55, n. 1, 79–87. 2011.

SILVEIRA NETO, S.; MONTEIRO, R. C.; ZUCCHI, R. A.; MORAES, R. C. B. Uso da análise faunística de insetos na avaliacao do impacto ambiental**.** *Scientia Agricola*, Piracicaba, v. 52, n. 1, p. 9 -15, 1995.

SILVEIRA, N, S. O.; NAKANO, D. BARBIN N.A. VILA NOVA. Manual de ecologia dos insetos. São Paulo. *Agronômica Ceres*. p. 420, 1976.

TAUHYL, L. G. M.; GUIMARÃES, M. V. Urso. Dipterofauna de fragmentos vegetacionais da UFSCar - campus Sorocaba, SP, Brasil. *Revista Trópica – Ciências Agrárias e Biológicas*, v. 6, n.2, p. 81, 2012.

THOMPSON, F. C. The Diptera site. The biosystematic database of world Diptera. *Nomenclatorstatus statistics.* Version10.5.

TORRES, F. R.; MADI-RAVAZZI, L. Seasonal variation in natural populations of Drosophila spp. (Diptera) in two woodlands in the State of São Paulo, Brazil. Iheringia, *Série Zoologia*, v. 96, p. 437–444, 2006.

TRIPLEHORN, C. A.; JOHNSON, N. F. Estudo dos insetos. Tradução da 7ª edição de *Borror and Delong´s introduction to the study of insects*.2ª ed., São Paulo. Cengage Learning, 809 p. 2015.

TRIPLEHORN, C. A.; JONNSON, N. F. *Estudo dos insetos*. 1. ed. São Paulo: Cengage Learning, 2011. 809 p.

TRIVINHO-STRIXINO, S. E.; STRIXINO, G. Chironomidae (Diptera) do Rio Ribeira (Divisa dos Estados de São Paulo e Paraná) numa avaliação ambiental faunística. *Entomological Vectors***,** v. 12, n. 2, p. 243-253, 2005.

URSO-GUIMARAES, M. V.; SCARELI-SANTOS, C. Galls and gall makers in plants from Pé-de-Gigante Cerrado Reserve, Santa Rita do Passa Quatro, SP, Brazil. *Brazilian Journal of Biology***,** São Carlos, SP. v. 66, n. 1, p. 357 – 369, 2006.

WINK, C.; GUEDES, J. V. C.; FAGUNDES, C. K.; ROVEDDER, A. P. Insetos edáficos como indicadores da qualidade ambiental. *Revista de Ciências Agroveterinárias*, v. 4, n. 1, p. 60-71, 2005.

6. ACKNOWLEDGMENTS

We thank the staff of the Laboratory of Soil Fauna (LAFS) of the Maranhão State University for collecting and identifying the specimens.

Received in: 13/02/2020
Accepted for publication in: 17/11/2020