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A survey of Calliphoridae and Mesembrinellidae (Diptera) in semideciduous seasonal forest, Paraná, Brazil

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Resumo

Um levantamento de Calliphoridae e Mesembrinellidae (Diptera) em Floresta Estacional Semidecidual, Paraná, Brasil. Calliphoridae e Mesembrinellidae incluem espécies de Diptera que são bons indicadores de alterações em ambientes florestais. O presente trabalho objetivou inventariar a fauna de Calliphoridae e Mesembrinellidae no Parque Nacional da Ilha Grande, bem como correlacionar a abundância desses organismos às variáveis ambientais. Os dípteros foram coletados em duas campanhas em 2019, utilizando dois métodos de coleta: armadilha Malaise e armadilhas atrativas, distribuídas em duas ilhas do Parque. Foram coletados 1.007 indivíduos de 12 espécies de Calliphoridae e quatro espécies de Mesembrinellidae. A família Calliphoridae foi mais abundante, 97,12%. A abundância das espécies nativas apresentou forte correlação negativa com a abundância do gênero *Chrysomya*. A Ilha Rodrigues (Ilha I) apresentou maiores índices de diversidade, e não foram registradas espécies do gênero *Chrysomya*, o que pode indicar maior grau de preservação do ambiente. Esses resultados revelam indícios que a ação humana em ambientes naturais pode impactar negativamente a diversidade de espécies, como no Parque Nacional de Ilha Grande que, historicamente teve grande parte de sua área ocupada e ainda se encontra em processo de regeneração.

Palavras-chave: Calyptratae; *Chrysomya*; Diversidade; Mata Atlântica; Varejeiras

Abstract

Calliphoridae and Mesembrinellidae include Diptera species that are good indicators of changes in forest environments. The present work aimed to inventory the Calliphoridae and Mesembrinellidae in Ilha Grande National Park and correlate the abundance of these organisms with environmental variables. Adult dipterans were collected during two expeditions in 2019 using two sampling methods, a Malaise trap and baited traps, distributed on two islands in the park. During the study, 1,007 individuals of 12 species of Calliphoridae and four species of Mesembrinellidae were collected. Family Calliphoridae was more abundant (97.12%). The abundance of native species showed a strong negative correlation with the abundance of the genus *Chrysomya*. Rodrigues Island (Island I) had higher diversity levels and no species of *Chrysomya* were recorded in this area, which may indicate a greater degree of environmental preservation. The results indicate that human action in natural environments can negatively impact species diversity, as found in Ilha Grande National Park that, historically, was partially occupied and is still in the process of regeneration.

Key words: Atlantic Forest; Blowflies; Calyptratae; *Chrysomya*; Diversity

Introduction

The insect family Calliphoridae (Diptera, Oestroidea) is cosmopolitan, popularly known as blowflies and comprises more than 1,500 species (PAPE et al., 2011), of which approximately 60 species occur in the neotropical region (KOSMANN et al., 2013). The larvae of most species develop in decomposing organic matter and some species are reported to cause myiasis (GUIMARÃES; PAPAVERO, 1999). Due to the fact that immatures use decomposing organic matter, many species are extremely important for forensic entomology, since they can be used to calculate the post-mortem interval and even indicate the place of death (AMENDT et al., 2004). When adults, many Calliphoridae species act as pollinators (SAEED et al., 2016).

Calliphoridae species have different degrees of tolerance to environmental conditions and, therefore, are very affected by human impact in natural environments (SOUSA et al., 2014). Thus, from a conservation point of view, fly communities are directly affected by both environmental degradation and exotic species (CARMO; VASCONCELOS, 2016). As a result, they are excellent indicators of anthropogenic impacts, as well as indicators of forest regeneration and conservation degree (SOUSA et al., 2014).

The fly family Mesembrinellidae (Diptera, Oestroidea), in turn, is exclusively neotropical (WHITWORTH; YUSSEFF-VANEGAS, 2019). For many years, this group was treated as a subfamily of Calliphoridae; however, numerous taxonomic and developmental differences allowed it to be separated (GUIMARÃES, 1977). Females of Mesembrinellidae produce one egg at a time that hatches into a larva while still inside the uterus, which is then deposited on the substrate (VARGAS; WOOD, 2010). Additionally, species of Mesembrinellidae are more robust than Calliphoridae, with a metallic abdomen and brown chest (WHITWORTH; YUSSEFF-VANEGAS, 2019). This group has a distribution restricted to forests and preserved environments (MELLO et al., 2007). Thus, due to these characteristics, Mesembrinellidae species are excellent bioindicators of preserved areas (GADELHA et al., 2009).

In recent years, forest environments in practically all states of Brazil have suffered from an intense devastation process that has increasingly decreased the amount of preserved area (SCHIELEINA; BÖRNERA, 2018; NASSER et al., 2019). The expansion of urban areas into natural environments causes the destruction of countless habitats of different species (PIGNATARO et al., 2020). In general, an increase in the anthropization level decreases insect species diversity (MARINONI; GANHO, 2006; FERRAGUTI et al., 2016) and, therefore, it is important to recognize the entomofauna of certain areas to monitor the impacts of anthropic action in these communities (HALLMANN et al., 2017). In addition, local biodiversity loss directly affects humans, both in terms of health and economically (CRUZ et al., 2020). In this context, zoological inventories aim mainly to know which species make up the analyzed communities and, thus, provide necessary data for fauna conservation and management (SILVEIRA et al., 2010).

Therefore, this study aimed to inventory the Calliphoridae and Mesembrinellidae of Ilha Grande National Park and correlate the abundance of the two families with environmental variables in the region.

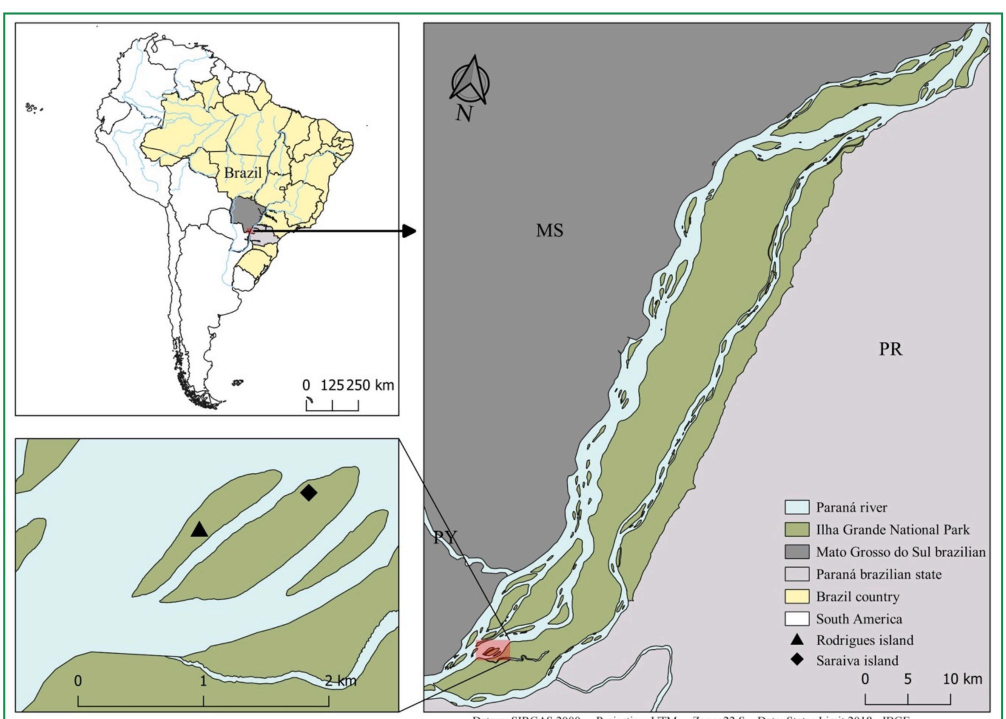
Materials and Methods

Ilha Grande National Park (53°41’09.2”, 23°16’32”S and 54°16’21.7”W, 24°04’11.5”S) includes several islands in the Paraná River on the border between the states of Paraná and Mato Grosso do Sul, Brazil. The phytophysiognomy of the park has characteristics of seasonal semideciduous alluvial forest, as well as submontane and dense ombrophilous forest of the Atlantic Forest domain, which can be classified macro-regionally as a transition zone between the Atlantic Forest and Cerrado (CAMPOS, 2001; IBGE, 2012). The park has an average temperature of 22ºC, annual precipitation of 1,200 to 1,300 mm and a humid subtropical mesothermal climate (Cfa) with a hot summer, according to the Köeppen-Geiger system (CAMPOS, 2001).

The study, authorized by ICMBio through the license SISBIO 65047-1, was conducted in February and November 2019 and included two collection expeditions that totaled about 10 days of sampling. Collections were made on two islands (Figure 1) in the southern region of Ilha Grande National Park: Rodrigues Island (24°00’31”S, 54°10’36”W) and Saraiva Island (24°00’13”S, 54°09’55”W). For the collections and statistical analysis, the islands were identified as the following: Rodrigues Island = Island I; and Saraiva Island = Island II.

Two collection methods were used to maximize the number of species collected: i) a Malaise trap (MI) modified according to Duarte et al. (2010) (a single trap was set up only on Island I on the first day of collection and removed on the last day); and ii) traps made from polyethylene bottles (PET) following the model proposed by Mello et al. (2007). On each island, 15 PET traps were set up, 150 m apart from each other and 1.5 m from the ground, containing ground beef as an attractive substrate that was removed from refrigeration 24 h before collecting began. The data obtained from the PET bottle method, used on islands I and II, were grouped into a single item. Thus, Group I (GI) corresponds to the total of PET traps on Island I and Group II (GII) corresponds to the total of PET traps on

FIGURE 1: Map of the islands where the traps were installed to capture Calliphoridae and Mesembrinellidae species in Ilha Grande National Park, Paraná.



Island II. The analysis of fauna diversity was performed for each collection method using Shannon, Simpson, Margalef and equitability indices.

The correlation of species collected abundance with the average values for temperature, humidity and precipitation, of the four days when the traps were exposed during each expedition, was analyzed using Pearson's correlation according to the methodology proposed by Ferraz et al. (2010a). Based on this methodology, the abundance and precipitation values were transformed into a logarithm $(x + 1)$; x is the value of each of these variables. The correlation between *Chrysomya* species abundance and the abundance of the main species collected was also analyzed. For these analyses, only species with more than 15 individuals sampled were used. Climatological data were provided by the Climatological Station of the Paraná Meteorological System (SIMEPAR).

To verify the similarities between the collection methods, a cluster analysis was made using a similarity matrix (based on a presence/absence matrix) obtained by the Jaccard coefficient, and a dendrogram was made using the unweighted pair group method with arithmetic mean (UPGMA). All analyses in this study were conducted with the software PAST 3.2.4 (HAMMER et al., 2001).

The collected specimens were fixed in 70% alcohol and taken to the laboratory for screening and identification. The biological material was identified using the taxonomic keys in Kosmann et al. (2013), Whitworth (2014) and Whitworth and Yusseff-Vanegas (2019). Reference material was deposited in the didactic-scientific collection at the Federal Institute of Paraná (IFPR), campus Umuarama.

Results

In total, 1,007 individuals (Table 1) were collected, including 12 species (six genera) of Calliphoridae and four species (two genera) of Mesembrinellidae.

TABLE 1: Distribution of individuals of each Calliphoridae and Mesembrinellidae species in the collection points, and percentage by sex, in Ilha Grande National Park. 0 = absence and 1 = presence.

Calliphoridae	AF	RF (%)	F (%)	M (%)	GI	GII	MI
Chrysomya albiceps (Wiedemann, 1819)	529	53.4	94.1	5.9	1	0	1
Chrysomya megacephala (Fabricius, 1794)	311	30.7	60.5	39.5	1	0	1
Chrysomya putoria (Wiedemann, 1818)	11	1.0	63.6	36.4	1	0	1
Cochliomyia macellaria (Fabricius, 1775)	5	0.3	80	20	0	1	1
Cochliomyia hominivorax (Coquerel, 1858)	1	0.1	100	0	0	0	1
Chloroprocta idioidea (Robineau-Devoidy, 1830)	7	0.7	85.7	14.3	0	0	1
Hemilucilia segmentaria (Fabricius, 1805)	28	2.8	53.6	46.4	0	1	1
Hemilucilia semidiaphana (Rondani, 1850)	18	1.7	55.6	44.4	1	1	1
Lucilia cuprina (Wiedemann, 1830)	4	0.3	50	50	1	0	1
Lucilia eximia (Wiedemann, 1819)	46	4.6	57.5	42.5	1	1	1
Lucilia sericata (Meigen, 1826)	8	0.8	62.5	37.5	1	0	1
Paralucilia pseudolyrcea (Mello, 1969)	15	1.5	53.3	46.7	0	1	1
Mesembrinellidae							
Lanella nigripes Guimarães, 1977	3	0.3	75	25	0	1	0
Mesembrinella bicolor (Fabricius, 1805)	2	0.2	100	0	0	1	0
Mesembrinella semihyalina Mello, 1967	7	0.7	78.6	21.4	0	1	1
Mesembrinella bellardiana Aldrich, 1922	8	0.8	66.7	33.3	0	1	1

AF = Absolute Frequency; RF = Relative Frequency; M = Male; F = Female; MI = Malaise trap Island I; GI = PET trap Island I; GII = PET trap Island II.

Calliphoridae correspond to 97.12% of the collected material. In addition, blowflies correspond to the largest portion of fauna observed for all collection methods (Table 2) and all sampled environments. However, *Chrysomya albiceps* and *Chrysomya megacephala* correspond to 53.4% and 30.7% of the total individuals collected, respectively.

For the diversity indices (Table 3), Group II (GII) had the highest values in all indices used, while Group I (GI) had the lowest values in the same indices. The similarity analysis (Figure 2) formed a GII+MI group with low similarity (0.41). The total abundance of species was correlated with climatic variables in only one situation (Table 4), the GI that had a strong negative correlation

TABLE 2: Percentage of individuals of the Calliphoridae species * collected in Ilha Grande National Park in relation to the total number of individuals collected in each method.

Taxon	GI (%)	GII (%)	MI (%)
Chrysomya albiceps	65.5	0	34.9
Chrysomya megacephala	32.7	0	31.4
Hemilucilia segmentaria	0	22.2	5.9
Hemilucilia semidiaphana	0.5	15.5	2.6
Lucilia eximia	0.1	34.4	8.6
Paralucilia pseudolyrcea	0	9.8	3.8

MI = Malaise trap Island I; GI = PET trap Island I; GII = PET trap Island II; * species with more than 15 individuals were selected.

TABLE 3: Total diversity indices of species collected in Ilha Grande National Park by each method.

Index	GI	GII	MI
Simpson_1-D	0.4741	0.8629	0.742
Shannon_H	0.7856	2.205	1.732
Margalef	0.925	2.525	2.293
Equitability_J	0.4037	0.8872	0.6562

MI = Malaise trap Island I; GI = PET trap Island I; GII = PET trap Island II.

FIGURE 2: Dendrogram of similarity between the methods used. MI = Malaise trap Island I; G I = PET trap Island I; G II = PET trap Island II.

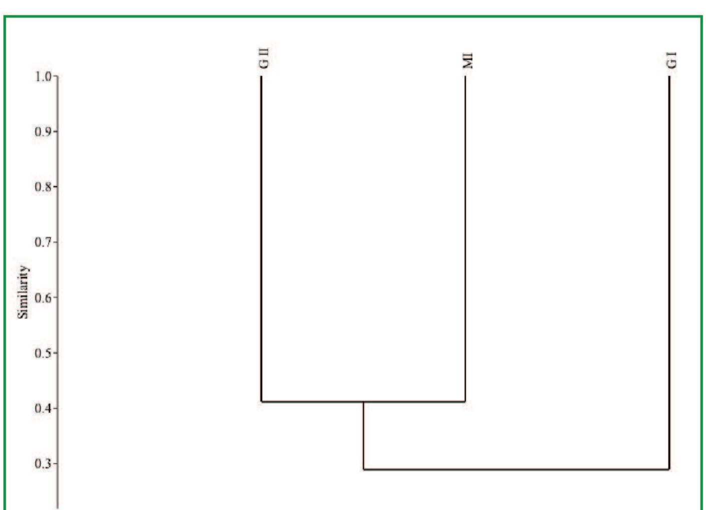


TABLE 4: Pearson's correlation indeces of total species abundance in each method in relation to climatic variables.

Method	Climate Variable		
	Precipitation	Temperature	Relative Humidity
GI	-0.690	0.408	0.501
GII	-0.375	0.527	-0.392
MI	0.486	-0.279	0.429

MI = Malaise trap Island I; GI = PET trap Island I; GII = PET trap Island II.

(r = -0.690) with precipitation. In the remaining cases, no correlation was found between abundance and climatic variables. For the individual species analysis (Table 5), no species showed a correlation with precipitation and only *Lucilia eximia* was correlated with relative air humidity. Only *Chrysomya albiceps* and *Chrysomya megacephala* were correlated with temperature. The correlation analysis of *Chrysomya* abundance with the abundance of the main species collected had a strong negative correlation for all analyzed species (Table 6).

Discussion

The absence or low correlation between Calliphoridae species abundance and the climatic variables observed in this work was also found in previous studies (MELLO et al., 2007; FERRAZ et al., 2010a). In addition, it is common to find regionalized population fluctuations in the group (PARALUPPI; CASTELLÓN, 1994; VIANNA et al., 2004), which could indicate that biotic factors might be more decisive in relation to distribution. However, when analyzed separately, the genus *Chrysomya* showed a strong positive correlation with temperature. This indicates that with rising temperatures, due to imminent climate change, there is a strong tendency for fly communities to be affected. Furthermore, since this genus has a short development time compared to native species, a temperature rise can lead to an increase in invasive species abundance and, therefore, native species exclusion.

This study also reports three new records for the South Region of Brazil: i) *Laneella nigripes* that only had records for the Southeast Region of the country

TABLE 5: Pearson's correlation indices of total species abundance for each method in relation to climatic variables.

Taxon	Precipitation	Temperature	Relative Humidity
Chrysomya albiceps	0.459	0.825	0.326
Chrysomya megacephala	0.390	0.818	0.109
Hemilucilia segmentaria	0.019	0.193	-0.455
Hemilucilia semidiaphana	0.190	0.022	0.419
Lucilia eximia	0.212	0.345	-0.660
Paralucilia pseudolyrcea	0.011	0.201	0.340

* species with more than 15 individuals were selected.

TABLE 6: Pearson's correlation indeces of the abundance of the *Chrysomya* genus in relation to the other species.

	Chrysomya megacephala	*Hemilucilia segmentaria*	*Hemilucilia semidiaphana*	*Lucilia eximia*	*Paralucilia pseudolyrcea*
Chrysomya albiceps	0.975	-0.770	-0.912	-0.925	-0.762
Chrysomya megacephala	-	-0.609	-0.798	-0.818	-0.600

(MARINHO et al., 2017; WHITWORTH; YUSSEFF-VANEGAS, 2019); ii) *Mesembrinella semihyalina*, which had records for the Southeast, North and Northeast regions (MARINHO et al., 2017; WHITWORTH; YUSSEFF-VANEGAS, 2019); and iii) *Chloroprocta idioidea*, which only had records for the North, Northeast, Southeast and Central-West regions (BATISTA-DA-SILVA et al., 2010; URURAHY-RODRIGUES et al., 2013; SOUSA et al., 2014; KOSMANN et al., 2017). Considering the relatively short exposure period of the Malaise trap, as well as PET bottle traps, this study collected a significant number of species.

Although family Calliphoridae is relatively well studied, its fauna in Paraná is still poorly known. The first record was a study about synanthropy by Ferreira (1978) that listed eight species for Curitiba. Subsequently, Moura et al. (1997) and Caleffe et al. (2015) recorded three species of Calliphoridae each, in studies focusing on forensic entomology. The other species records of this family in Paraná are in taxonomic revisions (WHITWORTH, 2014; MARINHO et al., 2017; WHITWORTH; YUSSEFF-VANEGAS, 2019).

Together, *Chrysomya albiceps* and *Chrysomya megacephala* make up about 83% of the total collected individuals. In addition, all of the *Chrysomya* individuals were collected on Island I, which can be explained by the fact that this island has greater remnants of anthropization, such as abandoned houses, remnants of fruit tree plantations, and the presence of a family of resident islanders. Since the 1950s, and before the park was delimited in 1997, many islands were occupied and used for housing, summer vacation and agriculture (ROSA, 1997; MOTTA; CAMPOS, 2001). The genus *Chrysomya* was introduced to Brazil in the 1970s (GUIMARÃES et al., 1978). Invasive species in the group quickly spread throughout the country; they are highly synanthropic species and very well adapted to human environments (FERRAZ et al., 2010a). On the other hand, no individuals of this genus were collected on Island II, which may indicate a greater degree of preservation in this area.

Lucilia was the second most abundant genus in the present study. Three species were sampled: *Lucilia cuprina*, *Lucilia sericata* and *Lucilia eximia*. The first two are invasive species and the last is exclusive to the New World. Although *L. eximia* has been suffering from the impacts of invasive species in recent years, it is still well distributed in Brazil (FERRAZ et al., 2010b; CARMO; VASCONCELOS, 2016). It can be inferred that with a greater collection effort in the country, the known richness of *Lucilia* would increase because, in review of the genus, Whitworth (2014) described four new species for Brazil.

Cochliomyia macellaria is a neotropical species, while *Cochliomyia hominivorax* is a species that causes myiasis and is easily collected in urban environments (GUIMARÃES; PAPAVERO, 1999). Both species are relatively common in Brazil and a previous study found that *Chrysomya albiceps* tends to prefer preying on *Cochliomyia macellaria* larvae over other studied species (FARIA et al., 1999).

Paralucilia pseudolyrcea is a wild neotropical species that has two synonyms: *Myolucilia lyrcea* (KOSMANN et al., 2013) and *Paralucilia xanthogeneiates* (MADEIRA-OTT et al., 2019). The first had already been observed by Ferreira (1978) in Paraná State and the second has been recorded in the three southern states of Brazil (CARVALHO; RIBEIRO, 2000). *Chloroprocta idioidea* also has a wide distribution in Brazil, based on fauna and forensic entomology studies (FERRAZ et al., 2010b; URURAHY-RODRIGUES et al., 2013), and occurs in wild areas with varied phytophysiognomies. However, there were no records for Paraná State, although there were records in nearby regions, such as Mato Grosso do Sul State (KOSMANN et al., 2017) and Paraguay (DEAR, 1985).

Hemilucilia segmentaria and *Hemilucilia semidiaphana,* observed in this study, are also native species commonly found throughout Brazil, generally in forest environments (FERRAZ et al., 2010b; URURAHY-RODRIGUES et al., 2013).

Regarding the family Mesembrinellidae, four species were collected, with most of the material coming from Island II. In the case of Island I, all collected individuals came from the Malaise trap. The species in this family are exclusive to the neotropical region, characterized as asynanthropic and are commonly collected in preserved environments (CABRINI et al., 2013). The absence of individuals in the group GI traps can be explained by two factors: i) the high abundance of the genus *Chrysomya*, which may have excluded Mesembrinellidae individuals; and ii) this area has the most pronounced anthropogenic action, and the species of this family are more sensitive to habitat disturbance (GADELHA et al., 2009; CABRINI et al., 2013).

The traps of the GII group and GI group had a very low degree of similarity. Moreover, GI had low diversity in all indices used. This pattern can be explained by the low abundance of the genus *Chrysomya* found on Island II, since *Chrysomya* specimens were not collected in GII traps. On the other hand, in the GI traps the genus *Chrysomya* exhibited high abundance. This, added to the fact that all native species showed a high negative correlation with species of *Chrysomya*, may explain the patterns found in this study; especially because *Chrysomya* species are highly excluding, since they have a shorter development time in relation to native species that makes them excellent competitors. MI and GII were more similar, although the similarity (below 0.50) was low. According to Kent and Coker (1992), only values equal to or greater than 0.50 can be considered as high similarity. The degree of similarity between MI and GII can be explained by the Jaccard index evaluating the similarity qualitatively. Thus, this index analyzes the proportion of species shared among the samples in relation to the total number of species. In this case, the index does not consider the number of individuals present in the sample, but their presence and absence (FERREIRA et al., 2008).

Furthermore, in the PET traps an attractive substrate was used. This could explain the high abundance of *Chrysomya* and is a strong exclusion factor for other species due to the predatory character of immatures of this genus that, in some cases, can practice cannibalism (FARIA et al., 2004). Thus, native species tend to choose substrates for laying eggs where immature *Chrysomya* do not occur (GALINDO et al., 2016; SPINDOLA et al., 2017). This exclusion becomes evident because necrophagous species use ephemeral resources and tend to have an aggregate distribution (MOURA, 2004), so the competition for substrate becomes inevitable. An increase of invasive species in neotropical environments, with the consequent decrease in native species, has already been observed for islands (CARMO; VASCONCELOS, 2016), coastal regions (BARBOSA et al., 2017), the Atlantic Forest (FERRAZ et al., 2010b) and the Chaco ecoregion (DUFEK et al., 2019).

Based on this, the results highlight that human action can play a decisive role in the diversity of species. This is because environmental degradation and/or urbanization can contribute positively to the dispersal of invasive species, especially in combination with temperature rise due to climate change, which increases the abundance of exotic species and, consequently, decreases species diversity. These data draw attention to new challenges in terms of land use and conservation. If natural areas continue to be degraded, native species must be monitored and/or included in management programs so they do not go extinct.

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