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Study of Edaphic Macrofauna in Environmental Protection Area of Inhamum, Caxias-Maranhão

Estudo da Macrofauna Edáfica em Área de Proteção Ambiental do Inhamum, Caxias-Maranhão

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Abstract: The soil macrofauna comprises organisms ranging from 2 to 10 mm in size, being represented by more than 20 taxonomic groups. These organisms are highly sensitive to environmental changes. Therefore, assessing their composition in different regions allows us to understand the influence of anthropic actions on natural environments. This study aimed to survey the soil macrofauna in two environmental fragments of the Inhamum Environmental Protection Area, Caxias, MA, Brazil. The following two experimental areas were chosen: gallery forest (Area I) and Cerrado *sensu stricto* (Area II). Provid traps were used to capture soil macrofaunal organisms. A total of 19,993 individuals were recorded. The most abundant orders of macrofauna in both areas were Hymenoptera, Coleoptera, and Diptera.

Keywords: Abundance; Bioindicator; Dominance; Macrofauna; Richness.

Resumo: A macrofauna edáfica compreende organismos com tamanho entre 2 a 10 mm, sendo representada por mais de 20 grupos taxonômicos. Apresentam vasta sensibilidade às mudanças ambientais. No entanto estudar ambientes diferentes, permite perceber as ações antrópicas realizadas no ambiente natural. O estudo teve como objetivo realizar um levantamento da macrofauna edáfica em dois fragmentos ambiental na Área de Proteção Ambiental do Inhamum, Caxias, MA. Foram escolhidas duas áreas experimentais: Mata de Galeria sendo demarcada como Área I e Cerrado sensu stricto demarcada como Área II. Para captura da macrofauna edáfica, foram distribuídas armadilhas Provid. Foram contabilizados 19.993 indivíduos. As ordens mais abundantes da macrofauna foram Hymenoptera, Coleoptera e Diptera para as duas áreas de estudo.

Palavras-chave: Abundância; Bioindicador; Dominância; Macrofauna; Riqueza.

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1. Introduction

The soil is not merely a substrate for plant development and food production but a living system that serves as a dwelling for thousands of animals and microorganisms. Soil organisms, also known as edaphic fauna, include thousands of species of invertebrates with sizes ranging from micrometers to meters and life cycles ranging from days to years (Brown et al., 2015). The macrofauna comprises organisms measuring between 2 and 10 mm, being represented by more than 20 taxonomic groups. These organisms are capable of removing soil particles, opening tunnels, and creating connections between soil horizons (Brady; Weill, 2013). Soil macrofaunal species are highly sensitive to environmental factors, and, when exposed to disturbances, respond more rapidly than chemical or physical indicators (Matsumoto; Marques, 2015). The soil macrofauna influences nutrient cycling, pore formation, and soil disaggregation. These organisms also act as biological control agents by predating on other invertebrates. The activity of these organisms in soil is fundamental for the sustainability of ecosystems, both natural and managed. Inadequate management can affect the soil fauna, considerably modifying the abundance and diversity of soil communities (Marques et al., 2014).

The Inhamum Environmental Protection Area (EPA) has been affected by anthropogenic activities that have negative consequences on inhabiting species. The region is covered by grasses in flatlands, characteristic of cerradões, chapadas, cerrado, and gallery forests, and also contains closed forests that ensure the survival of many animal species and maintenance of biodiversity (Albuquerque, 2012).

The Cerrado biome has great biological relevance. It is an important biodiversity hotspot and the second largest biome in the Neotropics, covering an area of about 1.8 million km^2 (Myers et al., 2000). Despite its importance, the Cerrado is the biome with the lowest percentage of protected areas. Only 8.21% of its territory is legally protected by conservation units, including 2.85% by integral protection conservation units and 5.36% by sustainable use conservation areas (Brasil, 2019).

By studying the soil fauna of different areas, it is possible to understand the effects of anthropic actions on natural environments. The hypothesis raised in this study was that vegetation type can directly influence macrofaunal diversity. The aim was to conduct a survey of soil macrofauna in two vegetation fragments of the Inhamum EPA, Caxias, MA, Brazil (ICMBio/IBAMA Permit No. 583781).

2. Methods

2.1 Location and characterization of experimental areas

The survey was conducted in the Inhamum Municipal EPA (04°53′30″S 43°24′53″W), Caxias, MA, Brazil. Two experimental areas were chosen for this study, namely gallery forest (Area I) and Cerrado *sensu stricto* (Area II). Six parallel transects about 10 m apart were established in each area. Along each transect, five equidistant sampling units (10 × 10 m) were marked, totaling 30 points per area. Collections were performed monthly from September 2017 to April 2018, totaling eight collections per studied area. Soil macrofaunal individuals were captured with Provid traps (Fornazier et al., 2007).

Each Provid trap consisted of a 2 L PET bottle with four 2 × 2 cm holes at a height of 20 cm from the base and containing 200 mL of a 5% detergent solution and 5 drops of formaldehyde P.A. Traps were buried with the four holes at ground level and were kept in the field for 4 days (96 h). After 96 h, the traps were collected from the field and identified with the place and date of collection. Then, traps were transported to the Laboratory of Environmental Quality Bioindicators (LABIOQ), State University of Maranhão (CESC, UEMA), where the contents were washed over a 0.25 mm sieve and transferred to plastic jars containing 70% ethanol. Organisms were counted and identified using a magnifying glass, entomological tweezers, and a stereomicroscope (Stemi DV4 Zeiss). Individuals were classified into orders and/or other taxonomic groups using the identification key proposed by Triplehorn and Johnson (2011).

Data on the occurrence and distribution of taxonomic orders were entered into an Excel spreadsheet and subjected to faunal analysis using Anafau software for calculation of abundance, frequency, constancy, and dominance indices.

3. Results and discussion

3.1 Abundance, frequency, constancy, and dominance of soil macrofauna

In this study, 19,993 soil macrofaunal individuals were recorded. Table 1 shows the dominance, abundance, frequency, and constancy of each taxonomic group. A total of 7,585 individuals distributed in 13 groups were collected from Area I (gallery forest) and 12,408 individuals distributed in 15 groups from Area II (Cerrado *sensu stricto*). Taxonomic groups from Area II had the highest richness. In Area I, the orders with the highest abundance of individuals were Hymenoptera, with 3,608 individuals (48%); Coleoptera, with 2,186 individuals (29%); and Diptera, with 748 individuals (10%).

Dominance analysis showed that Araneae, Blattaria, and Orthoptera were dominant, whereas Coleoptera, Diptera, and Hymenoptera were super dominant. As for frequency, which does not depend on diversity, the orders Araneae, Blattaria, and Orthoptera were very frequent in Area I. Constancy analysis showed that Araneae, Blattaria, Chilopoda, Coleoptera, Diplopoda, Diptera, Hemiptera, Hymenoptera, Isoptera, Mantodea, Orthoptera, and Pseudoscorpiones were constant (Table 1).

Table 1 – Dominance (D), abundance (A), frequency (F), and constancy (C) of taxonomic groups of soil macrofauna collected from Areas I (gallery forest) and II (Cerrado sensu stricto*) in the Inhamum Environmental Protection Area, Caxias, MA, Brazil.*

	Area I							**Area II**						
Taxonomic group	**No. of individuals**	**%**	**No. of collections**	**D**	**A**	**F**	**C**	**No. of individuals**	**%**	**No. of collections**	**D**	**A**	**F**	**C**
Araneae	365	4.81	8	D	VA	VF	W	492	3.96	8	SD	SA	SF	W
Blattaria	186	2.45	8	D	A	VF	W	101	0.81	8	D	A	VF	W
Chilopoda	6	0.08	4	ND	D	IF	W	20	0.16	3	ND	c	F	Y
Coleoptera	2,186	28.82	8	SD	SA	SF	W	1,582	12.74	8	SD	-	SF	W
Diplopoda	21	0.28	6	ND	d	IF	W	22	0.17	7	ND	c	F	W
Diptera	748	9.86	8	SD	SA	SF	W	932	7.51	8	SD	SA	SF	W
Embioptera	-	-	-	-	-	-	-	1	0.008	1	ND	R	IF	Z
Hemiptera	77	1.02	8	ND	c	F	W	20	0.16	7	ND	c	F	W
Hymenoptera	3,608	47.57	8	SD	SA	SF	W	8,831	71.17	8	SD	SA	SF	W
Isoptera	21	0.28	5	ND	D	IF	W	82	0.66	7	D	c	F	W
Lepidoptera	-	-	-	-	-	-	-	1	0.08	1	ND	R	IF	Z
Mantodea	35	0.46	6	ND	c	F	W	22	0.17	3	ND	c	F	Y
Orthoptera	291	3.84	8	D	VA	VF	W	225	1.81	8	D	VA	VF	W
Pseudoscorpiones	33	0.44	8	ND	c	F	W	45	0.36	3	ND	c	F	Y
Scutigeromorpha	8	0.11	2	ND	d	IF	W	32	0.25	4	ND	c	F	W
TOTAL	**7,585**	**100**						**12,408**	**100**					

Legend: SD, super dominant; D, dominant; ND, non-dominant; A, abundant; SA, super abundant; VA, very abundant; c, common; d, dispersed; R, rare; SF, super frequent; VF, very frequent; F, frequent; IF, infrequent; W, constant; Y, accessory; Z, accidental. Source: prepared by the authors (2018).

As shown in Table 1, the orders Blattaria, Isoptera, and Orthoptera were classified as super dominant and Araneae, Hymenoptera, Coleoptera, and Diptera as dominant. The very frequent orders were Blattaria and Orthoptera. Araneae, Blattaria, Coleoptera, Diplopoda, Diptera, Hemiptera, Hymenoptera, Isoptera, Orthoptera, and Scutigeromorpha were classified as constant. The orders Embioptera and Lepidoptera were exclusive to Area II. In general, the order Hymenoptera was the most abundant in both areas but had a higher occurrence in Cerrado *sensu stricto*. Martins (2021) obtained similar results in the same study area in a survey of edaphic macrofauna in environmental protection areas of Maranhão State; the order Hymenoptera predominated over the others.

Various studies on the soil macrofauna of Cerrado regions using the same collection method reported similar findings (Bussinguer, 2018; Araújo et al., 2010). Other studies in different biomes, such as the Caatinga (Santos et al., 2018; Santos, 2014) and Atlantic Forest (Machado et al., 2015), also found that Hymenoptera was the most dominant order. According to Backes (2017), ants (Hymenoptera) and other macrofauna serve as detritivores and also play a role in soil formation and structure, acting as soil engineers. Given their high abundance and richness in different phytophysiognomies, ants are used to assess environmental changes associated with the state of conservation or degradation of a given area. The variation in soil temperature and rainfall during the study period also directly influenced the abundance of soil macrofauna. The variation in ant species as a function of season observed here is in agreement with previous reports showing that ant richness is greater in the dry season (Oliveira et al., 2016; Dorval et al., 2017).

3.2 Diversity and evenness

Table 2 shows the diversity indices (Shannon-Wiener index and Simpson's index). The data observed in Area I and Area II were considered for this analysis. In general, the diversity of orders between the two environments studied was analyzed (Shannon-Wiener).

Table 2 – Shannon–Wiener (H') and Simpson's (D') diversity indices of Areas I (gallery forest) and II (Cerrado sensu stricto*) in the Inhamum Environmental Protection Area, Caxias, MA, Brazil.*

Area	*H′*	*D′*
Area I	1.44	0.68
Area II	1.05	0.47

Source: Prepared by the authors (2018).

Area I had a higher diversity (*H′* =1.44) than Area II (*H′* =1.05). The Simpson dominance index was high in Area I (*D′* = 0.68) compared with Area II (*D′* = 0.47) (Table 2). The Shannon index ranges from 0 to 5, and small values indicate greater dominance of some groups, as observed in Area II (Souto et al., 2008). According to the heterogeneity hypothesis, habitats with a diverse structure have a greater diversity of orders owing to the variety of ecological niches and natural resources to be exploited by these individuals (Tews et al., 2004).

Table 3 shows the groups with the highest diversity and evenness (*J′*) indices. In Area I, Chilopoda had the highest diversity, whereas Hymenoptera (*H′* = 0.32, *J′* = 0.08), Coleoptera (*H′* = 0.54, *J′* = 0.14), and Diptera (*H′* = 1.01, *J′* = 0.26) had the lowest diversity and evenness indices. In Area II, the groups with the highest diversity and evenness were Embioptera and Lepidoptera and those with the lowest indices were Hymenoptera (*H′* = 0.15, *J′* = 0.04), Coleoptera (*H′* = 0.89, *J′* = 0.22), and Diptera (*H′* = 1.12, *J′* = 0.27). According to Pasqualin et al. (2012), the Pielou index, which can range from 0 to 1, is directly related to the dominance of groups, that is, the lower the evenness, the greater the dominance of a few groups.

Table 3 – Shannon's diversity index (H') and Pielou's evenness index (J') of Areas I (gallery forest) and II (Cerrado sensu stricto*) in the Inhamum Environmental Protection Area, Caxias, MA, Brazil.*

Area I			Area II		
Taxonomic group	***H′***	***J′***	**Taxonomic group**	***H′***	***J′***
Chilopoda	3.1	0.80	Embioptera	4.09	1
Scutigeromorpha	2.98	0.77	Lepidoptera	4.09	1
Isoptera	2.56	0.66	Hemiptera	2.79	0.68

Diplopoda	2.56	0.66	Chilopoda	2.79	0.68
Pseudoscorpiones	2.36	0.61	Mantodea	2.75	0.67
Mantodea	2.34	0.6	Diplopoda	2.75	0.67
Hemiptera	1.99	0.51	Scutigeromorpha	2.59	0.63
Blattaria	1.61	0.42	Pseudoscorpiones	2.44	0.6
Orthoptera	1.42	0.36	Isoptera	2.18	0.53
Araneae	1.32	0.34	Blattaria	2.09	0.51
Diptera	1.01	0.26	Orthoptera	1.74	0.43
Coleoptera	0.54	0.14	Araneae	1.4	0.34
Hymenoptera	0.32	0.08	Diptera	1.12	0.27
			Coleoptera	0.89	0.22
			Hymenoptera	0.15	0.04

Source: Prepared by the authors (2018).

It was observed that, in both gallery forest and Cerrado *sensu stricto*, Hymenoptera was recorded in high quantities, having the lowest diversity (Area I, $H' = 0.32$, and Area II, $H' = 0.15$) and the lowest evenness (Area I, $J' = 0.08$, and Area II, $J' = 0.04$). The greater the number of individuals of a group, the greater the chances of the group predominating over others, reducing evenness (Nunes et al., 2008).

3.3 Estimated richness (*S*) and accumulation curve

Figure 1 depicts the observed richness of 13 taxonomic groups in Area I and 15 groups in Area II. Richness was obtained by using estimators (Chao1, Chao2, Jackknife1, and Jackknife2). Richness estimates are correlated with the accumulation curve. As shown in Figure 1, the accumulation curve for Area I reached an asymptote, demonstrating stabilization. This indicates that the sampling effort was sufficient to fully quantify the groups and that it would not be possible to record a higher richness in the studied area. By contrast, for Area II, the accumulation curve did not approach an asymptote, indicating that further sampling efforts could result in a higher number of recorded taxa.

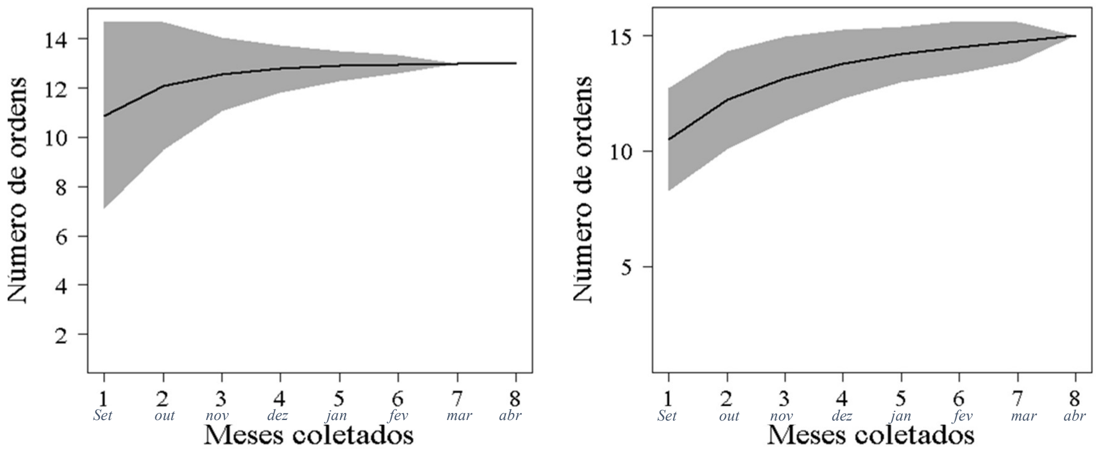

Figure 1 – Accumulation curve of taxonomic groups in Areas I (gallery forest) and II (Cerrado sensu stricto*) in the Inhamum Environmental Protection Area, Caxias, MA, Brazil.*
Source: Prepared by the authors (2018).

In an inventory study, Erwin (1988) found that the proportion of rare species was high and that accumulation curves did not reach asymptotes. According to Colwell and Coddington (1994), Chao2 and Jackknife2 provide estimates with greater accuracy and lower bias for datasets with a small sample size. An estimator must achieve or approach stability with fewer samples than the observed accumulation curve. Moreover, one estimator should not differ greatly from another (Toti et al., 2000).

4. Conclusion

The most abundant orders of macrofauna in both study areas were Hymenoptera, Coleoptera, and Diptera. The highest frequency and constancy of orders were observed in Area I. Hymenoptera showed greater dominance in both areas. The diversity of soil macrofauna varied according to rainfall distribution. Diversity and evenness indices showed that the most diverse groups were Chilopoda in Area I and Embioptera and Lepidoptera in Area II. Area II had the greatest richness of soil macrofauna. The accumulation curve constructed for Area I revealed that the sampling effort was sufficient to fully quantify taxa but that constructed for Area II did not show an asymptotic trend.

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