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Temporal variation of soil entomofauna from an urban forest fragment in southern Brazil

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ABSTRACT. Insects are important environmental bioindicators, due to the species diversity and wide range of habitats occupied. The present study evaluated the temporal variation in composition and abundance of soil insects in an urban forest fragment in the municipality of Toledo, in the state of Paraná, by analyzing their abundance and seasonality. Monthly samplings were conducted between August 2011 and July 2012 at four sampling sites within the fragment. At each site, three pitfall traps remained exposed for 48 hours. Captured insects were fixed in alcohol, sorted and identified. Throughout the study period, we captured 11,568 insects from 11 orders and 35 families. Coleoptera was the richest order (12 families), followed by Diptera and Hemiptera (5), Hymenoptera and Orthoptera (3). The order Hymenoptera was the most abundant (4,789 individuals), followed by Coleoptera (4,630) and Diptera (1,985). Coleoptera was represented mainly by the families Staphylinidae and Silphidae. Formicidae (Hymenoptera) was the least abundant in colder months. Collembola was positively correlated with soil moisture. In general, the insect fauna in the forest fragment exhibited characteristics of the fauna from impacted habitats, that is, low diversity of families and dominance of generalist groups.

Keywords: soil insects, fragmentation, survey, *pitfall*.

Variação temporal da entomofauna edáfica de um fragmento florestal urbano no sul do Brasil

RESUMO. Pela diversidade de espécies e hábitats que ocupam, os insetos são importantes bioindicadores ambientais. Este estudo objetivou avaliar variações temporais na composição e abundância de insetos edáficos em um fragmento florestal urbano no município de Toledo, Paraná, em que são analisadas a abundância e a sazonalidade dos grupos. Para isso foram realizadas coletas mensais entre agosto de 2011 e julho de 2012, em quatro pontos amostrais no interior do fragmento. Em cada ponto foram colocadas três armadilhas *pitfall* que ficaram expostas durante 48h. Os insetos capturados foram fixados em álcool, triados e identificados. Durante o período amostral, foram capturados 11.568 insetos, distribuídos em 11 ordens e 35 famílias. Coleoptera foi a ordem que apresentou maior riqueza de famílias (12), seguido de Diptera e Hemiptera (5), Hymenoptera e Orthoptera (3). Quanto à abundância, Hymenoptera foi o grupo mais numeroso (4.789), seguida de Coleoptera (4.630) e Diptera (1.985 indivíduos). Os Coleoptera foram representados principalmente pelas famílias Staphylinidae e Silphidae. Os Formicidae (Hymenoptera) foram menos abundantes em meses com baixa temperatura. Já Collembola apresentou relação positiva com a umidade do solo. De modo geral, a entomofauna do fragemento apresentou características da fauna de ambientes alterados: baixa diversidade de famílias e dominância de grupos generalistas.

Palavras-chave: insetos edáficos, fragmentação, levantamento, *pitfall*.

Introduction

Insects are the most abundant animal group on Earth, accounting for by 70% of the known fauna, and exceed in number all the other animal groups together (BRANCHER; ROZA-GOMES, 2012). Their abundance and evolutionary success are related to a number of factors, including small size, short life cycle, metamorphosis and ability to fly (HICKMAN et al., 2004). In addition, insects have high species diversity and establish broad ecological relationships, which make them indispensable for the characterization of biological systems and, consequently, with great potential for bioindication (HUTCHENSON et al., 1999).

In forest ecosystems, soil insects have an important role in nutrient cycling (BRANCHER; ROZA-GOMES, 2012) and in the regulation of soil biological processes, in addition to being essential for soil fertility and ecosystem productivity (NUNES et al., 2009). These organisms are primarily responsible for the breakdown of animal organic matter and litter originating from the local vegetation (BRANCHER; ROZA-GOMES, 2012).

Insects living in the soil (and in litter, vertical layers of soil, deadwood and carcasses) of the orders Collembola, Isoptera, Coleoptera, Hymenoptera and Diptera can be considered as bioindicators of negative environmental impacts (WINK et al., 2005) such as forest fragmentation, and can reveal the conditions of the area where they are.

In an attempt to characterize the local fauna and identify indicator species of environmental disturbance, several surveys of soil macrofauna have been undertaken in different environments, such as agricultural areas (NUNES et al., 2009; SILVA et al., 2012), reforestated areas (COPATTI; DAUDT, 2009) and forest fragments (MARQUES; DEL-CLARO, 2010; AZEVEDO et al., 2011; BRANCHER; ROZA-GOMES, 2012). Forests and even forest remnants concentrate the greatest diversity of insect species in tropical regions. Thus, the increased fragmentation is a major cause of biodiversity loss.

In this context, the present study aimed to evaluate temporal variations in the composition and abundance of soil insects of an urban forest fragment and to identify indicators of environmental impact of anthropic origin.

Material and methods

Study area

The study was conducted at the Municipal Park Diva Pain Barth (Figure 01), located in the municipality of Toledo, in the State of Paraná (24° 42' 49"S and 53° 44' 35"W). The climate is humid mesothermal subtropical with hot summers, no dry period, with few frosts and average annual temperature of 20-21°C (IAPAR, 2006).

This Park houses a forest fragment of 8.94 ha, composed of several non-native and native tree species, mostly from reforestation, but with characteristics of seasonal semideciduous forest. The fragment has a triangular shape, with 1400m perimeter and is crossed by a nature trail.

Sampling

Monthly samplings were undertaken from August 2011 to July 2012 at four sites within the Park (Figure 1). At each site, three pitfall traps containing 70% alcohol were placed at one meter away from each other (Figure 2) for 48 hours. Traps were then inspected and the samples were taken to the laboratory, washed, and insects were fixed in 70% alcohol. Next, insects were sorted and identified to the family level using identification keys (TRIPLEHORN, JONNSON; 2011). Data of temperature (°C), relative humidity (%) and rainfall (mm) during the study period were provided by the weather station of PUCPR, Toledo campus.

Figure 1. Aerial view of the Municipal Park Diva Pain Barth indicating the sampling sites.

Figure 2. Pitfall traps installed at the Municipal Park Diva Pain Barth, from August 2011 to July 2012.

Statistical analysis

A non-metric multidimensional scaling (NMDS) was employed to summarize the composition of the insect fauna over time. The general procedure of NMDS summarized in McCune and Grace (2002) was followed and the

Sorensen distance method was computed. A random initial configuration was used, with 100 randomizations of actual data; the stability criterion was ≤ 0.005 standard deviations in stress over 100 iterations. These analyses were performed on the matrix of abundance of insect families caught over the sampling months.

Differences in the composition of the insect fauna between the months, summarized by NMDS, were tested by a permutational multivariate analysis of variance (PERMANOVA) (ANDERSON, 2001).

The influence of environmental variables (temperature, relative humidity and rainfall) in the abundance of insect families was tested by a linear correlation analysis using the software Statistica 7.0.

Results and discussion

During the sampling period, we collected 11,568 insects of 11 orders and 35 families. The order Coleoptera showed the highest family richness (12), followed by the orders Diptera and Hemiptera (5), Hymenoptera and Orthoptera (3) and Collembola (2). The orders Thysanoptera, Lepidoptera, Isoptera, Neuroptera and Dermaptera were represented by only one family (Table 1).

Table 1. Taxonomic classification and abundance of soil insects caught with pitfalls in the Municipal Park Diva Pain Barth, Todelo, Paraná State, from August 2011 to July 2012. (NI=non-identified).

	August	September	October	November	December	January	February	March	April	May	June	July	Total
Hymenoptera													
Formicidae	277	266	359	511	416	397	505	417	508	457	263	286	4,662
Cynipidae	18	8	5	18	24	20	1	0	0	1	1	1	97
Diapriidae	0	0	0	0	0	0	6	6	1	4	11	2	30
Collembola													
Emtomobryidae	97	192	323	222	137	38	25	122	125	103	100	80	1,564
Sminthuridae	0	0	1	5	3	0	1	41	85	4	10	2	152
Coleoptera													
Staphylinidae	43	65	98	212	81	192	398	51	58	68	122	97	1,485
Silphidae	77	87	75	79	86	100	83	29	29	59	147	124	975
Scarabaeididae	0	1	32	23	41	0	0	1	0	1	2	0	101
Curculionidae	14	7	4	4	29	2	0	4	0	0	0	0	64
Histeridae	7	8	5	20	4	6	4	4	8	4	1	5	76
Carabidae	1	8	9	4	2	4	1	3	1	3	1	0	37
Bostrichidae	7	2	1	3	6	5	9	15	4	3	6	10	73
Coccinelidae	1	0	0	1	0	0	0	0	0	0	0	0	2
Chrysomelidae	2	0	1	1	2	1	0	5	3	11	9	23	58
Cicindelidae	0	0	0	2	6	16	1	7	0	0	0	0	32
Pitilidae	0	0	0	2	0	1	0	0	0	1	0	2	6
Cleridae	0	0	0	0	0	0	0	0	2	0	1	2	5
Diptera													
Phoridae	1	82	170	436	201	18	6	3	3	9	25	15	901
Drosophilidae	326	31	25	28	1	14	4	4	16	91	324	149	1,013
Tipulidae	7	0	0	1	3	15	0	7	1	2	0	0	36
Mycetophilidae	5	1	0	0	0	0	0	0	0	1	24	15	47
Muscidae	0	0	1	1	0	0	0	1	0	2	0	0	5
Orthoptera													
Gryllidae	10	0	3	5	1	3	2	2	3	0	0	1	30
Tetrigidae	2	1	0	0	0	0	0	0	0	0	0	0	3
Acrididae	0	0	1	0	0	0	0	0	0	0	0	0	1
Hemiptera													
Cydinidae	0	1	1	9	3	0	4	6	2	3	0	2	33
Nabidae	1	2	3	2	0	0	0	0	0	0	0	0	8
Mesovelidae	3	0	0	0	0	0	0	0	0	0	0	0	3
Cicadidae	9	13	0	0	0	0	2	3	0	0	0	0	26
Cicadelidae	0	0	0	0	0	0	2	1	4	0	0	0	14
Dermaptera													
Forficulidae	1	2	0	6	2	5	10	1	1	2	1	4	35
Neuroptera													
Ascalaphidae	0	0	1	0	0	0	0	0	0	0	0	0	1
Isoptera													
NI	1	0	0	0	0	0	0	0	0	0	0	2	4
Lepidoptera													
Nymphalidae	0	0	0	0	0	0	0	0	0	0	1	0	1
Thysanoptera													
NI	0	0	0	0	0	0	0	0	0	0	0	1	1
Total of indivíduals	910	777	1,120	1,602	958	838	1,066	735	854	834	1,051	823	11,568

The order Hymenoptera was the most abundant throughout the study period (4,789 individuals), followed by Coleoptera (2,914), Diptera (1,985) and Collembola (1,716). The distribution of abundance among these orders seems to be a recurring pattern for forest fragments. Giracca et al. (2003) collected soil arthropods in Agudo, in the state of Rio Grande do Sul, and found the same trend in the distribution of abundance among the orders.

Hymenoptera is one of the most abundant groups in Brazilian forests, representing one third of the total biomass of insects in these areas (WINK et al., 2005). According to Lewinsohn et al. (2005), the high incidence of Hymenoptera, especially the family Formicidae, is common in forest fragments. Given their presence in all strata of vegetation and their close relationship with the environment, ants are commonly used as bioindicators of environmental impacts. Species richness of ants is correlated with the type and variety of vegetation, and the increased complexity of vegetation ensures increase in their diversity.

In the present study, the family Formicidae was very abundant throughout the period, with the lowest abundance in colder months, in June (19°C) and July (16°C), when 263 and 286 individuals were collected, respectively. Foraging activity of ants is positively associated with temperature (ILHA et al., 2009), and some species have a preference for temperatures between 20 and 29ºC (CHAGAS; VASCONCELOS, 2002). However, the linear correlation analysis showed no significant relationship between temperature and the abundance of Formicidae.

Coleoptera was the second most abundant order, accounting for by 25% of total insects caught. The most abundant families were Staphylinidae, with 51% of the total of the order, followed by Silphidae with 33%. Similar results were found by Fernandes et al. (2011) who investigated the biodiversity of Coleoptera in a fragment of Atlantic Forest, where the families Silphidae and Staphylinidae were the most abundant, representing 56 and 39%, respectively, of the total. According to Freitas et al. (2005), approximately half of the species of family Staphylinidae consists of inhabitants of litter, forming one of the most important components of the soil fauna, one of the groups better represented in surveys of this environment. As for Silphidae, most species are associated with decaying carcasses of animals (OLIVEIRA-COSTA, 2007).

The order Diptera was the third most abundant herein, mainly individuals of the families Drosophilidae and Phoridae. These insects have a remarkable biological role in the cycling of organic matter, once Phoridae larvae act in decaying animal or plants, while Drosophilidae larvae develop in fungi or decaying fruit (TRIPLEHORN; JONNSON, 2011).

Collembola was the fourth most numerous group, with 15% of total insects collected. Culik et al. (2006) stated that this group is the most abundant of soil mesofauna, often reaching densities of hundreds of thousands of individuals per m^2 in the first centimeters of soil. Nevertheless, despite their abundance, these insects are rarely seen due to their small size (0.25-6 mm) and the habit of living concealed (TRIPLEHORN; JONNSON, 2011). Most species live in soil and feed mainly on fungi, bacteria, plant and animal debris (BELLINI; ZEPPELINI, 2009). The presence or absence of some species may be related to pH changes, availability of certain ions and water, pesticides or even heavy metals in contaminated soils (CASSAGNE et al., 2003).

In our study, abundance peaks of Collembola were recorded in October (332 individuals), November (227) and April (210), which showed high rainfall indices in the days prior to collections (137.6; 96.8 and 109 mm, respectively) (Table 2). In contrast, in February, only 26 individuals were collected and there was no rainfall event in the ten days prior to collection. There was a significant positive relationship between rainfall and Collembola abundance ($r = 0.79$, $p < 0.05$) (Figure 3). According to Fernandes et al. (2009), Collembola are highly dependent on soil moisture, and reduced rainfall can lead to migration, low reproduction and high mortality.

Table 2. Monthly abiotic data for the region of Toledo, Paraná State, from August 2011 to July 2012.

	August	September	October	November	December	January	February	March	April	May	June	July
Temperature (°C)	24.2	20.0	22.2	24.7	20.0	26.5	27.2	35.1	21.0	18.6	19.0	16.0
Relative humidity %	44	67	78	76	54	80	68	63	82	77	88	86
Rainfall (mm)	11.6	2.6	137.6	96.8	27	9.4	0	77.2	109	60.8	70.4	17.4

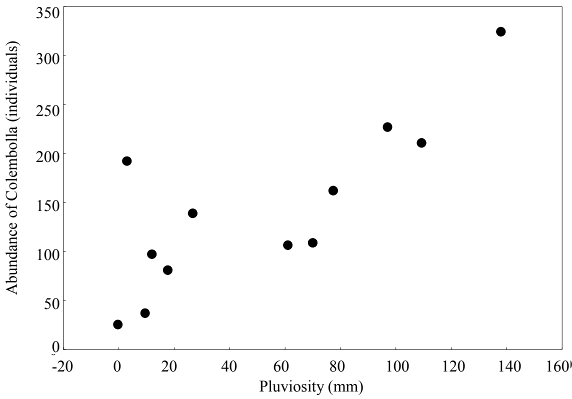

Figure 3. Relationship between rainfall (mm) and the abundance of Collembola caught in the Municipal Park Diva Pain Barth, Toledo, Paraná State, from August 2011 to July 2012.
Source: The authors.

Temperature is an environmental factor that directly interferes with the behavior and development of insects, since they do not have a thermoregulation system (RODRIGUES, 2004). According to Busato et al. (2004), the optimum temperature at which the insects show greater development and produce greater numbers of offspring is around 25°C. Between 15 and 38°C is the minimum and maximum threshold temperature for most species (SILVEIRA NETO et al., 1976). The temperatures recorded in the study region during the study period did not exceed the limits ideal for the development of insects. Thus, the relatively high abundance in our study may be because the temperature was not a limiting factor.

The relative humidity is directly linked to the rainfall. In agreement with Rodrigues (2004), favorable humidity range for insects is between 40-80%. Thus, our study area was considered favorable to the development of insects almost the whole year, as the lowest relative humidity recorded was 44.5% (August). Studies relating the relative humidity and the soil insect fauna are scarce, but the effects of this variable on actively flying insects is known.

The composition in abundance of insects families captured over the months was summarized by a non-metric multidimensional scaling (NMDS) and the scores from this analysis were plotted in the graph (Figure 4). The PERMANOVA identified significant differences in the composition of the insect fauna between months. An a posteriori test indicated which months were significantly different from each other (Table 3).

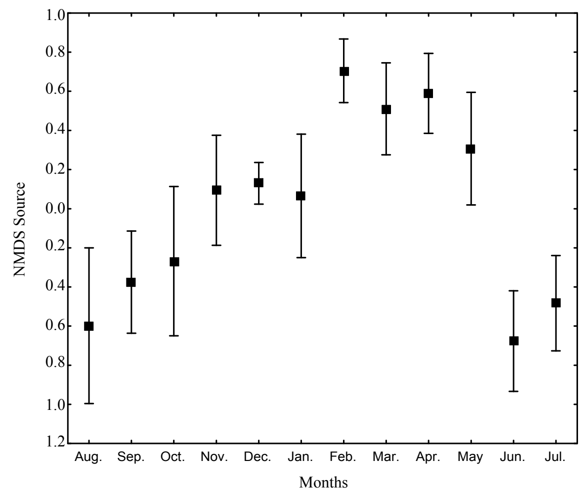

Figure 4. Monthly mean variation of NMDS scores for soil insects collected at the Municipal Park Diva Pain Barth, Toledo, Paraná State, from August 2011 to July 2012.
Source: The authors.

The faunal composition of February was significantly different from the other months except January. This was possibly due to the lack of rainfall events in days prior to collection, since soil moisture is important for soil insects. This is evidenced by increased abundance of Formicidae (505 individuals) in this month, and the lowest number of individuals of Entomobryidae (Collembola; 25 individuals), which, as discussed earlier, is extremely dependent on soil moisture.

Table 3. Results of an a posteriori PERMANOVA, indicating significant differences in the soil insect fauna collected at the Municipal Park Diva Pain Barth, Toledo, Paraná State, from August 2011 to July 2012. Included only the values of the pairs of months that differed significantly.

	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.
August	*			0.0292			0.0316					
September		*					0.0254					
October			*				0.0258		0.0296		0.0252	0.0252
November				*			0.0286			0.0270	0.0264	0.0282
December					*		0.0286				0.0270	0.0262
January						*					0.0226	
February							*	0.0264	0.0264	0.0288	0.0294	0.0258
March								*			0.0314	0.0290
April									*		0.0276	0.0292
May										*	0.0330	
June											*	
July												*

Likewise, June also differed significantly from most months, being similar only to July, August and September. This month presented the combination of high rainfall and low temperature, which may have affected the behavior of the insect fauna collected, as even the ants, which were the dominant group throughout the study, exhibited the lowest number in June (263 individuals). Furthermore, this combination of abiotic factors may have favored increased representation of groups such as Drosophilidae, Staphylinidae and Silphidae.

July also showed different composition from most months, but similar to January, May, June, August and September. The low temperature recorded in this month (17°C) possibly affected the composition of the soil entomofauna in general, which resulted in the lowest total insect abundance (826 individuals).

Conclusion

The most abundant orders in our study were Hymenoptera, Coleoptera, Diptera and Collembola. There was no clear seasonal pattern for the groups, but there were differences in the composition of the fauna over the months, mostly caused by abiotic factors.

Formicidae (Hymenoptera) was the dominant group during the study, and their lowest number were observed in colder months. Collembola was positively correlated with soil moisture, being more abundant in months with higher rainfall.

In general, the soil entomofauna from the forest fragment exhibited characteristics of the fauna of fragmented environments, with low diversity of families and dominance of generalist groups.

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