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STRUCTURAL AND FUNCTIONAL CHARACTERIZATION OF THE LEAF LITTER INSECT FAUNA IN DIFFERENT PLANTS COVERS - SERRA DO ITAJAÍ NATIONAL PARK

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Resumo

Caracterização estrutural e funcional da entomofauna da serrapilheira em diferentes coberturas vegetais - Parque Nacional da Serra do Itajaí. Os insetos se destacam pela sua diversidade, representatividade, importância ecológica e sensibilidade a alterações ambientais, sendo afetados pelas modificações antrópicas dos ecossistemas naturais. O estudo teve como objetivo caracterizar a entomofauna da serapilheira em quatro diferentes áreas, sendo duas de floresta nativa e duas de pastagem no Parque Nacional da Serra do Itajaí (PNSI). Os dados foram coletados no período de agosto/2014 até agosto/2015 a partir da instalação de armadilhas *pitfall*. Foram analisados a abundância, riqueza de famílias, diversidade, composição e grupos funcionais. Ao total, foram coletados 16.062 indivíduos distribuídos em 16 ordens e 101 famílias. Observou-se que a abundância, riqueza de famílias e diversidade foi semelhante entre as áreas. Entretanto, a composição diferiu, demonstrando que os ambientes possuem diferentes comunidades da entomofauna em relação a composição de famílias. A ordem Coleoptera, com a família Ptiliidae foi mais abundante em floresta nativa, enquanto que Hemiptera: Cercopidae e Cicadellidae foram mais abundantes na pastagem. A composição de fungívoros e fitófagos foi significativamente diferente entre as áreas. O número de famílias exclusivas e a composição demonstra uma entomofauna da serapilheira adaptada as condições ambientais e recursos disponíveis em cada ambiente.
Palavras-chave: bioindicador, ecologia, Mata Atlântica, Coleoptera, fauna edáfica

Abstract

Insects stand out for their diversity, representativeness, ecological importance, and sensitivity to environmental changes that are affected by anthropogenic changes in natural ecosystems. This study aimed to characterize the leaf litter insect fauna in four different areas that included two native forests and two pastures in Serra do Itajaí National Park. Data were collected from August 2014 to August 2015 from pitfall trap installations. The abundance, richness, diversity, family composition, and functional groups were analyzed. In total, 16,062 individuals were collected that were distributed across 16 orders and 101 families. Abundance, family richness, and diversity were similar among the areas. However, the composition differed, demonstrating that the environments possessed different insect fauna communities based on the composition of families. The Coleoptera order with the Ptiliidae family was more abundant in the native forest, while the Hemiptera (Cercopidae and Cicadellidae) were more abundant in the pasture area. The composition of fungivores and phytophagous fungi differed significantly among the areas. The number of exclusive families and their composition demonstrated a leaf litter insect fauna that was adapted to the environmental conditions and resources available within each environment.
Keywords: bioindicator, ecology, Atlantic forest, Coleoptera, edaphic fauna

INTRODUCTION

The Atlantic Forest biome is recognized for its high biodiversity and high levels of endemism. However, it is also one of the most threatened biomes in the world due to the intense process of exploration, use, and occupation of the soil that has transformed the Atlantic Forest into a set of small and disconnected fragments of secondary forest with intense human influence (MARQUES; GRELLE, 2021). In this context, conservation and restoration actions are essential to minimize and reverse the negative effects of biodiversity loss and the other ecological and social factors that are involved. With this, it is possible to promote the maintenance of the diversity hotspot status of the Atlantic Forest, improve human health standards in its domains, and reduce vulnerability to the effects of climate change. (SCARANO; CEOTTO, 2015).

Among the various human activities that occur in the forest formations of the Atlantic Forest, the replacement of native vegetation stands out due to the severe biotic and abiotic changes that affect the fauna (HOPP *et al*., 2010; BEIROZ *et al*., 2014; SALOMÃO *et al*. 2018) and the physical, chemical, and biological parameters of the soil (GUARIGUATA; OSTERTAG, 2001; NOGUEIRA *et al*., 2016). Among the faunal groups, it is worth mentioning insects due to their representativeness, diversity, ecological importance, and bioindicator capacity (HOPP *et al*., 2010; MELONI, VARANDA, 2015; POMPEO *et al*., 2016; AMAZONAS *et al*., 2017).

Litter fauna exhibit different responses to environmental changes that vary according to taxonomic and functional aspects and the type of disturbance (AUDINO *et* al. 2014; COYLE *et al*., 2017), where each species or group of species has different levels of sensitivityto environmental changes and respond in different ways (BEIROZ *et al*., 2014). Environmental changes can directly and indirectly influence components that interact with edaphic fauna such as plant communities and edaphic and climatic parameters (MARINONI; GANHO, 2003; HOPP *et al*., 2010; COYLE *et al*., 2017).

Although insects are essential for the regeneration of forests, they possess different ecological functions. In the context of restoration of degraded areas and the management plans of conservation units, they are rarely considered in evaluation and monitoring. Thus, surveys that generate information regarding changes in insect communities can serve as a subsidy to observe the consequences of replacing native vegetation and alternative uses of the soil.

In this study, we compared the structural and functional parameters of leaf litter insect fauna in pasture and native forest areas to evaluate the effects of the suppression of native vegetation on this faunal group in the phytophysiognomy of the Ombrophilous Dense Montana forest in the Serra do Itajaí National Park, Santa Catarina.

MATERIAL AND METHODS

Study area

The present study was performed in the municipality of Indaial in an area known as Faxinal do Bepe located in the Serra do Itajaí National Park (SINP), an integral protection conservation unit located in the State of Santa Catarina between 27º00' and 27º17' S and 49º01' and 49º21' W. The region is located in the Itajaí river basin with altitudes ranging from 600 to 800 m and is located in the Atlantic Forest biome with the phytophysiognomy of the Ombrophilous Dense Montana forest (BRASIL, 2009).

According to the Köppen climate classification, the predominant climate in the region is Cfa, a subtropical humid mesothermal climate with hot summers (ALVARES *et al*., 2013). The average annual temperature varies between 16 °C and 20 °C, the average relative humidity varies between 82 and 84%, and precipitation is well distributed throughout the year with an average annual variation of 1,500–1,700 mm (PANDOLFO *et al*., 2002).

Four sample areas were evaluated that consisted of the following characteristics: native forest (FOR), two areas with native forest vegetation in advanced and intermediate stages of ecological succession with a high richness of tree and herbaceous species; pasture (PAS), two areas with vegetation cover of approximately 90% grasses (native and exotic) and some regenerating individuals of the Asteraceae family (SCHORN; MAÇANEIRO, 2018).

Data collection

Sampling was performed bimonthly from August 2014 to August 2015. Data were collected by installing a pitfall trap (height:18.5 cm; upper diameter:21.5 cm; lower diameter:17 cm) every 20 m in 80 m transects. A transect was installed in each sample area, with a total of 20 pitfalls. Then, 250 ml of water, 20 ml of alcohol (70%), and 5 ml of a biodegradable detergent were added. The collected samples were sorted, counted, and identified to the family level using dichotomous keys (RAFAEL *et al*., 2012), and the specimens were deposited in the entomological collection of the Monitoring and Forest Protection Laboratory (LAMPF) of the Regional University of Blumenau (FURB).

Data analysis

Structural parameters

For the analysis of litter insect fauna community structure, the values for abundance, family richness, diversity, and composition were determined. Data detailing total abundance and the most representative families and richness of families were submitted to the Shapiro-Wilk normality test, and later, to the Kruskal-Wallis test ($p<0.05$) and the Mann-Whitney post-hoc test for nonparametric data and to analysis of variance (ANOVA) and Tukey's test ($p<0.05$) for parametric data. As the most representative family, those with a frequency greater than 4% were considered. For the analysis of abundance, data from Formicidae were excluded due to the social behavior of the family, as pitfall traps could collect all individuals belonging to a single nest.

Functional parameters

After identification, the insects were classified into functional groups according to the predominant feeding and behavioral habits of the family based on the methods of Rafael *et al*. (2012). Thus, the following functional groups were identified: detritivores, fungivores, phytophagous, predators, parasitoids, and omnivores. Abundance data were submitted to the Shapiro-Wilk normality test, and later, to the Kruskal-Wallis test ($p<0.05$)

and Mann-Whitney post-hoc test for non-parametric data and to analysis of variance (ANOVA). and Tukey's test (P <0.05) for parametric data.

To test if there were differences in composition, total data from families and according to functional group were considered through non-metric multidimensional scaling (NMDS) ordering analysis based on Bray-Curtis dissimilarity followed by analysis PERMANOVA (permutational multivariate analysis of variance) at a 5% significance level. All analyses were performed using PAST 4.03 software (HAMMER *et al*., 2001).

RESULTS

Structural parameters

A total of 16,062 individuals were distributed across 15 orders, and 101 families were collected (Table 1). The highest abundance, diversity, and richness of the families were observed in the native forest area. However, no significant differences were observed in pasture area. Of the total richness of exclusive families, 23 were recorded in the native forest and 22 were recorded in the pasture (Table 2).

Table 1. Abundance and composition of orders and families in native forest and pasture areas in Serra do Itajaí National Park, Santa Catarina state.
Tabela 1. Abundância e composição de ordens e famílias nas áreas de floresta nativa e pastagem no Parque Nacional da Serra do Itajaí, Santa Catarina.

Taxonomic Group	Native Forest	Pasture	Taxonomic Group	Native Forest	Pasture
Order Blattodea	**16**	**11**	**Order Hemiptera**		
Sub. Ord. Isoptera	2	1	Cydnidae	8	4
Family 1	14	10	Enicocephalidae	32	1
Order Coleoptera	**3057**	**1271**	Fulgoridae	1	2
Anobiidae	5	9	Gelastocoridae	3	17
Bentridae	1	0	Geocoridae	2	0
Biphyllidae	18	0	Hydrometridae	1	1
Bostrichidae	0	1	Lygaeidae	0	3
Bruchidae	4	0	Miridae	15	2
Carabidae	12	15	Nabidae	8	2
Cerambycidae	1	0	Naucoridae	3	0
Ceratocanthidae	2	0	Pentatomidae	6	2
Chrysomelidae	26	14	Psyllidae	1	1
Cicindelidae	5	0	Pyrrhocoridae	3	7
Coccinellidae	2	4	Reduviidae	0	4
Cucujidae	5	12	Rhyparochromidae	0	1
Cupedidae	2	1	Tingidae	1	0
Curculionidae (Subfamily Scolytinae)	734	112	Family 1	2	0
Curculionidae (Subfamily 1)	14	6	Family 2	0	1
Dermestidae	1	0	Family 3	1	0

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Elateridae	17	10	Family 4	0	2
Endomychidae	0	1	Immatures	156	239
Geotrupidae	1	6	**Order Hymenoptera**	**3377**	**2757**
Gyrinidae	0	1	Apidae	1	1
Histeridae	22	7	Bethylidae	3	2
Hydrophilidae	1	4	Braconidae	1	0
Leiodidae	21	3	Cephidae	1	0
Lymexylidae	1	0	Chalcidoidea	159	137
Mordellidae	1	1	Formicidae	3203	2608
Nitidulidae	42	36	Ichneumonidae	1	0
Passalidae	1	6	Pompilidae	2	1
Phalacridae	0	2	Sphecidae	0	1
Platypodidae	0	2	Vespidae	6	4
Ptiliidae	891	122	Family 1	0	1
Ptilodactylidae	2	0	Family 2	0	2
Salpingidae	1	0	**Order Lepidoptera**	**15**	**25**
Scarabaeidae	20	9	Family 1	13	24
Scydmaenidae	42	10	Family 2	2	1
Silphidae	25	5	**Order Mantodea**	**1**	**0**
Staphylinidae	909	593	Family 1	1	0
Tenebrionidae	6	3	**Order Neuroptera**	**0**	**1**
Family 1	2	0	Family 1	0	1
Family 2	2	0	**Order Orthoptera**	**258**	**133**
Family 3	0	1	Acrididae	27	4
Family 4	1	0	Gryllidae	215	115
Family 5	0	1	Tetrigidae	5	1
Family 6	0	2	Tettigonidae	0	1
Family 7	0	1	Family 1	11	12
Family 8	0	1	**Order Psocoptera**	**1**	**4**
Immatures	217	270	Family 1	1	4
Order Dermaptera	**19**	**5**	**Order Thysanoptera**	**27**	**17**
Family 1	19	5	Family 1	27	17

Order Diptera	**1446**	**1481**	**Order Trichoptera**	**10**	**67**
Adults	1436	1449	Family 1	10	67
Immatures	10	32	**Order Zoraptera**	**0**	**2**
Order Hemiptera	**659**	**1401**	Family 1	0	2
Anthocoridae	0	1	**Order 1**	**1**	**0**
Aphididae	57	187	Family 1	1	0
Aradidae	3	2			
Belostomatidae	2	1			
Cercopidae	117	410			
Cicadellidae	204	492			
Coreidae	33	19			

Table 2. Abundance, family richness, and number of exclusive families observed in native forest and pasture areas.
Tabela 2. Abundância, riqueza de famílias e número de famílias exclusivas observadas nas áreas de floresta nativa e pastagem.

Variable	Native Forest	Pasture	p
Abundance*	8.887 a	7.175 a	0,333
Families richness	82	81	0,776
Exclusive families	23	22	-

*Values followed by the same letter are not statistically different according analysis of variance (ANOVA) and Tukey test (5%).

The most frequent Orders were the Hymenoptera (38.19%), Coleoptera (26.95%), Diptera (18.22%), and Hemiptera (12.83%). The most representative families were in Coleoptera (N = 44), and this was followed by Hemiptera (n = 27) (Table 1). The most representative individuals were Hymenoptera: Formicidae (45.94%); Coleoptera: Staphylinidae (11.88%); Ptiliidae (8.01%); Curculionidae (6.85%); Hemiptera: Cicadellidae (5.50%); and Cercopidae (4.17%). The families Ptiliidae, Staphylinidae, and Curculionidae were more representative of native forest areas; however, only Ptiliidae was significantly superior (p = 0.025) (Figure 1). The families Cicadellidae (p = 0.009) and Delphacidae (p = 0.009) were significantly more abundant in the pasture areas (Figure 1).

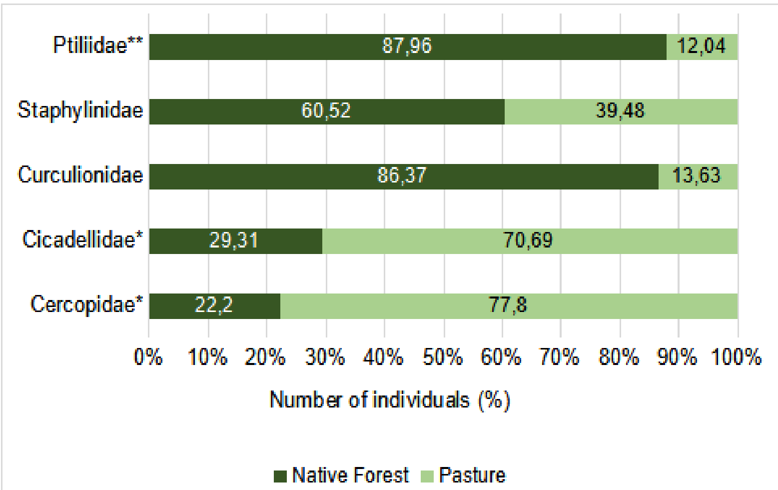

Figure 1. Relative abundance of Ptiliidae, Staphylinidae, Curculionidae, Cicadellidae, and Cercopidae families in native forest and pastures areas. (*Values significantly different according to analysis of variance (ANOVA) and Tukey test (5%).

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Figura 1. Abundância relativa das famílias Ptiliidae, Staphylinidae, Curculionidae, Cicadellidae e Cercopidae nas áreas de floresta nativa e pastagem. (* Valores significativamente diferentes pela análise de variância (ANOVA) e teste de Tukey (5%); ** Valores significativamente diferentes pelo teste de Kruskal-Wallis e *post-hoc* Mann-Whitney (5%)).

Functional groups

The most representative functional groups were phytophagous (32.56%), omnivores (32.43%), detritivores (18.29%), fungivores (11.25%), parasitoids (3.28%), and predators (2, 20%). Only the abundance of fungivores exhibited significant differences among the areas and was higher in the native forest (Table 3).

Table 3. Abundance of functional groups in native forest and pasture areas.
Tabela 3. Abundância dos grupos funcionais nas áreas de floresta nativa e pastagem.

Functional group	Native Forest	Pasture	p
Detritivores*	1026 a	663 a	0,214
Phytophagous**	1502 a	1505 a	0,522
Fungivores**	914 a	125 b	0,021
Omnivores*	1487 a	1508 a	0,948
Predators**	127 a	76 a	0,305
Parasitoids*	164 a	139 a	0,594

Values followed by the same letter are not statistically different according: * Analysis of variance (ANOVA) and Tukey test (5%); ** Kruskal-Wallis test and Mann-Whitney *post-hoc* test (5%).

Composition

In the NMDS and PERMANOVA, differences were observed in the total composition of the insect fauna (stress 0.1314, F = 1.89, p = 0.07) and also in the composition of fungivores (stress 0.021; F = 3.28, p = 0.03), phytophagous (stress 0.085, F = 2.57, p = 0.01), detritivores (stress 0.034, F = 1.01, p = 0.34), and predators (stress 0.28, F = 1.53, p = 0.07) (Figure 2). Of these, only fungivorous and phytophagous exhibited significant differences.

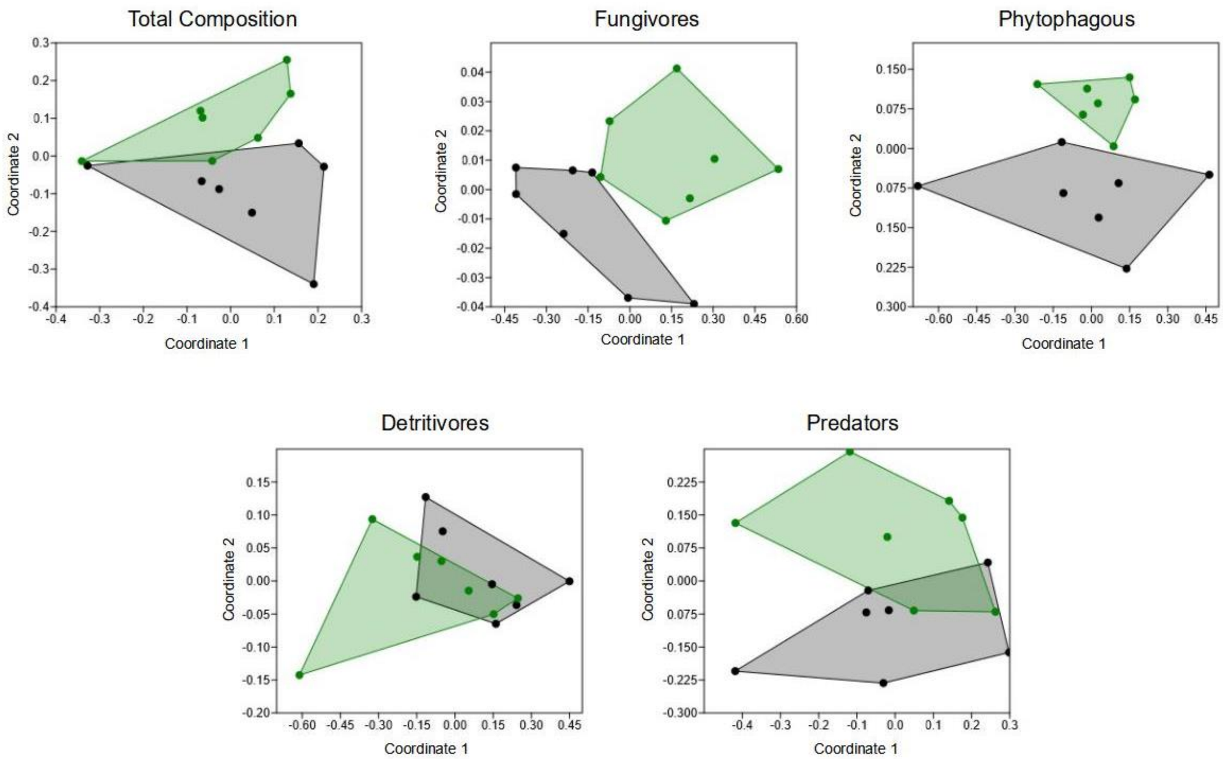

Figure 2. NMDS analysis of the total composition of leaf litter insect fauna and functional groups of fungivores, phytophagous, detritivores, and predators in native forest (black) and pasture (green) areas.
Figura 2. Análise NMDS da composição total da entomofauna e dos grupos funcionais dos fungívoros fitófagos, detritívoros e predadores nas áreas de floresta nativa (preto) e pastagem (verde).

DISCUSSION

In terms of structural parameters (Table 2), the most abundant group was the Formicidae (Hymenoptera) family, and this was expected due to the social habits of this family and the knowledge that this pattern often observed in terrestrial insect fauna surveys (for example, AMAZONAS *et al*., 2017). The composition of Coleoptera, the order with the highest number of families (Table 1; Figure 1) with greater representation of Staphylinidae, Ptiliidae, and Curculionidae, was similar to that observed in other surveys in the Atlantic Forest (MARINONI; GANHO, 2003; HOPP *et al*., 2010).

Based on the data presented in Figure 1 and Table 1, the most representative families were Coleoptera: Ptiliidae, Staphylinidae, Curculionidae (subfamily Scolytinae), Hemiptera: Cicadellidae, and Cercopidae. Staphylinidae is frequently recorded as one of the most representative families at the soil-litter interface (MARINONI; GANHO, 2003; POMPEO *et al*., 2016), thus indicating its importance in this habitat. This family exhibits quite variable habits and is detritivorous, fungivorous, and phytophagous but predominantly predatory (CASARI; IDE, 2012). Of the family Curculionidae, 97.69% belong to the subfamily Scolytinae (Table 1) that are predominantly xylomycetophagous beetles that form galleries and live between the bark and the wood of plants (WOOD, 1982). Specifically, they depend on woody material present in the environment. Coleoptera is highly mobile and disperses well throughout the environment, and the presence of nearby native vegetation fragments can act as a source (HOPP *et al*., 2010). This may explain the lack of significance in the abundance of these families and the structural and functional parameters of the litter insect fauna. Among beetles, only the Ptiliidae family exhibited significantly lower abundance in the pasture area (Figure 1), with the family being more sensitive to environmental changes. This is in agreement with the data recorded by Marinoni and Ganho (2003) for the ombrophilous mixed montana forest in Paraná.

Of the order Hemiptera, the second order with the highest number of families, the representativeness of the families Cicadellidae, Cercopidae, and Aphididae is the highest (Table 1; Figure 1). These families are composed of sucking insects that feed on the sap flow of grasses (GRAZIA *et al*., 2012), and therefore pastures favor the presence of these families due to the availability of food resources.

Data regarding the abundance and richness of the families were not significantly different (Table 2). These results are surprising, as we expected higher values for these parameters in the native forest. The greater complexity of the native vegetation cover of the more advanced successional stages provides a better-structured litter and habitat for these organisms by providing more resources and better overall conditions (GUARIGUATA; OSTERTAG, 2001) that favor insect fauna (MACHADO *et al*., 2015). However, the number of exclusive families (Table 2) and the composition (Figure 2) demonstrated a litter insect fauna that was adapted to environmental conditions and available resources in each of the analyzed environments. This can be reinforced by observing differences in the composition of the functional groups.

Regarding the functional groups studied, significant differences were observed in the abundance of fungivores and the composition of fungivores, predators, detritivores, and phytophagous fungi (Table 3 and Figure 2). Due to the replacement of native vegetation with pasture, the habitat was strongly altered by the simplification of the plant community, and there was a change in environmental conditions. Canopy closure is an important structural parameter, as it is related to the formation of litter, habitat of these organisms, and greater microclimatic stability (AMAZONAS *et al*., 2017). Additionally, the presence of woody material in the native forest favors the presence of families that exploit this type of resource (xylophages) such as Curculionidae and Cerambycidae. In contrast, in the pasture, families that feed on the flow of grass sap (suckers) are favored as evidenced by the greater abundance of Cicadellidae and Cercopidae (Figure 1).

Fungivores exhibited differences in both abundance (Table 3) and composition (Figure 2). These differences are reinforced by the greater abundance of Ptiliidae, the most representative family of the group, and by the exclusivity in the record of Biphylidae (Coleoptera) (Table 1). This pattern may have occurred due to differences in litter structure between the sampled areas such as litter accumulation, chemical composition, and species richness and due to the existence of environmental conditions that were more limiting for this group. This is due to the observation that in the native forest, the formation and diversity of the litter and the microclimate offer better conditions for the proliferation of fungi (a food resource for this group), as the occurrence of insects can also be limited by the tolerance of their food resources (SCHOWALTER, 2006).

Although no significant change was recorded in the richness of families, the data revealed a negative effect of pasture on the community of litter insect fauna families through the reallocation/replacement of species, as evidenced by the difference in composition between the natural vegetation and pasture areas (Figure 2). As it is an integral protection conservation unit, restoration initiatives in these areas are fundamental for the restructuring of the insect community and also for the UC to fulfill its role in environmental protection. In this context, the dataset and analyses presented in this manuscript can serve as a basis for the evaluation and monitoring of restoration initiatives in the PNSI, where insects are one of the parameters for evaluating the quality.

Certain studies have demonstrated the potential for insect fauna to act as bioindicators of environmental quality. When observing the results obtained in the present research, the composition of functional groups presents itself as a promising parameter due to the possibility of obtaining structural and functional information from this dataset. It should be noted that the simplification events to which the pasture areas in this study were submitted occurred decades ago (BRASIL, 2009). Therefore, there is sufficient time for colonization by species (and functional groups) that are adapted to their environmental conditions and resource availability. Thus, comparison of the present study with others that evaluated recent processes of environmental simplification by anthropic action must be performed with extreme caution, as in addition to the difference in composition, these typically present a significant reduction in species richness and diversity.

CONCLUSION

- The structural and functional attributes of the litter insect fauna exhibited different patterns in the native forest and pasture areas. The abundance and richness of families were similar among the environments. However, the total composition, exclusive families, abundance, and composition of functional groups of fungivores and phytophages revealed characteristic litterfall insect faunal communities in different environments.
- From the dataset, it is possible to observe the great diversity of insects in the Serra do Itajaí National Park, thus highlighting the importance of further studies examining this faunal group.
- The results can help in the determination of bioindicator families and the selection of the best parameters for bioindicator analyses in the evaluation and monitoring of ecological restoration in areas of protection and conservationin addition to the knowledge of the biodiversity of the dense Montana rainforest of Santa Catarina state.

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