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Trabalho de Conclusão

Composition and structure of Heteroptera (Insecta: Hemiptera) assemblages along a vegetational gradient at Itacolomi State Park, southern Brazil

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Abstract. Heteroptera are insects highly abundant and rich in the Atlantic Forest in Brazil. Despite their use as bioindicators and biocontrol agents, this group is not charismatic and thus is often not included in environmental assessments. Minas Gerais is a state in Southern Brazil with high level of species endemism where parks such as the Itacolomi State Park are suggested biodiversity hotspots. In this study we evaluated the composition, abundance and species richness of Heteroptera along a vegetational gradient (late succession, early succession and rupestrian field). Samples were collected between December 2010 and October 2011, totalling 336 hours over 28 sampling events across all four seasons. One thousand individuals of 38 morphospecies were collected. Abundance was significantly higher in the Summer and lower in the Winter, and it was the highest in the rupestrian field. Richness and diversity also varied across seasons, but not between sites. The most abundant morphospecies was *Euchilocoris* sp. (22.1%), followed by *Neostenotus* sp. (21.4%), both in the Miridae family. Combining the high number of singletons identified in our study (8 spp.) with the accumulation curves that show new species records still being added in our last sampling season, we suggest that there are likely more species that were not collected. Despite the fact that our specimens were only identified to the genus level in most cases, this is the first study to characterize the Heteroptera fauna at Itacolomi State Park, as the park management plan did not include hemipterans.

Keywords: Biodiversity; fauna inventory; hemipterans.

Composição e estrutura de de comunidades de Heteroptera (Insecta: Hemiptera) ao longo de um gradiente vegetacional no Parque Estadual do Itacolomi, no sudeste do Brasil

Resumo. Heteroptera é um grupo de insetos abundante na Floresta Atlântica. Apesar de seu uso como bioindicadores ou no controle biológico, eles não são carismáticos e frequentemente são excluídos de estudos ambientais. O estado de Minas Gerais apresenta elevado grau de endemismo e parques como o Parque Estadual do Itacolomi são sugeridos como hotspots de biodiversidade. Neste estudo nós avaliamos a composição, abundância e riqueza de Heteroptera ao longo de um gradiente vegetacional (clímax, floresta secundária e campo rupestre). As amostras foram coletadas entre Dezembro de 2010 e Outubro de 2011; no total coletamos durante 336 horas ao longo de 28 dias, cobrindo assim todas as estações climáticas. A abundância de Heteroptera foi significativamente mais alta durante o verão do que durante o inverno, e foi mais alta no campo rupestre. Riqueza e diversidade variaram durante as diferentes estações climáticas, mas não entre as áreas de coleta. A morfoespécie mais abundante foi *Euchilocoris* sp. (22.1%), seguida de *Neostenotus* sp. (21.4%), ambas na família Miridae. Considerando o alto número de singletons (oito espécies) e a curva de acumulação de espécies não estabilizada, podemos sugerir que outras espécies de Heteroptera não foram coletadas. Apesar de termos identificado as espécies a nível de gênero, este é o primeiro estudo a caracterizar a fauna de Heteroptera no Parque Estadual do Itacolomi, uma vez que o plano de manejo não incluiu este grupo de insetos.

Palavras-chaves: Biodiversidade; inventário da fauna, hemípteros.

Species inventories are important for decision-making processes in relation to undertakings that may impact the environment (SILVEIRA et al., 2010), including the selection of areas for conservation, environmental impact assessments, and political discussions on biodiversity (GREEN et al., 2009). Nonetheless, species inventories often neglect insects (BARCELLOS et al., 2011), possibly because they are not considered charismatic species (DUCARME et al., 2013).

Hemipterans of the suborder Heteroptera (Insecta: Hemiptera) are an expressive group of insects in Brazil, with at least 7,482 species in approximately 74 families registered (RAFAEL et al., 2012). Most hemipterans are terrestrial, and predominantly phytophagous, but aquatic and semi-aquatic species also occur. Phytophagous insects, such as hemipterans, are sensible to plant diversity (LEAL et al., 2016) given their strict functional association to the plant community where they live, but they are also known to have populations fluctuate in response to seasonality (BRAMAN and BESHEAR, 1994). Hemipterans are often used to study plant-insect associations due to their high diversity of phytophagous species (HENRY and

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FROESCHNER, 1988). Specifically, Wheeler (2000) shows that several subfamilies of Heteroptera are sensible to disturbances on plant cover because they are closely associated with host plants. For instance, nymphs and adults of Miridae are known to feed mostly on plants (SCHUH and SLATER, 1995), with species considered major agricultural pests (DE PAULA and BARRETO, 2020; Wheeler, 2001) or even biocontrol agents (HENRY, 2000) illustrating this close association with plants, which allows for the development of studies on the composition of Heteroptera in response to changes in plant cover and successional stages of vegetation.

Here we aimed to describe the composition and structure of assemblages of Heteroptera in three areas differing in plant community composition at the Itacolomi State Park, Minas Gerais, Brazil: a late succession forest community, an early succession forest community, and a rupestrian field. Specifically, we tested whether 1) the structure of the Heteroptera assemblage reflects the successional vegetational stages, 2) the Heteroptera composition responded to seasonality. We expected the Heteroptera communities in the late succession forest to be more diverse in response to higher variability of resources.

This study took place at Itacolomi State Park (20°22'30" S, 43°32'30" W). The park is located in the municipalities of Ouro Preto and Mariana, Minas Gerais state, Southern Brazil. The park is 7,543 ha (ANJOS et al., 2016), and it encompasses a transition zone between Cerrado and Atlantic Forest. Specifically, the vegetation is composed of rupestrian fields ("*Campo rupestre*"), plantations of *Eremanthus* spp. (Asteraceae) and *Eucalyptus* spp. (Myrtaceae), and a submontane semi deciduous seasonal forest ("*Floresta estacional semi decidual submontana*") (ANJOS et al., 2016; VELOSO et al., 1991) (see GASTAUER et al., 2012 for vegetation description). The weather in the region is humid with dry winters and hot summers (Cwa) in low altitude areas, and temperate summers (Cwb) in high altitude areas of the park (IEF, 2007), where the elevation reaches up to 1,772 m a.s.l. (FUJACO et al., 2010).

Three areas different in vegetational succession stages, and accessed by public trails, were selected for this study. Area 1 ("Trilha do Forno I" - 20°25'S, 43°30'W) is a secondary late succession Atlantic Rainforest characterized by mature tall trees, low occurrence of fern and Candeia (*Eremanthus erythropappus* (DC)), and forest floor covered in litter, besides a closed canopy. Area 2 ("Trilha do Forno II" - 20°25'S, 43°30'W) is an early succession Atlantic Rainforest community (impacted up to 40 years prior to sampling) with short vegetation, sparsely distributed trees, high presence of grasses and fern, and higher incidence of light reaching the soil, where little litter accumulates. Both areas 1 and 2 have suffered lower levels of disturbance compared to area 3 (LOURENÇO, 2013). Area 3 ("Trilha da Capela" - 20°26'S, 43°30'W) is situated in a rupestrian field (transition between Atlantic Rainforest and Cerrado) with fewer trees and grasses, and with Candeia as the dominant tree species.

A single UV-light trap was installed on a tree branch at 1.80 m in each area, and the height was chosen such to ensure greater light dispersion. The traps worked between dusk and dawn and were equipped with an automotive 12.6 V battery. Sampling occurred in two consecutive nights on tentatively every two weeks between December 2010 and October 2011; all four seasons were covered. Sampling did not occur in full moon nights due to the moon luminosity interference in catching efficiency (NOWINSZKY, 2004). The total sampling effort was 336 hours over 28 sampling events (days) for each site. Heteroptera specimens were pinned and identified under a stereomicroscope (Zeiss Discovery V8) following Schuh and Slater (1995) and Rafael et al. (2012), and through comparison with specimens deposited in the scientific collections National Museum, Museum of the Federal University of Rio de Janeiro, Entomology Museum of the Federal University of Viçosa. Specimens were identified to the genus level, where possible.

We determined species abundance, richness, and Shannon's diversity (H') and compared them using a type III Anova in the "car" (FOX, 2020) and "vegan" (OKSANEN et al., 2019) packages in R statistical program (R CORE TEAM, 2020) with site and season as factors, and Tukey HSD was used as a *post hoc* test. Species richness was estimated using Chao, Jackknife 1, Jackknife 2, and Bootstrap estimators, and we compared the overall community composition between sites using PerManova with Bray-Curtis dissimilarity and visualized it using Nmds ordination (CLARKE, 1993). All analyses use an alpha of 0.05, and final plots were created in R with "ggplot2" package (WICHKAM, 2016).

In total, we collected 1,000 individuals of Heteroptera. Although no overall significant differences were found for abundance between seasons ($F_{3.72}$ = 1.64, P = 0.18) or in the season × site interaction ($F_{6.72}$ = 0.33, P = 0.91), significantly less individuals were collected during the Winter (Tukey HSD: Winter × Spring, P = 0.05; Winter × Summer, P = 0.004) (Table 1). More than half of the individuals were sampled in the rupestrian site (51% of the specimens), followed by the late succession community (28%) and the early succession community (21%) (Table 1). These differences led to a main marginally significant effect of site on abundance ($F_{2.72}$ = 2.58, P = 0.08), with significantly more individuals present in the rupestrian field compared to the early succession community (Tukey HSD, P = 0.01).

We identified 38 morphospecies in the families Lygaeidae, Pentatomidae, Miridae, Reduviidae, Rhopalidae and Cydnidae (Table 2 - Supplement), while the total species richness estimates varied between 42 species (Bootstrap) and 50 species (Jackknife 2). The accumulation curves showed no plateau (Figure 1). Miridae was the richest and most abundant family, with 22 morphospecies and 76% of all individuals in this study; two morphospecies *Euchilocoris* sp. and *Neostenotus* sp. together accounted for almost half of all individuals. Eight species were singletons, and the families Rhopalidae and Cydnidae only had one morphospecies with three individuals each (Table 2 - Supplement). Combining the high number of singletons with the non-stabilized accumulation curves, we suggest there are likely more species that were not collected. Similar trends have been seen for heteropterans (Pentatomoidea) in rainforest

Table 1. Abundance, richness, and diversity of Heteroptera sampled with UV light traps over a year in three different sites at Itacolomi State Park, Southern Brazil. Values are means with standard error. Values followed by different letters in rows are significantly different based on Tukey HSD post hoc analysis.

	Spring	Summer	Fall	Winter
Abundance	17.00 ± 5.87^{b}	22.16 ± 7.58^{a}	11.70 ± 6.38^{ab}	5.43 ± 2.04^{b}
Richness	7.06 ± 2.31^{a}	7.91 ± 1.64^{a}	2.92 ± 1.04^{b}	2.80 ± 0.86^{b}
Diversity (H')	1.32 ± 0.33^{a}	1.66 ± 0.20^{a}	0.64 ± 0.22^{b}	0.78 ± 0.23^{b}
	Late Succession	**Early Succession**	**Rupestrian**	
Abundance	10.03 ± 1.90^{ab}	7.60 ± 1.82^{b}	18.07 ± 3.99^{a}	
Richness	3.92 ± 0.67	3.64 ± 0.65	5.42 ± 1.00	
Diversity (H')	0.92 ± 0.14	0.91 ± 0.14	1.05 ± 0.14	

fragments in south Brazil indicating higher sampling effort is necessary (CAMPOS et al., 2009).

Although site ($F_{2,72}$ = 0.79, P = 0.45) and the site ×season interaction ($F_{6,72}$ = 0.13, P= 0.99) were not statistically significant, richness significantly varied between seasons ($F_{3,72}$ = 4.22, P = 0.008), being higher during the Spring and Summer compared to Winter (Tukey HSD, P = 0.003; P < 0.001, respectively) and Fall (Tukey HSD, P = 0.005; P = 0.001, respectively) (Table 1). Shannon's diversity index mirrored the results for richness being significantly different between seasons ($F_{3,72}$ = 4.51, P = 0.005) (Table 1), but not between sites ($F_{2,72}$ = 0.26, P = 0.77) or in the interaction ($F_{6,72}$ = 0.36, P = 0.89). In total, 14 species were consistently collected across all seasons, and other 22 species occurred in all three sites, but overall composition was significantly different between seasons (PERMANOVA: $F_{3,66}$ = 3.96, P = 0.001) (Figure 2A) and sites (PERMANOVA: $F_{2,67}$ = 2.63, P = 0.003) (Figure 2B). Notably, of the shared morphospecies, *Banasa* sp. and *Neostenotus* sp. were sampled in all sites across all seasons (Table 2 - Supplement). We sampled heteropterans during all seasons, and abundance, richness and diversity significantly varied across them, which is established in the literature (MAY, 1979; DE PAULA and FERREIRA, 2010). The higher abundance and richness in our study occurred during Spring and Summer compared to Fall and Winter is line with de Paula and Ferreira (2010), who also observed higher numbers during the wet season and explained by the fluctuations in rain distribution and evaporation.

Heteroptera species live in association with their host plants exhibiting little flight activity. Leston (1957) and Southwood (1960) listed the families of Heteroptera in decrescent order based on their flight activity as Miridae, Lygaeidae, and then Pentatomidae. Our results are in line with those studies, with most individuals collected belonging to the family Miridae, although de Paula and Ferreira (2009) found the majority of individuals to belong to Lygaeidae in a conservation area about 80km distant from our sites. Our average number of individuals per morphospecies (26.13 ± 8.41) is also comparable with that of de Paula and Ferreira (2009) (31.00 ± 105.76), although they sampled considerably more than we did (215 vs. 28 sampling events). In addition, from the 38 morphospecies we list, 20 genera also occurred in de Paula and Ferreira (2009); when solely considering Miridae, the richest and most abundant family here and with 296 species listed for Minas Gerais state (FERREIRA et al., 2001), eight of 22 genera also occurred in Barcellos et al. (2011), a fragment of deciduous rainforest ~1,300 km distant from our sites.

Interestingly, and contrary to our prediction, the rupestrian field had the greatest species richness and abundance and the morphospecies *Allommatus* sp. only occurred there. These results may be explained by the open aspect of the site that where the trap could have been more efficient at intercepting insect flight compared to the other two sites with higher growth of trees in the canopy. Similar trends of high species richness and diversity are also seen for vegetation in the rupestrian fields in the park (GASTAUER et al., 2012), which together with at least two plant species endemic to it (BATISTA et al., 2004; DUTRA et al., 2008) justifies the declaration of the park as a local hotspot of biodiversity. Lourenco (2013) sampled Heteroptera from the canopy of trees in the rupestrian fields at the same park, but no species-level identification were made; nonetheless they also observed overall higher abundance compared to the other sites.

Despite the fact that our specimens were only identified to the genus level in most cases, this is the first study to characterize the Heteroptera fauna at Itacolomi State Park, as the park management plan did not include hemipterans (IEF, 2007). However, other studies have assessed the biodiversity of the area (GASTAUER et al., 2012; ANJOS et al., 2016; LOURENCO, 2013, DE ALMEIDA, 2013, DE SOUZA, 2010). Ultimately, advancing the study of heteropterans is important; the Pentatomidae has been indicated as a practical, informative and ecologically faithful indicator for monitoring environmental changes in the Brazilian Atlantic Forests (BROWN JR, 1997).

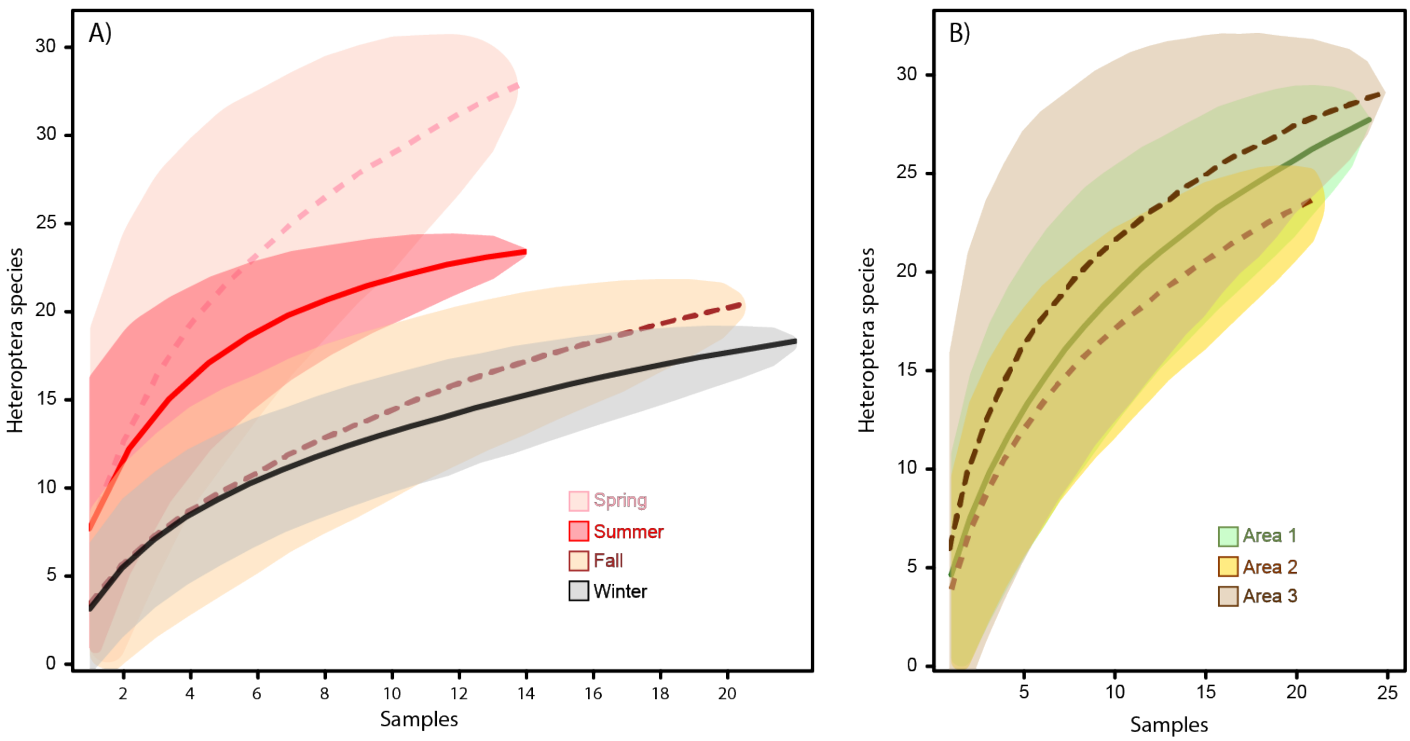

Figure 1. Species accumulation curves. A) Curves are presented for each season; B) Curves are presented for each area. Rarefied accumulation curves are plotted from means and standard deviation of 1000 permutations of samples in random order.

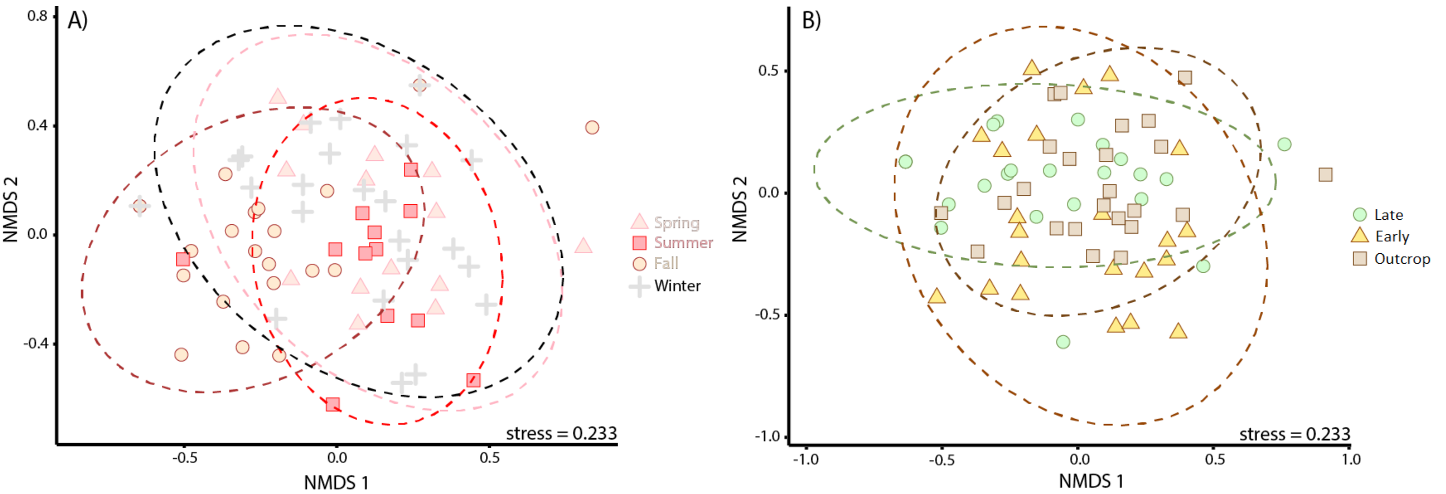

Figure 2. Compositional similarities of Heteroptera communities at Itacolomi State Park sampled over one year. A) Communities are plotted by season and B) Communities are plotted by site. Heteroptera communities are based on abundance of individual species from each sampling event. Stress = 0.233, number of dimensions (k) = 2. The ellipses indicate 95% confidence intervals.

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