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ARTICLE

Animal Ecology

Micronutrients are drivers of abundance, richness, and composition of soil insect communities in tropical rainforests

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Abstract

Communities of soil insects in tropical rainforests are among the richest and most complex, but the mechanisms structuring them remain mostly unknown. Identifying whether nutrient availability plays a relevant role in the assembly of these communities poses several challenges due to the diverse nutritional requirements of insects. We investigated the importance of nutrient availability accounting for the abundance, richness, and composition of soil insect communities in tropical rainforests. We sampled soil insects in 72 1-m^2 sampling points at two sites in French Guiana, counted all specimens, and characterized each assemblage using DNA metabarcoding. We then determined the importance of nutrient availability by measuring 19 nutrient concentrations and collected 18,000 specimens from 2634 operational taxonomic units (OTUs). Despite an extraordinary diversity and spatial heterogeneity, the concentrations of sodium, potassium, and magnesium positively correlated with either the abundance or the richness of the communities. These micronutrients were also important

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predictors of the composition of the assemblages. However, we found different relationships when analyzing the data separately for Blattodea, Coleoptera, Hemiptera, Hymenoptera, and Orthoptera, the most abundant insect orders with the most OTUs. Our results demonstrated that the availability of micronutrients played a large role in species selection during the assembly of the soil insect communities in these tropical rainforests, in contrast to the null impact of macronutrients. By accounting for the response at lower taxonomic levels, we argue that part of the unexplained variance might arise from contrastingly different responses to micronutrient availability among the most diverse orders. The high unexplained variance, however, also suggests that processes such as stochastic population drift and biotic interactions likely play complementary roles in structuring insect communities in the soils of tropical rainforests.

KEYWORDS
environmental filtering, French Guiana, insects, litter, metabarcoding, micronutrients, soil, tropical forests

INTRODUCTION

Insects and other arthropods are the most diversified lineages of metazoans on Earth, representing 70% of all known species of terrestrial animals (Mora et al., 2011), with tropical regions harboring more species of insects per hectare than any other biome on Earth (Basset et al., 2012). However, the lack of specialized taxonomic knowledge has severely limited our understanding of insect communities in the tropics (Basset et al., 2022). Even simple questions about the most basic community features, such as how many species and individuals they contain, consequently remain either unknown or uncertain at best. The recent advent of DNA metabarcoding has helped us to finally identify the richness and composition of these highly diverse communities (Basset et al., 2022). Clarifying the drivers controlling the assemblages of soil insect communities and the abundance, richness, and distribution of their species is therefore key for anticipating their responses and designing sound conservation actions.

Tropical soils are in late developmental stages, with scarce nutrient inputs coupled with a high output from plants and insects (Wright et al., 2018). Extensive research has thus found that the availability of macronutrients such as carbon, nitrogen, and phosphorus in tropical soils can limit the decomposition of leaf litter and consequently the structure of soil food webs (Kaspari et al., 2007; Sayer et al., 2010). Prior studies focusing on P addition suggest increased litter decomposition, arthropod density, and diversity (Kaspari et al., 2007; McGlynn et al., 2007; Sayer et al., 2010). Studies focusing on N addition suggest control over plant primary production and abundance losses in herbivore invertebrates (Elser et al., 2007; Kaspari et al., 2017; Kaspari & Yanoviak, 2008; LeBauer & Treseder, 2008). Recent evidence also suggests that micronutrients can amplify the impact of macronutrients, altering N fixation and decomposition (Kaspari, 2021; Langenhove et al., 2021; Wright et al., 2018). Moreover, fluxing micronutrients such as calcium, potassium, magnesium, and sodium (sensu Kaspari, 2021) often play more critical roles than P and N in shaping ground insect communities due to their involvement in osmoregulation and neural functions (Frausto da Silva & Williams, 2001; Rong et al., 2019; Yamamoto & Fujiwara, 2023).

However, insects belong to all trophic levels and have complex nutritional needs that vary across taxonomic orders. For example, studies have reported that increases in N availability can favor aphid fitness and decrease the richness of grasshoppers (Hendriks et al., 2013; Sudderth et al., 2005), and P addition can lower overall ant diversity but may favor predatory ants if combined with C, N, and P (Bujan et al., 2016; Jacquemin et al., 2012). General conclusions about soil insect communities as a whole can consequently be elusive. Identifying specific responses at finer taxonomic levels thus becomes crucial for discerning potential discrepancies among groups. While some research has been carried out including multiple environmental drivers (Hishi et al., 2022; Kaspari et al., 2017; Noguerales et al., 2023; Peguero et al., 2021), to our knowledge, none has focused on the distinct relative effect of macronutrient and micronutrient beyond NPK.

We investigated whether macronutrients and micronutrients were relevant environmental filters for assemblages of tropical soil insects. We sampled complete communities of soil insects across three topographic levels in two tropical rainforests in French Guiana. We counted and sorted all specimens by order and classified them into operational taxonomic units (OTUs) using DNA metabarcoding. We also determined the concentration of 19 macronutrients and micronutrients. We specifically evaluated whether the availabilities of macronutrients and micronutrients influenced the abundance, richness, and composition of the communities of soil insects. We specifically hypothesize that (1) macronutrients and micronutrients drive the abundance, richness, and composition of the communities of soil insects; (2) the relative impact of macronutrients will be larger than that of fluxing micronutrients (Ca, K, Mg, and Na); and (3) the impact of nutrient availability on soil insect communities can be traced back to the most diverse insect orders.

MATERIALS AND METHODS

Study sites

This study was conducted in two tropical rainforests in French Guiana at the research stations of Paracou (05°16′38″ N, 52°55′38″ W) and the Nouragues (04°04′53″ N, 52°41′13″ W). Both sites share the same climate, with a wet season from December to June and a dry season from August to November. Mean annual precipitation and temperature are similar at Paracou and the Nouragues (3102 mm and 25.7°C vs. 3000 mm and 25.2°C, respectively). The Guiana Shield has one of the lowest concentrations of soil nutrients in tropical South America (Hammond, 2005). The bedrock is Precambrian schist at Paracou and Caribbean granite and gneiss at the Nouragues. Acrisols dominate at both sites, with more extractable soil N and P at the bottom of hills and higher total nutrient concentrations in the hilltops (Langenhove et al., 2021). We established 12 plots of 0.25 ha at each site, stratified by three topographic positions to account for spatial heterogeneity (i.e., hill-tops, slopes, and hill-bottoms; with four plot replicates per topographic level). We set a central 20-m quadrat in each plot, where we marked three evenly spaced sampling points around which we carried out our measurements. This design thus contained a total of 72 sampling points (2 sites × 3 topographic positions × 4 replicate plots per position × 3 sampling points in each plot).

Nutrient variables

We compiled data for 19 variables describing the total nutrient concentrations and ratios in the soil and litter compartments (Appendix S1: Table S1). We collected three randomized soil cores (4 cm in diameter and 15 cm deep) at each sampling point. These three cores were combined as a single composite sample, forming one sample per sampling point. Litter samples for nutrient analysis were collected at each sampling point within a randomly placed 20 cm square of polyvinyl chloride (PVC). We then determined the concentrations of macronutrients and micronutrients (carbon [C], N, P, calcium [Ca], magnesium [Mg], potassium [K], and sodium [Na]) in the litter and soil for each sampling (see Urbina et al., 2021 for methodological details). We also derived the C:N, C:P, and N:P ratios due to their relevance to nutrient cycling. Finally, nutrient data at the sampling level were summed up at the plot level.

Taxa sampling

We sampled the soil hexapod communities at the end of the dry season in 2015. The hexapod communities were sampled from the litter surrounding three sampling points per plot. We collected all litter inside four randomly placed 0.25 m^2 PVC frames and sifted it through a Winkler bag with a 0.7-cm mesh, manually catching all escaping macrofauna. The sifted litter was hung in Moczarsky traps for 48 h and was then carefully inspected in white plastic trays, and any remaining specimens were captured using entomological aspirators. The bulk communities were stored in 70% ethanol. Before the molecular analyses, we classified and counted all specimens into order level using stereomicroscopes. We focused only on specimens belonging to Hexapoda (i.e., classes Insecta and Entognatha *s.l.*) for our molecular analyses. We will, however, refer to all of them as insects for simplicity.

Molecular analyses

The communities of soil insects were characterized to OTUs using DNA metabarcoding as in Peguero et al. (2022). See Appendix S1: Section S1: Molecular analyses for detailed information on the laboratory procedures. The resulting OTU table had a total of 2634 OTUs and 14,000 reads. We built community matrices of the metabarcoded OTUs at the plot level, aggregating the sampling point data in each plot, thus leading to 24 characterized communities.

Data analyses

We partitioned total β-diversity (Sørensen index) into its turnover (Simpson index) for each sampling scale (either point-level or plot-level community matrices) using the betapart package (Baselga & Orme, 2012) to quantify the compositional dissimilarities between sampling units and sites. Site and topography did not drive richness (with the sole exception of Hemiptera's abundances between sites; see Appendix S1: Tables S2 and S3), and as a result, we did not set either as a random effect term. Nutrient impact on abundance and richness was assessed using general linear models (GLMs). Normal distribution was selected over other alternatives in all models based on Shapiro–Wilks tests of normality, and we assessed the model-data fit using Akaike information criterion. Due to a high read variability between samples (Figure 1a) and to avoid the potential impact of laboratory artifacts, richness estimates were based on rarefied communities following hill number $q = 0$ (Hsieh et al., 2024). All nutrient variables were standardized to z-scores (zero mean and unit variance) to remove the original measurement units and scales before modeling, easing the interpretation and helping to address multicollinearity (Borcard et al., 2011). Variable selection for compositional dissimilarities of the plot-level community matrices was done using variance inflation factors (VIFs) due to multicollinearity. The significance of constraining variables was assessed using permutation tests for canonical correlation analysis (CCA) with marginal effects of terms and 999 permutations, and we used CCA-based ANOVAs for model inference. We used CCA to focus on species composition rather than abundances and to account for potential unimodal responses to nutrients (Ter Braak & Smilauer, 1998). We ultimately selected the most diverse orders (i.e., those with >100 OTUs in total) and repeated all analyses for Blattodea, Coleoptera, Hemiptera, Hymenoptera, and Orthoptera. All data handling, visualization, and statistical analyses were carried out using R v4.0.6 (R Core Team, 2020).

RESULTS

Abundance and richness of the soil insect communities

We collected 18,070 specimens belonging to 17 orders, with an average density of 262 individuals/m^2. We identified a total of 2634 OTUs from class Hexapoda, with an estimated turnover of 0.98 OTU/m^2, and densities of up to 60 OTUs/m^2 (Figure 1; Appendix S1: Figure S1). Orders with more than >100 OTUs were Blattodea (28.5% of all OTUs), Hymenoptera (19.7%), Coleoptera (12.6%), Orthoptera (10.9%), and Hemiptera (6.2%) (see Figure 1b,d for mean rarefied OTU estimates and composition per square meter). The remaining orders were Entomobryomorpha, Trichoptera, Neuroptera, Diptera, Dermaptera, Psocoptera, Lepidoptera, Thysanoptera, Diplura, Poduromorpha, Embioptera, and Mantodea. Despite the large number of OTUs, the curves of species accumulation had no asymptote (Appendix S1: Figure S1), suggesting undersampling.

Response of soil insect communities to soil nutrient availability

The concentration of soil Na increased the abundance of Hexapoda, Blattodea, and Hymenoptera (Table 1, Figure 2), while litter Mg also increased the abundance of Blattodea. However, macronutrients had no impact on soil hexapods, except that of soil C leading to a decrease in Hemiptera abundance. Similarly, micronutrients drove the number of OTUs, but macronutrients did not. The richness of Hexapoda, Blattodea, Hymenoptera, and Orthoptera significantly increased with the concentration of K (Table 1, Figure 2). Litter Ca also increased the richness of Blattodea and Orthoptera, while soil Na increased Hymenoptera richness. But unlike the aforementioned nutrients, litter Mg and Litter Na decreased the OTU richness of Orthoptera. All significant correlations had low to moderate effect sizes with $R^2 = 0.21 \pm 0.06$, with the latter impact on Orthoptera having the largest explained variance with 0.38 and 0.33 for litter Mg and litter Na, respectively (Table 1, Figure 2).

The composition of soil insect communities was driven by macronutrients and micronutrients (Table 2, Figure 3). But macronutrients only caused compositional shifts through litter C over Hymenoptera and Orthoptera taxa. On the other hand, multiple micronutrients drove the composition of Hexapoda and the main orders. Litter Ca caused compositional shifts in Coleoptera, Hymenoptera, and Orthoptera; K availability drove the OTU composition of Hexapoda, Coleoptera, and Hymenoptera; litter Na drove Hexapoda and Orthoptera composition; and litter Mg led to compositional shifts in Hexapoda and Hymenoptera. In contrast, the compositions of the Blattodea and Hemiptera communities were not driven by nutrient variables.

DISCUSSION

Our results suggest that micronutrient availability is a multivariate environmental feature that plays a relevant role in species selection during the assembly of the communities of soil insects in the tropical rainforests. The availabilities of Na and K, and to a lower extent of Mg and Ca, were correlated with the abundance, richness,

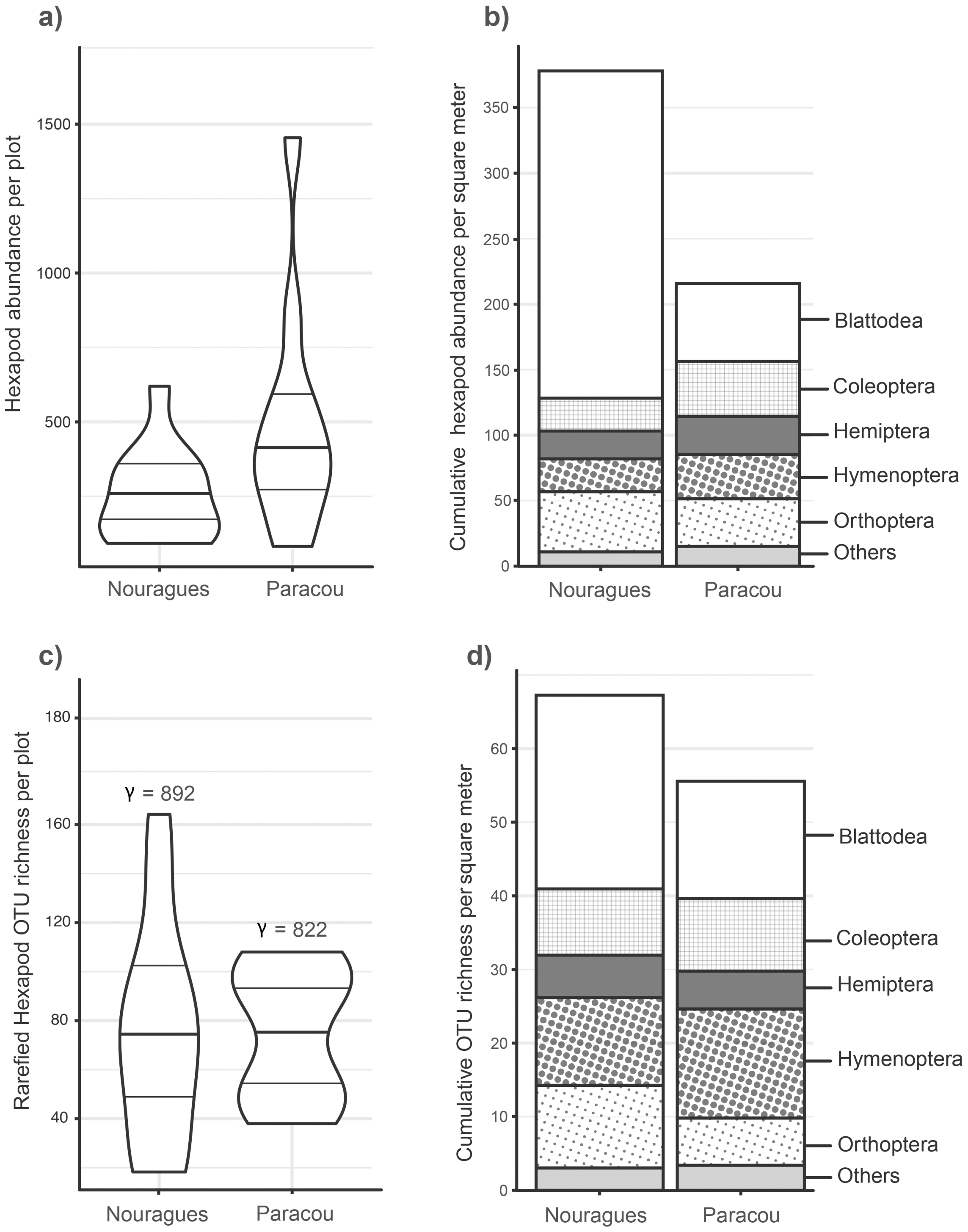

FIGURE 1 (a) Distribution of the abundance (number of specimens) of Hexapoda per plot. (b) Total abundance (in number of specimens) per square meter by order. (c) Distribution of richness (in number of operational taxonomic units [OTUs]) per plot. (d) Total species richness per square meter by order. γ indicates the total pool of OTUs identified at each site (γ-diversity).

and composition of the communities, with varying degrees of effect size among the most diverse orders. In contrast to micronutrients, the soil or litter concentrations of macronutrients such as C, N, and P, typically the main limiting elements in tropical rainforests, were not as important drivers of the soil insects in the communities as they are for plants and microbes (Peguero et al., 2022, 2023; Vallicrosa et al., 2023). These findings agree with long-term experiments of micronutrient addition eliciting the largest responses of soil invertebrates in tropical rainforests (Kaspari et al., 2017). Ecological stoichiometry deals with the balance of

TABLE 1 Relationships between community richness, abundance, and the concentrations of soil nutrients in the Hexapoda and the main orders in Insecta.

Taxon	Nutrient	Estimate	*F*	*p*	Adjusted R^2
Abundance					
Hexapoda (df = 21)	Soil Na	146 ± 59.1	6.16	0.02	0.19
Blattodea (df = 20)	Litter Mg	50.2 ± 22.06	5.19	0.03	0.16
	Soil Na	51.7 ± 19.41	7.10	0.01	0.22
Coleoptera (df = 21)	Soil Na	5.84 ± 2.94	1.98	0.06	0.11
Hemiptera (df = 20)	Litter C	−4.74 ± 2.61	3.29	0.08	0.09
	Soil C	−5.29 ± 2.17	5.93	0.02	0.19
	Litter K	−4.22 ± 2.30	3.36	0.08	0.10
	Soil Mg	4.39 ± 2.25	3.80	0.05	0.11
	Soil N	−4.68 ± 2.28	4.20	0.05	0.13
Hymenoptera (df = 21)	Soil C	−68.6 ± 37.8	3.27	0.08	0.09
	Soil Na	81.5 ± 36.6	4.94	0.03	0.15
	Soil P	−70 ± 37.7	3.44	0.07	0.10
Orthoptera (df = 13)	Soil C	1.10 ± 0.60	3.30	0.09	0.14
	Litter Ca	1.29 ± 0.63	4.08	0.06	0.18
Richness					
Hexapoda (df = 21)	Litter Ca	14.1 ± 7.43	3.61	0.07	0.10
	Litter K	13.3 ± 7.50	3.16	0.08	0.08
	Soil K	17.2 ± 7.12	5.83	0.02	0.18
	Soil Na	13.0 ± 7.53	2.99	0.09	0.08
	Soil P	−14.8 ± 7.37	4.04	0.05	0.12
Blattodea (df = 19)	Litter Ca	18.3 ± 7.50	5.98	0.02	0.19
	Litter K	18.3 ± 7.50	5.98	0.02	0.19
	Soil K	16.2 ± 7.75	4.40	0.04	0.14
Coleoptera (df = 19)	Litter Ca	5.26 ± 2.80	3.53	0.07	0.11
Hymenoptera (df = 21)	Soil K	9.54 ± 3.09	9.50	0.005	0.27
	Soil Mg	6.30 ± 3.46	3.31	0.08	0.09
	Soil Na	9.55 ± 3.09	9.53	0.005	0.27
Orthoptera (df = 18)	Litter Ca	9.77 ± 3.89	6.28	0.02	0.21
	Litter K	9.44 ± 3.94	5.74	0.02	0.19
	Litter Mg	−12.3 ± 3.45	12.8	0.002	0.38
	Litter Na	−11.6 ± 3.59	10.5	0.004	0.33

Note: Results from generalized linear mixed models, with the abundance (in number of specimens per plot) richness (in rarefied number of operational taxonomic units per plot) of each community as response variables modeled against soil nutrient concentrations as single covariates. All nutrient variables were standardized to z scores (zero mean and unit variance) due to the different units and scales and to ease the interpretation and comparability of different model outputs. Mean estimates of effect are followed by their SEs. *F* statistic numerators are 1 for all models, and denominators are equivalent to the model's df.

multiple chemicals in ecological interactions and processes (Sterner & Elser, 2002). This theory has been built upon the observed variation and strong constraints imposed by C:N:P ratios on organisms and ecosystems. Our results, however, highlight the need to extend this theoretical framework to the entire elementome of species, thereby including the multidimensionality of the biogeochemical niche of species (Kaspari, 2021; Peñuelas et al., 2019). This need is particularly crucial for understanding the ecology of soil fauna, due to the importance of several micronutrients in their elementomes (Warnke et al., 2023; Zhang et al., 2022).

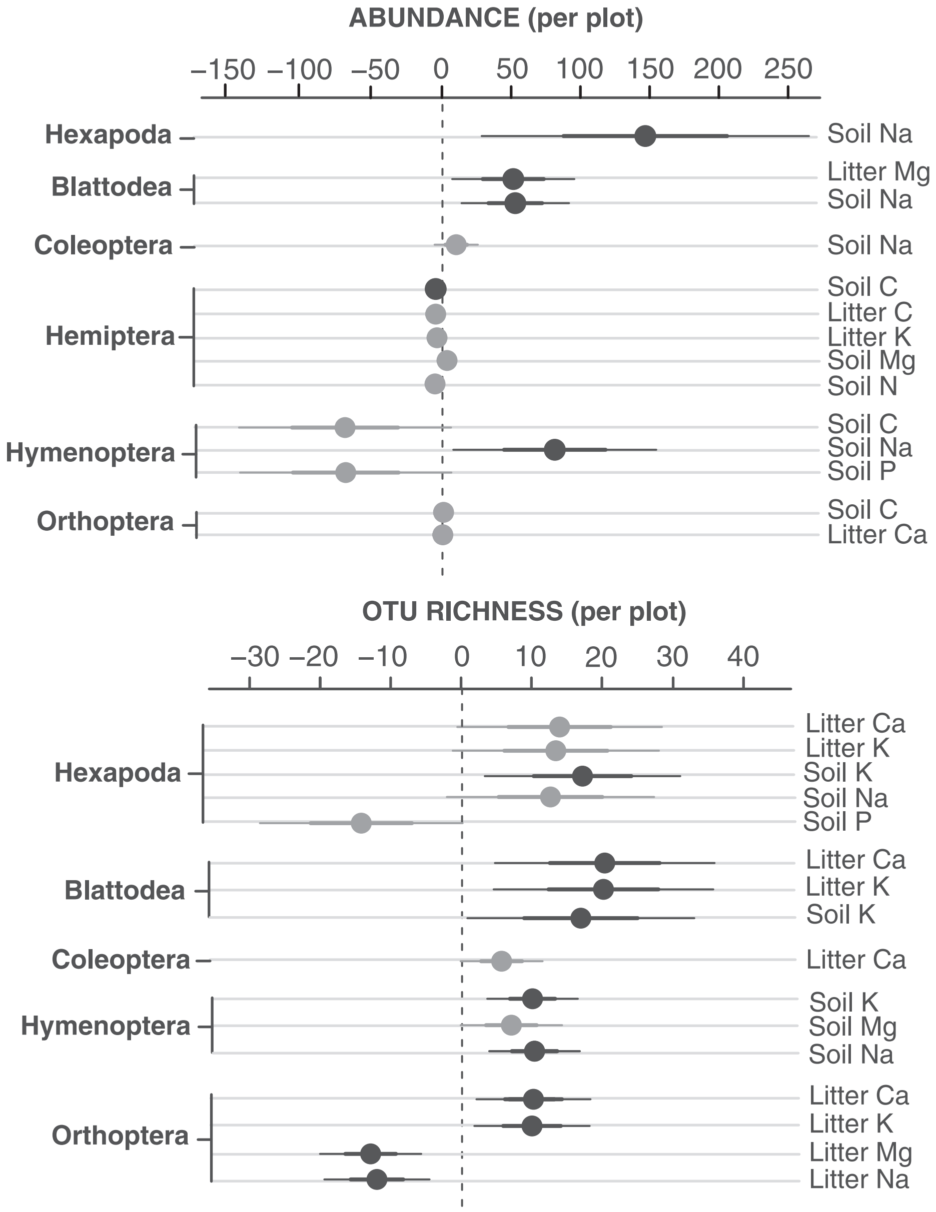

FIGURE 2 Results from coefficient plots from general linear models, with abundances (in number of specimens per plot) and richness (in number of rarefied operational taxonomic units [OTUs] per plot) of community as response variables modeled against soil nutrient concentration as single covariates. All nutrient variables were standardized to z scores (zero mean and unit variance) due to the different units and scales, and to ease interpretation and comparability of different model outputs. The gray coefficient plots indicate nonsignificant regressions ($p \geq 0.05$), and the black coefficient plots indicate significant regressions ($p < 0.05$) (see Table 1 for complete outputs).

The metabolism of all animals depends on the proper functioning of the several kinds of ion pumps in the membranes of their cells. The higher Na concentration in animal tissue than in leaf litter suggests that Na may be a limiting nutrient for soil fauna (Kaspari, 2021), and while Na is highly mobile, it is also known to enhance litter decomposition and accumulate in fungal fruiting bodies, thus attracting insect microbivores and fungivores (Kaspari et al., 2014; Schowalter, 2006). Moreover, Na-K pumping activity accounts for 25%–75% of the entire ATPase energetic budget of an animal cell (Frausto da Silva & Williams, 2001), regulating the cellular volume, the electrochemical potential, and glycolysis. The correlation between K availability and the richness of OTUs in the soil is consistent with K also being a limiting nutrient for soil insect communities; in fact, Na and K are highly soluble so their continuous fluxing across membranes makes them prone to loss (Kaspari, 2021). Mg is also an important element for osmoregulation, excretion, and both nervous and motor systems (Kaspari, 2021). Cuticle biomineralization is not common within Insecta, but recent findings suggest that Mg may play a role in the

TABLE 2 Relationships between community composition and the concentrations of soil nutrients in the subphylum Hexapoda and the main orders in the class Insecta.

Taxa	Environmental variable	χ^2	F	p
Hexapoda (df = 15)	Litter C	0.87	0.98	0.73
	Litter C:N ratio	0.89	1.00	0.22
	Soil C:N ratio	0.89	1.00	0.23
	Litter Ca	0.91	1.02	0.05
	Litter K	0.90	1.02	0.02
	Litter Mg	0.92	1.03	0.01
	Litter Na	0.90	1.02	0.02
Coleoptera (df = 13)	Litter C	0.91	1.01	0.32
	Soil C:N ratio	0.93	1.03	0.09
	Litter Ca	0.95	1.05	0.02
	Litter K	0.90	1.00	0.26
	Soil K	0.95	1.04	0.03
	Soil Mg	0.87	0.96	0.65
	Litter Na	0.93	1.03	0.06
	Soil Na	0.90	0.99	0.36
Hymenoptera (df = 13)	Litter C	0.89	1.09	0.009
	Soil C:N ratio	0.84	1.03	0.38
	Litter Ca	0.87	1.07	0.042
	Litter K	0.92	1.12	0.001
	Litter Mg	0.93	1.13	0.001
	Litter Na	0.85	1.04	0.113
Orthoptera (df = 17)	Litter C	0.94	1.12	0.002
	Soil C:N ratio	0.84	1.00	0.42
	Litter Ca	0.92	1.10	0.019
	Litter Na	0.93	1.11	0.007

Note: Results from models of canonical correlation analyses (CCAs) for the marginal effects of terms and 999 permutations, based on the first CCA axis. All nutrient variables were standardized to z scores (zero mean and unit variance) due to the different units and scales and were selected based on variance inflation factors (VIFs). Variable selection for compositional dissimilarities of the plot-level community matrices was done using VIFs due to multicollinearity. The significance of constraining variables was assessed using permutation tests for CCA with marginal effects of terms and 999 permutations, and we used CCA-based ANOVAs for model inference. Significance of the first CCA axis is $p = 0.008$, 0.03, 0.003, and 0.03 for Hexapoda, Coleoptera, Hymenoptera, and Orthoptera, respectively.

sclerotization of the pupal cuticle in holometabolan groups (Rong et al., 2019; Yamamoto & Fujiwara, 2023). Previous research also shows that Mg and Ca can drive K biochemical cycling, as the cations Ca^{2+} and Mg^{2+} directly compete with K^+ on adsorption sites and inhibit K^+ plant uptake (Han et al., 2019; Otieno et al., 2018; Ouimet et al., 1996). If so, the impact of K on soil insects might be larger than previously discussed, and the responses to Ca and Mg might be a proxy of K availability.

Moreover, given the complex response of insects to environmental filtering, research also implies taxon-specific responses. A couple of micronutrients lead to similar responses between Hexapoda and the studied orders. Na availability increased the abundance of Hexapoda, Blattodea, and Hymenoptera, corroborating previous studies already reporting intensive Na foraging in ants (Arcila Hernández et al., 2012). K availability increased the richness of Hexapoda, Blattodea, Hymenoptera, and Orthoptera, with prior studies arguing that the dry season increases K allocation in leaves, favoring chewing herbivores such as grasshoppers and leafcutting ants (Jobbágy & Jackson, 2001; Stone & Kszystyniak, 1977). However, despite these similarities, the responses of Hexapoda and the studied orders remain otherwise quite different while reporting similar effect sizes. For instance, our results suggest that other nutrients like Mg and C also drive the abundances

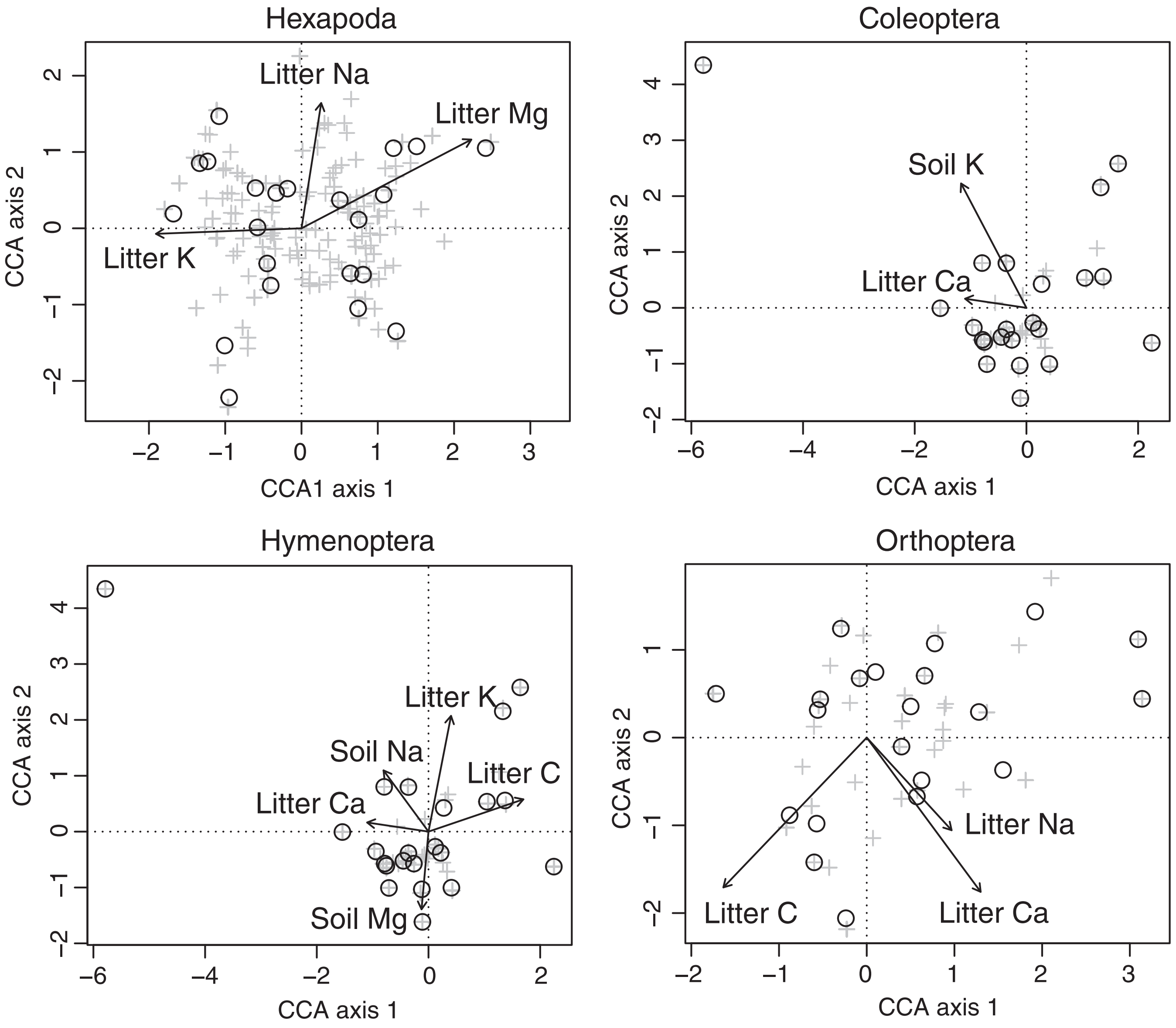

FIGURE 3 Canonical correspondence analyses (CCA) of Hexapoda, Coleoptera, Hymenoptera, and Orthoptera, with standardized nutrient concentrations in the litter or soil pools as environmental predictors. Only significant variables are shown. Significance of the first CCA axis is $p = 0.008$, 0.03, 0.003, and 0.03; for Hexapoda, Coleoptera, Hymenoptera, and Orthoptera, respectively. CCA axis 2 was never significant with $p = 0.98$, 0.92, 0.34, and 0.36 for Hexapoda, Coleoptera, Hymenoptera, and Orthoptera, respectively. The crosses and circles indicate samples and plots, respectively. For coefficient plots and CCA, nutrient variables were standardized to z scores (zero mean and unit variance) due to the different units and scales, and to ease interpretation and comparability of different model outputs.

of orders such as Blattodea and Hemiptera, while micronutrients such as Ca, Na, and Mg also cause richness increases and losses among Blattodea, Hymenoptera, and Orthoptera. In fact, the compositional shifts caused by nutrient availability further exemplify the complex dissimilarities between the response of Hexapoda and that of Coleoptera, Hymenoptera, and Orthoptera. Hexapoda's OTU composition is driven by Na, Mg, and K, and while the impact of these micronutrients can also be found in Hymenoptera and to a lesser extent in Coleoptera and Orthoptera, all three orders show particular responses to nutrient fluctuation (e.g., Ca). Therefore, beyond general assertions about the overall soil insect community, it is important to further explore the underlying responses at lower taxonomic scales, recognizing the affected taxa and the potential differences between groups.

Our results also contrast with other studies that have found a more modest contribution of the nutrient environment on the assembly of soil insect communities (Peguero et al., 2022; Zinger et al., 2018). This discrepancy may likely be due to the aggregation of several abiotic variables (e.g., nutrient Euclidean distances in Peguero et al., 2022) to describe the environmental variability among sites, which may mask the importance of individual nutrient variables with low concentrations. The putative filtering exerted by micronutrient availability, however, only explained a portion of abundance, richness, and compositional variability. The high amount of unexplained variance suggests that processes such as stochastic population drift and biotic interactions may also play a role in structuring insect communities in the soils of tropical rainforests (Peguero et al., 2022; Zinger et al., 2018). By accounting for the response at lower taxonomic levels, we showcase the diversity of responses to nutrient availability, suggesting that part of the unexplained variance might arise from contrastingly different responses to micronutrient availability among the most diverse orders. Distinguishing between the importance of antagonistic biotic interactions, such as predation and competition, and neutral processes, such as stochastic population drift and dispersal limitation, as well as the purely abiotic sorting of species, would require a different approach. This approach should probably combine experimental methods with a focus on narrower taxonomic groups such as order-level analyses.

POSITIONALITY STATEMENT

The authors of this paper all completed undergraduate degrees at institutions in formerly colonizer nations in the so-called Global North before undertaking research positions at northern and southern universities. Being aware of multiple shapings of race, gender, and class, among others, we acknowledge the difficulty of writing about tropical ecology with most authors having no cultural or political connections to indigenous perspectives. We posit ourselves against neocolonial science, while admitting the colonial privilege allowing us to do research in French Guiana. This position is not a fix to centuries of violence but rather a contribution to an ongoing discussion (Baker et al., 2019).

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data (Ferrín Guardiola, 2024) are available from Figshare: https://doi.org/10.6084/m9.figshare.26233508.v2.

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