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ORIGINAL ARTICLE

Sampling local ant diversities and the importance of trait analyses

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Abstract

Ants are an incredibly diverse and ubiquitous group of invertebrates in most terrestrial ecosystems. Although extensively sampled, the majority of ant inventories do not evaluate the effect of different sampling techniques in capturing nontraditional metrics of diversity. We aimed to quantify TD (taxonomic) and FD (functional) diversities for a local ant assemblage by integrating metrics and evaluating complementarity of pitfall traps and Winkler extractors for the leaf litter versus epigeic ant faunas and to determine the effect of sampling techniques on functional composition (community-weighted means of 11 morphological traits) and functional diversity (multi-trait morphospace measured with three different metrics). We sampled the local community in an Atlantic Forest fragment using week-long pitfall traps and $1m^2$ leaf litter samples submitted to Winkler extractors and quantified the contribution on the technique to uniquely capture the ant morphospace by applying a new index (*PWindex*). Although ant TD overlapped, FD was significantly affected by the sampling technique. By controlling for TD effects, the community collected by each technique was differentially structured. Higher TD did not translate into wider morphospace for Winklers. Pitfalls recovered more functionally overdispersed assemblages. Pitfalls and Winklers overlapped in the sampling of the overall community, but each sampling method contributed with a unique spectrum to the ant morphospace. Our results suggest the importance of incorporating FD metrics in local ant inventories and the importance of sampling techniques when measuring the magnitude of FD and community structure. Our *PWindex* further illuminates sampling effects for ant assemblages.

Abstract in Portuguese & Spanish is available with online material.

KEYWORDS
complementarity, Formicidae, functional diversity, local assemblage, morphospace, pitfall trap, sampling method, Winkler extractor

1 | INTRODUCTION

Community ecologists have increasingly begun quantifying biodiversity variables within assemblages, spanning smallest to largest spatial scales (Pollock et al., 2020). While the most commonly measured variable of biodiversity is species richness (=taxonomic diversity (TD)), measuring biodiversity solely in TD terms disregards morphophysiological and ecological attributes (herein "traits") that contribute to specific ecological functions (=functional diversity (FD)) (McGill et al., 2006). The exploration of TD to FD relationships can facilitate our understanding of community-assembly rules and the degree of functional redundancy or complementarity among organisms. Plus, it can help researchers to select the best sampling methodology when estimating FD.

When considering ideal taxa for addressing trait-based questions, arthropods might be unmatched in their taxonomic and ecological diversities (Stork, 2017; Wong et al., 2019). Arthropods are ubiquitous terrestrial organisms, providing numerous ecosystem processes and services (Losey & Vaughan, 2006). Hence, trait-based research on terrestrial arthropods can illuminate our understanding of processes generating and maintaining diversities across different spatial scales. With numerous sampling methods available for those researching terrestrial arthropods (Coddington et al., 2009), the interpretation of a community's functional structure might be influenced by dominant traits detected in different sampling methods. However, trait detection on FD interpretation for arthropod assemblages and their link to sampling method is rarely acknowledged or addressed in most trait-based studies.

With a considerable portion of its diversity living in the leaf litter or epigeic stratum, pitfalls traps (pitfalls) and Winkler extractors (Winklers) are commonly applied sampling methods for terrestrial arthropods (Sabu et al., 2011). Within arthropods, ants are taxonomic, ecologically and morphologically diverse (Del Toro et al., 2012; Drager et al., 2023; Sosiak & Barden, 2020), making them an ideal group to study TD–FD effects. Similar to what observed for terrestrial arthropods, pitfalls and Winklers are extensively employed to sample ants (Agosti et al., 2000). The complementarity between those techniques is somewhat known for species composition, with pitfalls and Winklers favoring the collection of epigeic and leaf litter assemblages, respectively (e.g., Ivanov & Keiper, 2009; Olson, 1991; Wiezik et al., 2015). Therefore, sampling technique and protocol might constrain ant TD studies—further influencing the measurement of ant FD at different spatial scales. Recently, we have observed an increase in studies comparing ant functional space (=morphospace) captured using those two techniques (e.g., Lee & Guénard, 2019; Rocha-Ortega et al., 2017; Salata et al., 2020). Results show that Winklers and pitfalls might capture contrasting faunal components, with characteristic morphospaces directly related to soil/litter versus aboveground lifestyles. Surprisingly, despite this recent surge in implementing FD metrics for ant assemblages, little is known about bias effects when sampling ant FD with pitfalls and Winklers and FD structure when accounting for species richness (i.e., TD) effects. A better knowledge of the complementarity effect of pitfall traps and Winkler extractors at the local scale is desired, specifically considering the importance the myrmecofauna has as a proxy for disturbance impact (Majer et al., 2007) and the link between ant species and ecosystem functions (Elizalde et al., 2020). Here we aim to understand how Winkler and pitfall sampling method influences our understanding of local assemblage's functional structure and the complementarity effect of pitfalls and Winklers when species' relative abundances and TD effects are considered. We selected 11 morphological traits—10 previously hypothesized to relate to ant functional ecology—to evaluate the volume of morphological space and measured specimens from 115 different ant taxa to address the following questions: How similar/dissimilar is the functional (=morphological) space recovered when applying different sampling techniques? How do different functional metrics respond to pitfall versus Winkler sampling? What is the structure of the ant morphological space recorded in the local scale with two of the most utilized sampling techniques? We further included season in the functional analyses because ant biology can strongly be affected by it, and so could functional diversity (e.g., Castro et al., 2020; Mahon et al., 2017; Neves et al., 2021). By investigating local scale ants' functional structure with two widely used sampling methods, we hope to contribute information to a rapidly growing body of trait-based research.

2 | METHODS

2.1 | Study site and protocol

The present study was carried out between February and July 2011 in the State Park of Xixová-Japuí (PEXJ), a 901 ha (600 ha land) Atlantic Forest fragment located in the municipalities of Praia Grande and São Vicente, Southeast Brazil (23°59′ S 46°23′ W).

Three areas were selected inside the PEXJ, based on vegetational descriptions for that conservation unit (SÃO PAULO, 2010): trail edges, patches of secondary forest in an advanced degree of regeneration (>70 years), and patches covered by secondary forest in an intermediate degree of regeneration (around 35 years). Areas with advanced degree of regeneration were either located close to hilltops, in which access was difficult, or associated to controlled access—only researchers allowed on those areas; their vegetational predominantly composed of an arboreal physiognomy and a characteristic middle stratum, with few lianas and epiphytes and with the presence of palm trees. Areas with intermediate degree of regeneration were characterized by more significantly impoverished vegetational composition, with the presence of exotic and pioneer species, and many access trails. Based on the size of the fragment and the ant's dispersal abilities, we assumed that the same species pool could be present in the different areas selected inside the PEXJ. With that assumption, our goal was to design an intensive sampling protocol at the local scale to ensure a comprehensive account of the local species pool. At each area, we established two transects of 100 m (distant 100 m) with 10 equidistant sampling points. Each sampling point consisted of a pitfall trap filled with a mixture of detergent-saline solution that remained in the field for 7 days (=168 h). The material in the pitfall was collected after 7 days.

Additionally, five 1 m^2 leaf litter samples were collected in each transect (with the transect established in one of the trail edges being the only exception as leaf litter was absent). Sampling followed transect orientation; every 20 m we selected sampling points based on evaluation of the leaf litter structure at both transect sides. Leaf litter was vigorously sifted through a sieve of 1 cm grid size, and the sifted material submitted to Winklers for 48 h, sorted every 8 h. We used a total of 120 pitfalls and 60 Winklers and sampled on summer and winter, accounting for seasonality effects.

2.2 | Morphological data

Samples were sorted, and individuals from all morphospecies were mounted and identified by comparing specimens with the pinned ant collection from the MZSP and with the aid of species-level taxonomic keys for some of the ant genera when needed (e.g., *Acromyrmex* (Gonçalves, 1961); *Apterostigma* (Lattke, 1997), *Gnamptogenys* (Camacho et al., 2020), *Oxyepoecus* (Albuquerque & Brandão, 2009); *Strumigenys* (Bolton, 2000)). Morphospecies codes were assigned for undescribed species. The voucher material is deposited in the Hymenoptera collection at the MZSP. We included measurements for all ant species/morphospecies collected in the PEXJ in our matrix of morphological traits. To quantify FD for each sample, we selected 11 continuous morphological characters associated with various aspects of ant ecology (see Table S1 for the morphometric definition of each trait). These traits have been recognized in previous studies involving ant FD and related to dietary preferences and trophic position, habitat usage, and foraging strategies for different ant functional groups (e.g., Arnan et al., 2014; Drager et al., 2023; Gibb et al., 2015; Silva & Brandão, 2010, 2014; Yates et al., 2014). All linear measurements (recorded to the nearest 0.001 mm) were conducted on point-mounted specimens using an ocular micrometer attached to a Leica MZ95 with a maximum magnification of 60× and a 1.0× Plan Apo as the main objective. Only measurements of minor-caste workers were included in this study to avoid the influence of strong allometric variation in our analyses.

2.3 | Analysis

2.3.1 | Taxonomic diversity

We generated rarefaction-extrapolation accumulation curves with the R package "iNEXT" to assess inventory completeness (as measured by sample coverage) with respect to sample size (Hsieh et al., 2020). We compared observed species richness (*Sobs*) between treatments (pitfalls, Winklers, methods combined) for summer and winter seasons using ANOVA.

2.3.2 | Traits

Measurements of the collected assemblage were standardized by Weber's length to remove body size correlation with other morphological traits. Mean trait values were log-transformed to improve normality as is routinely done in studies of ant continuous morphological characters (Martello et al., 2018; Silva & Brandão, 2010, 2014; Yates et al., 2014). Morphological structure was described with a principal component analysis (PCA) performed on a correlation matrix of the 11 log-transformed morphological variables measured for all ant species collected. The PCA was computed using the *prcomp* function from the R "stats" package (Oksanen et al., 2019).

Because assemblage composition differences might be related to variation in trait composition, we calculated community-weighted means for each trait (CWM; mean trait value for all species in the community weighted by their relative abundances) (Cornell & Ackerly, 2009), with the number of samples each ant species was recorded (i.e., frequency) as the species abundance matrix. Frequency of occurrence was used as a proxy of abundance due to the heterogeneous use of space displayed by ants, and colony-modularity that can induce artificially high abundance of ant species in single traps (Ellison et al., 2007; Gotelli et al., 2011).

We computed three multi-trait metrics based on continuous methods to describe functional diversity components (richness, dispersion, and regularity) (see also Table S2F–D; hereafter FD_{PG} (Petchey & Gaston, 2002), computed using the *treedive* function in the "vegan" (Oksanen et al., 2019)), Rao's quadratic entropy (Rao Q, using the *rao. diversity* in the "SYNCSA" (Debastiani & Pillar, 2012)) (Rao, 1982; Ricotta & Moretti, 2011), and functional mean nearest taxon distance (MNTD, using the *mntd* function in the "picante" (Kembel et al., 2010)) (de Bello et al., 2021). FD_{PG} is generated from a functional traits distance matrix, being the sum of branch lengths in the dendrogram, and represents the functional complementarity among species (Petchey & Gaston, 2002). Rao Q is defined as a measure of diversity of ecological communities (Rao, 1982) based on the proportion of species abundances in a community and some measure of dissimilarity among them (Rao, 1982; Ricotta & Moretti, 2011). Finally, the MNTD index corresponds to the average distance between the most (functionally) similar pairs of species in the community (Swenson, 2014; Webb, 2000). MNTD index does not consider all the dissimilarities between all pairs of species in a sample, but computes a mean dissimilarity between closer species (the neighbors; de Bello et al., 2021). During our first data exploration, we detected a significant correlation between FD_{PG} and MNTD and *Sobs* at the transect scale. Therefore, we used standardized effect sizes (SES; Gotelli & Mccabe, 2002) to express the morphological structure of FD_{PG} and MNTD, and morphological clustering or overdispersion are indicated by positive or negative values of these indices, respectively (additional null model details in Table S2).

We tested differences in CWM values, *Sobs*, FD, and the interaction between predictors for the sampling techniques using two-way ANOVA models: response variables were CWMs, *Sobs*, and FD metrics at the transect scale; sampling techniques and season as predictor variables. Because season had no effect on CWM values and those followed non-normal distributions, we performed Wilcoxon sample tests to investigate CWM differences between pitfalls and Winklers. Normality was tested using a Shapiro–Wilk test on ANOVA residuals plus separate tests for groups of observations. All statistical analyses were carried out in the software R version 4.2.1 (R Core Team, 2022), using the abovementioned packages. Figures were either produced by those packages or using ggplot2 (Wickham, 2016).

2.3.3 | Species-specific contribution ratio (*PWindex*)

We developed a new index (*PWindex*) to measure the contribution ratio of each technique in capturing the species (i.e., from the total records a species was sampled, how often it was collected with either pitfalls or Winklers), using relative frequency (number of occurrences/total number of samples for each method). We calculated the contribution ratio of sampling method for all species as,

$$PW_{index} = \left(\frac{2 * freq_{Pn}}{freq_{Pn} + freq_{Wn}}\right) - 1$$

with $freq_{Pn}$ as number of occurrences collected with pitfalls and $freq_{Wn}$ with Winklers, ranging from −1 to +1 for species unique to Winklers and pitfalls, respectively. Therefore, species whose values are close to 0 would indicate that pitfall and Winkler are similarly contributing with the ratio of number of occurrences.

3 | RESULTS

3.1 | Taxonomic diversity

We collected 115 ant species, 94 with Winklers and 82 with pitfalls (Table S3). Fifty-nine species were collected with both techniques, 23 unique to pitfalls and 33 to Winklers. We collected a similar number of species in the summer (97) and winter (93) seasons with techniques combined. Accumulation curves suggest our sampling protocol covered most of the local assemblage (Figure S1, Table S6). The high sample completeness was found for the cumulative effect of Winklers (independent of season) (sample coverage = 0.974, *Sobs* = 92), followed by cumulative effect of pitfalls (0.956, 82). Values for sample completeness (seasonality included) were similar per technique (Tables S5–S7). We found a significant effect of both sampling method ($F_{1,19} = 22.78$, $p = .0001$) and season ($F_{1,19} = 7.49$, $p = .0131$); ant TD was significantly higher in Winklers than pitfalls and in the summer versus winter (Figure S1, Tables S5–S7).

3.2 | Functional diversity

We measured 536 ant workers for our morphological matrix, with a minimum of six conspecific individuals whenever possible (see Table S4 for details).

We found a significant effect of sampling method on FD (Figure 1; Table S7). Season was significant for TD and FD_{PG}. The leaf litter fauna showed significantly higher FD_{PG} than the epigeic fauna (Figure 1c,e), the latter recovering significantly higher MNTD values (Figure 1d). For SES, the leaf litter fauna had a significantly higher aggregation in functional space for FD_{PG} and MNTD (Figure 1e,f).

CWM values showed significant individual trait distribution for nine traits (Figure 2; Table S8). For pitfalls, the assemblage had bigger body size, bigger relative scape size, eye length, mandible width, and metafemur size (Figure 2). For Winklers, the assemblage was characterized by a significant higher contribution from the relative distance of the eye to the mandibular insertion, petiole size, and gaster width (Figure 2).

For the PCA, the first three PCs explained around 45% of morphospace variation, with the first two PCs explaining 32% of morphospace variation (Figure 3 and Figure S2; Table S9). For PC1, most of the variation observed was product of overall bigger body size, with the main contribution from Weber's length, followed by gaster width, interocular distance, and petiole length (Table S9). For PC2, most of the variation was also related to body size, the main contribution from relative metafemur length, followed by scape length, eye length, and clypeus length (Table S9). For PC3, most of the contribution was related to mandible width, followed by interocular distance, and distance of eye to the mandible insertion. By overlapping our PCA plot with results from the *PWindex*, our analysis emphasizes the sampling method effects in capturing ant morphospace at the local scale (Figure 3 and Figure S2). However, all three PC axes were not strongly correlated to our *PWindex* (Figure S3). Pitfalls and Winklers overlapped in sampling the overall assemblage (species whose *PWindex* values were close to 0, or uniquely captured by each of the techniques but closely located in the morphospace), but pitfalls contributed with a unique spectrum of the morphospace (see *PWindex* = 1 on Figure 2 and Figure S2, and boxplots on Figure S4). Therefore, pitfalls contributed to species sharing an overall bigger body size and unique biology (e.g., army ants and large epigeic trap jaw species), but we also uniquely captured (singletons included; see abundance values on Figure 3 and Figure S2) small-sized species with these traps with our sampling protocol. A similar scenario was observed for Winklers, with some medium-sized predators (e.g., small trap jaw species) being mostly captured with that technique (*PWindex* = −1), while uniquely contributing with extremes of the morphospace (albeit those tended to be collected in low abundance, for example, *Proceratium brasiliense*, *Fulakora elongata*, and *Acanthognathus ocellatus*).

4 | DISCUSSION

Our results highlight sampling method effects on diversity metrics and community-assembly processes at the local scale. FD metrics directly depended on the effect of TD (species richness and abundance). By controlling for TD effects, FD metrics showed that each sampling technique collected a strikingly different structure in community assembly—pitfalls resulted in more functionally overdispersed assemblies (and higher FD) than Winkler, but overall pattern suggests clustering (Figures 2 and 3).

Besides the intrinsic effect of sampling method choice, incomplete sampling of FD might also generate biased inferences about community processes (Lee & Guénard, 2019). A carefully planned

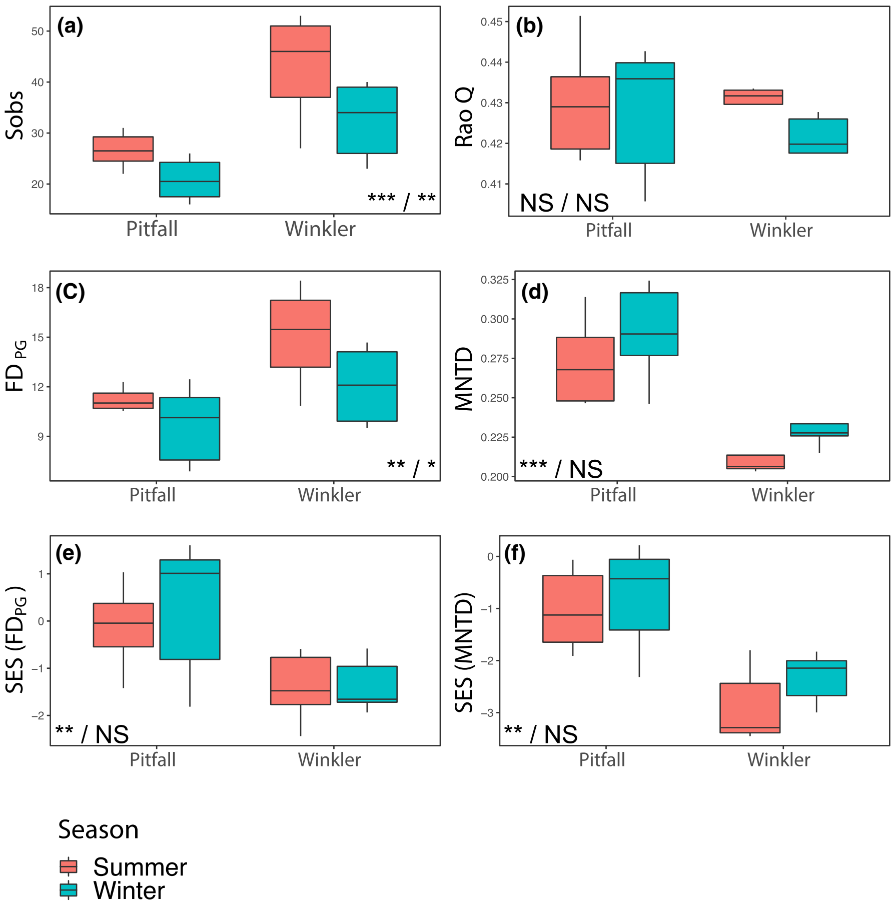

FIGURE 1 Mean values of multi-trait diversity metrics for the ant assemblage in the PEXJ: (a) Sobs = taxonomic richness; (b) Rao Q; (c) FD_{PG}; (d) MNTD; (e) and (f) standard effect size values for FD_{PG} and MNTD, respectively. See Subsection 2.3.2. of Section 2 for an explanation of each metric. Bars indicate standard error values; outliers excluded. Significant differences between sampling methods/season assessed by two-way ANOVA test (*$p < .05$, **$p < .01$, ***$p < .001$, NS = non-significant).

sampling design should be favored, reducing sampling method effect while allowing for more accurate detection of the taxonomic and functional diversities in fragments. Pitfalls might be more effective in capturing larger size species (Mahon et al., 2017; Salata et al., 2020; Wiezik et al., 2015). However, most studies in the literature applied 2-day protocols for pitfall sampling. Thus, more critical than biotic filters, longer sampling intervals (168 h) might allow pitfalls to capture infrequently collected species, considered uncharacteristic for the epigeic fauna. In our study, pitfalls captured a proportion of small body-sized species not captured with Winklers (Figure 3) while also overlapping with Winklers by capturing functionally unique species usually found in the leaf litter (Figure 3, Tables S3 and S7). Therefore, the morphospace captured with the pitfall traps might have been expanded by the extension of our sampling protocols. Future researchers aiming to obtain reliable overall diversity estimates of local ground-dwelling ant communities might consider applying a sampling protocol with reduced effort and trait filtering by focusing on one-week-long exposed pitfalls. However, a 2-day protocol for pitfall sampling might sometimes be more efficient than Winklers: a direct comparison of the efficiency of those sampling techniques found pitfalls to be more efficient than Winklers in capturing ants at multiple Amazonian forests (de Souza et al., 2012) and ground-dwelling arthropods in the wet-deciduous forests of the Western Ghats (Sabu & Shiju, 2010). However, TD to FD relationships were not included in those studies, thus preventing a comparison across metrics of diversity.

According to our results, the leaf litter assemblage was characterized by a species-packed structure; on average, species showed a more substantial functional overlap when compared to the epigeic fauna collected with pitfalls. Low MTND values (small morphological distances) have also been observed in other studies characterizing ant FD in litter assemblages (Silva et al., 2016; Silva & Brandão, 2010). Although Winklers collected higher TD, this does not translate to a wider morphospace, with most functionally similar species closer than what was observed for the epigeic fauna: lighter colored dots (more frequently collected with Winklers) are more clustered in the morphospace than darker hued dots (more frequently collected with pitfalls) (Figure 3, also see Table S9). This is probably an effect of niche compartmentalization: leaf litter's interstices favoring the coexistence of functionally similar ant species. It is also important to mention that natural history information for leaf litter assemblages is relatively scarce, so dynamics of recruitment, foraging, and colonization for most ant species are unknown – thus, a 48 h-window usually applied to pitfall trapping might fail to register upward movements by those ants to the epigeous stratum. In terms of traits, as expected based on functional significance of traits and habitat-dependence (Kaspari & Weiser, 1999) or environmental complexity and resources (Gibb & Parr, 2013), the leaf litter community captured by Winklers was mainly characterized by small-sized species, with dorsally located eyes, comparatively larger gaster and petiole. In particular, gaster size lacks functional significance tests in ant ecology studies, but our results suggesting proportionally wider

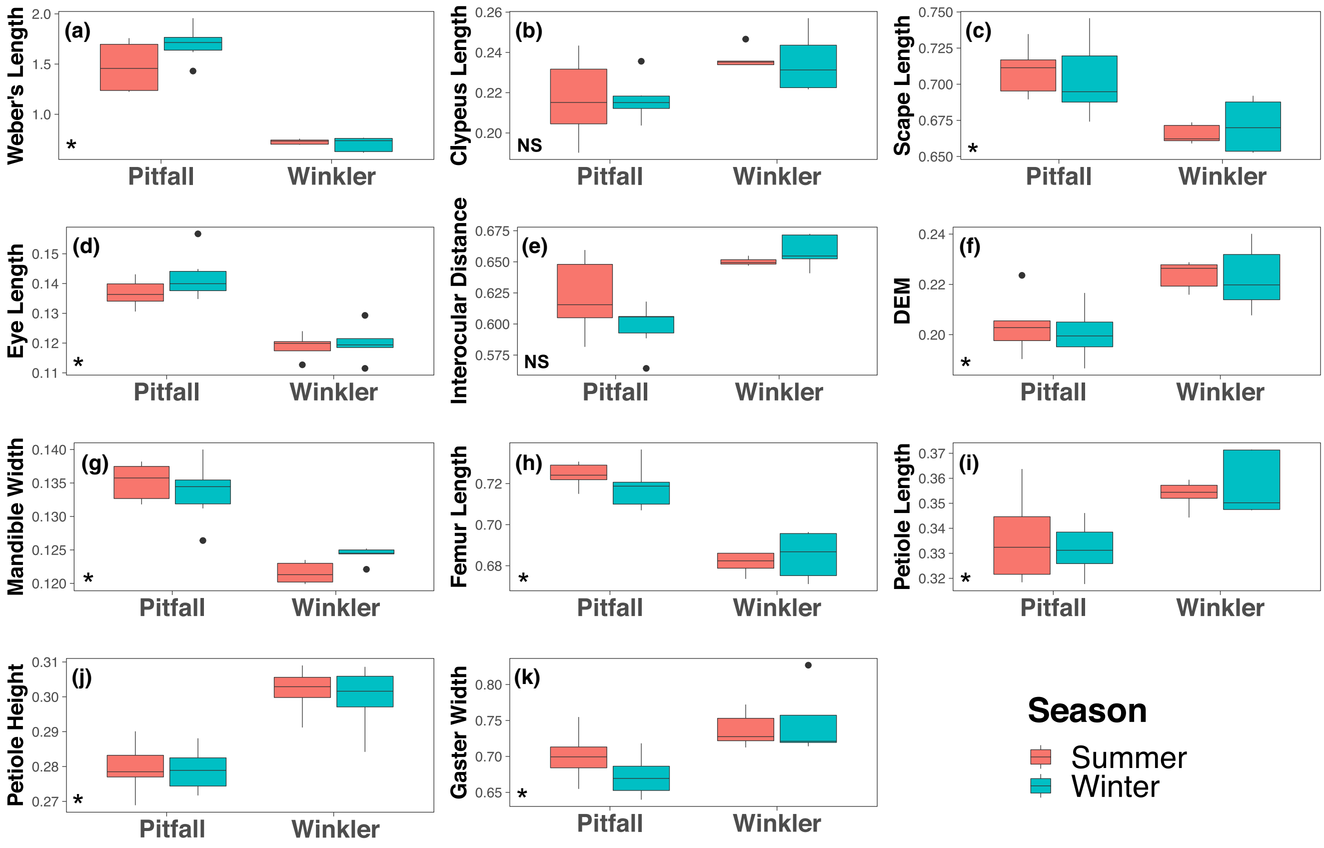

FIGURE 2 Community-weighted mean values (CWM) of all ant species for each of the 11 morphological traits, plotted by sampling method (pitfall and Winkler). (a) Weber's length; (b) clypeus length; (c) scape length; (d) eye length; (e) interocular distance; (f) distance from eye to mandibular insertion; (g) mandible width; (h) metafemur length; (i) petiole length (j); petiole height; (k) gaster width. All trait measurements (besides (a)) were standardized by Weber's length (see Section 2, also see Table S1 for an explanation on morphological traits). Error bars indicate standard error values. Significant values (*$p < .05$, NS = non-significant) for each morphological trait between sampling techniques were assessed by a Wilcoxon sample test.

gasters to be positively associated with leaf litter assemblages, we hypothesized that food intake and storage for detritivores or that predatory activities (in association with longer petioles) in the interstices of the leaf litter might be selecting for that association. Further, there are several potential drivers that may result in an increase of gaster size relative to body size (see Anderson et al., 2020 for a discussion of head expansion with concomitant gaster expansion in biomechanical models) in species whose workers are able to lay trophic or haploid eggs. Conversely, the epigeic fauna sampled by pitfalls selected larger sized species, more ventral eyes (probably linked to hunting methods or orientation (Fowler et al., 1991)), comparatively narrower gaster, and shorter petiole. Additionally, the second axis of morphological variation revealed differences (given body size) in scape, metafemur, eye, and clypeus lengths of the leaf litter assemblage (although not correlated with the *PWindex*), implying larger variation in the morphologies of smaller ants inhabiting the leaf litter (Silva & Brandão, 2010).

Significant higher SES FD_{PG} in pitfalls over Winklers were observed when accounting for TD (Figure 1e), revealing underlying effects of species richness for Winkler's FD. The TD-FD relationship is evident for FD_{PG} and MNTD, but not when comparing Rao Q values, the latter considering the ant trait-based pairwise distances by the product of their frequencies of occurrences. Rao Q values suggest the local assemblage structure might be similar for pitfall and Winkler as species are added to the sampled assemblage with these techniques. Relatively higher Rao Q values for the assemblage collected with pitfalls suggest that as species are added for the epigeic assemblage at the local scale, they might be functionally dissimilar from their nearest species – opposite what was found for the litter assemblage. By controlling the observed metrics for TD, SES for $FD_{PG,}$ and MNTD for pitfalls suggest a more overdispersed epigeic assemblage than the leaf litter fauna.

By generating an index that focus on the contribution ratio of the ant fauna captured with pitfall and/or Winkler traps, we were able to scrutinize each method's unique contribution in capturing components of the morphospace (Figure 2, also see Figures S2–S4). The *PWindex* offers a straightforward approach to evaluate how recurrent certain taxa might be collected by considering the whole spectrum of pitfall-to-Winkler contribution. Furthermore, when associated with ordination analyses, it allows researchers to explore morphospace complementarity—or redundancy—and how each of those sampling methods operates in retrieving the myrmecofauna

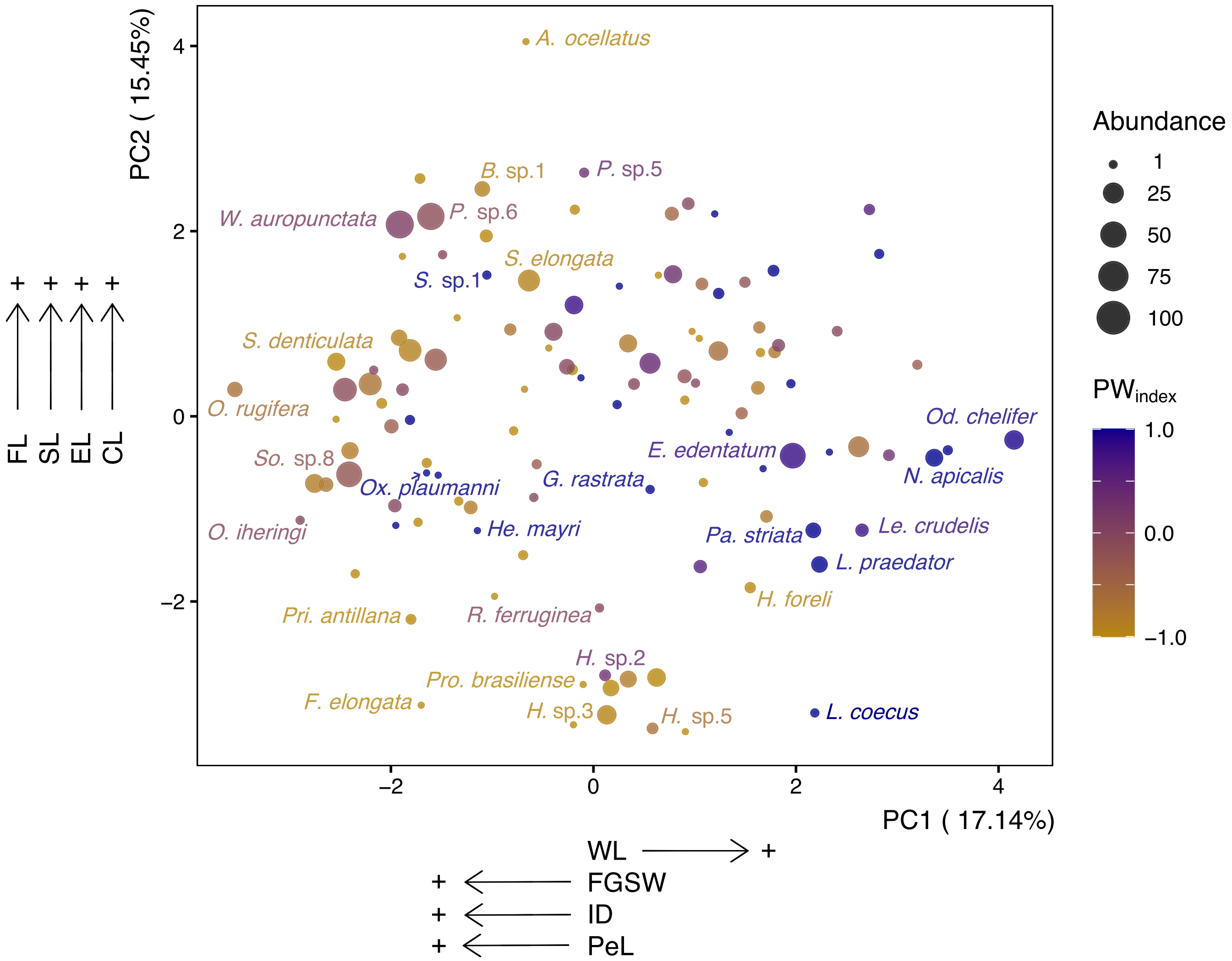

FIGURE 3 PCA plot showing trends in assemblage composition (ant morphospace) with respect to relative abundance (compound occurrences for pitfalls plus Winklers) and a contribution ratio index that evaluates the contribution of sampling technique (*PWindex*, ranging from −1 to +1 for species unique to Winklers and pitfalls, respectively; see Section 2). Labels nearest to the axis represent highest eigenvector scores (see Table S9 for individual correlations between morphological traits and the PC axes): PC1 = FGSW: first gastral segment width; ID: interocular distance; SL: scape length; WL: Weber's length; and PC2 = CL: clypeus length; EL: eye length; FL: metafemur length; SL: scape length. See also Figure S2 (for plot with PC1 and PC3) and Figure S3 (for correlations between PC axes and the *PWindex*). Bubble graphs indicate the relative abundance of each species, color-coded ranging from dark blue (darker tone for printed version) (those species uniquely collected with pitfalls) to golden yellow (lighter tone for printed version) (those uniquely collected by Winklers). Label names in alphabetical order: *A. ocellatus* = *Acanthognathus*, trap-jaw ant and leaf litter specialist; *B.* sp.1 = *Brachymyrmex*, biology unknown, potential generalist nesting on leaf litter; *E. edentatum* = *Ectatomma*, medium-sized generalist, epigeic species; *F. elongata* = *Fulakora*, leaf litter specialist; *G. rastrata* = *Gnamptogenys*, middle-sized leaf litter species, potential generalist; *H.* = *Hypoponera*, usually small ponerine species, putatively leaf litter predators; *He. mayri* = *Heteroponera*, small-sized generalist, nesting in leaf litter twigs; *L. coecus* and *L. praedator* = species from the army ant genus *Labidus*; *Le. crudelis* = *Leptogenys*, medium-sized ponerine, epigeic and probably specialist predator; *N. apicalis* = *Neoponera*, large epigeic ponerine species; *O.* = *Octostruma*, probably leaf litter specialists; *Od. chelifer* = *Odontomachus*, large epigeic trap-jaw ant species; *Ox. plaumanni* = *Oxyepoecus*, small-sized leaf litter myrmicine; *P.* = *Pheidole* species, probably generalist ants; *Pa. striata* = *Pachycondyla*, large epigeic ponerine species; *Pri. antillana* = *Prionopelta* and *Pro. brasiliense* = *Proceratium*, small leaf litter specialist predators; *R. ferruginea* = *Rasopone*, biology unknown, medium-sized ponerine; *S. denticulata* = *Strumigenys*, small trap-jaw species, leaf litter specialist; *So.* sp. 8 = small-sized *Solenopsis* ("thief ant"), biology unknown, probably generalist nesting in the leaf litter.

community (Figure 2 and Figure S3). Interestingly, when looking to *PWindex* values, for several species putatively associated with the leaf litter community those were close to or 0 (e.g., *Carebara previpilosa*, *Octostruma iheringi*, some small *Solenopsis* species, etc.), suggesting a strong redundancy between both techniques in contributing to components of the ant morphospace. At the same time, this redundancy-to-complementarity discussion can be further explored when we look to number of occurrences. Some species considered leaf litter dwellers were uniquely collected with pitfall traps (e.g., *Heteroponera mayri*, *Oxyepoecus plaumanni*, *Strumigenys* sp.1), in low abundance. Residing in the vicinity of their morphospace, other species were uniquely collected with Winkler traps (e.g., *Discothyrea neotropica*, *Oxyepoecus rastratus*, *Basiceros disciger*), also in low abundance. Thus, not only pitfalls and Winklers can be redundant for certain taxa (*PWindex* ≈ 0), but individually captured species, in low abundance, that were closely located in the morphospace.

Therefore, we suggest that inventories focusing on local ground-dwelling assemblages (of ants or other invertebrates) should implement different diversity metrics besides TD. If applying a combination of pitfalls and Winklers (or any other combination of two sampling techniques), those studies could compare complementarity or redundancy of those techniques by using our *PWindex*.

AUTHOR CONTRIBUTIONS

Conceptualization, R.R.S., C.R.F.B., and R.S.P.; methodology, R.S.P. and R.R.S.; software, R.R.S. and R.S.P.; formal analysis, R.S.P. and R.R.S.; investigation, R.S.P. and R.R.S.; data curation, R.S.P.; writing—original draft preparation, R.S.P. and R.R.S.; writing—review and editing, R.S.P., R.R.S., and C.R.F.B.; supervision, C.R.F.B. and R.R.S.; funding acquisition, R.S.P. and C.R.F.B.

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CONFLICT OF INTEREST STATEMENT

All authors have read and agreed to the published version of the manuscript. The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available in the Dryad Digital Repository: https://doi.org/10.5061/dryad.37pvmcvr3 (Probst et al., 2023).

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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