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RESEARCH ARTICLE - ANTS

Contribution of Omnidirectional Flight Traps to Assess the Ant (Hymenoptera: Formicidae) Diversity in an Agroforestry System

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Abstract

The Malaise trap is widely used for monitoring the diversity of flying insects. The omnidirectional model (Omnidirectional flight trap) is well known when hung in the understory, where it divides the sampling of these insects into two interception strata, a lower and an upper one. In general, the interest in using this trap type is because it allows to collect organisms with distinct flight behaviors to be discriminated against. Here, we investigated what information this trap can provide from samples of canopy ants and winged individuals as workers. We evaluated the sampling efficiency of the ant fauna, comparing the collection strata of this trap in a cocoa agroforestry system. To collect the ants, 40 traps were installed near an equivalent number of shading trees in a cacao plantation. A total of 374 specimens of ants belonging to 94 species or morphospecies of Formicidae were captured. Of these, 44 species were represented by alates of both sexes, while workers represented 68 species. A significant difference in the average number of ant species, both winged individuals and workers, was observed according to the trap interception stratum. A greater number of alates were collected in the upper stratum than in the lower one. An inverse pattern was observed for workers. However, we do not observe any difference according to the trap interception stratum when focusing on the whole ant diversity independently from their cast. On the contrary, the pattern of species composition comparing the two trap interception strata varied according to the ant casts. The Malaise traps are also interesting because they provide valuable information about the activity of canopy ants, such as foraging (workers) and mating flight (alates: height, orientation, time, according to the schedule of trap use).

Introduction

The diversity of terrestrial insects significantly decreased over the past few decades, with consequences for the functioning of several ecosystems worldwide (Hochkirch, 2016; Hallmann et al., 2017; Sánchez-Bayo & Wyckhuys, 2019; Seibold et al., 2019; Wagner et al., 2020). The main activities responsible for these organisms' loss of biodiversity and biomass are habitat destruction, agricultural intensification, competition with invasive species, and climate changes (Sánchez-Bayo & Wyckhuys, 2019). The diversity of the insect fauna is considered a potential indicator of environmental quality (Thomazini & Thomazini, 2000). Due to their abundance, insects stand out in terrestrial

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environments, playing essential roles in pollination, seed dispersal, decomposition of organic matter, and nutrient cycling (Rosenberg et al., 1986; Kim, 1993; Davis et al., 2001). They also respond quickly to environmental changes, as they generally have short biological cycles (Wink et al., 2005).

Among insects, ants (Hymenoptera: Formicidae) are essential components of tropical biodiversity in both natural and agricultural systems (Delabie et al., 2007). Ants interact with organisms at all trophic levels (Alonso & Agosti, 2000; Ribas et al., 2012; Dejean et al., 2014) and are among the primary agents of the structuration of invertebrate communities. For that reason, they are sometimes called "ecosystem engineers" (Folgarait, 1998; Jones, 1997; Klimes et al., 2012; Souza & Delabie, 2020). In addition, they have characteristics that make them helpful in assessing environmental conservation status (Majer, 1983; Alonso, 2000; Campiolo et al., 2015) since they have wide distribution, abundance, and easy sampling (Folgarait, 1998; Agosti et al., 2000; Delabie et al., 2021).

The lack of data on local biodiversity to allow a global diversity estimation is still challenging (Basset et al., 2012; Basset et al., 2015). For example, the canopy of agroforests and tropical forests, as well as the invertebrate fauna they harbor, are ignored in many studies, mainly due to insufficient or inadequate sampling (Basset et al., 2012; DaRocha et al., 2015; Amorim et al., 2022). A serious sampling within a single area, whether forested or not, and adequate for the organism focal group would be the first step in understanding how biodiversity is structured there.

Several sampling techniques are employed to collect insects (see Santos & Fernandes, 2021). Among these, pitfall trap sampling (Santos et al., 2017; Santos & Delabie, 2018), Winkler (Santos et al., 2017; Koch et al., 2019), sweep net (Doxon et al., 2011; Bakker et al., 2022), light trap (Szentkiralyi, 2002; Sheikh et al., 2016), Pan trap (Mason & Bordera, 2008; Heneberg & Bogusch, 2014) and Malaise trap (Malaise, 1937; Marinoni & Dutra, 1997; Mason & Bordera, 2008; Aguiar & Santos, 2010; Arnhold et al., 2022) are commonly used and very effective for collecting different orders of insects (New, 1998; Aguiar & Santos, 2010; Delabie et al., 2021). Of these mentioned collection methods, the traditional Malaise trap is mainly efficient for sampling low-flying insects (Malaise, 1937; Skvarla et al., 2020; Marinoni & Dutra, 1997; Mason & Bordera, 2008; Aguiar & Santos, 2010; Uhler et al., 2022).

The Malaise trap (flight interception trap) was first described by René Malaise in 1937 (Gressit & Gressit, 1962; Skvarla et al., 2020) and is among the most efficient instruments for collecting flying insects from the orders Hymenoptera, Diptera, and Thysanoptera (Malaise, 1937; Campos et al., 2000; Achterberg, 2009). Since then, modifications have been made to adapt the model to different situations and research proposals, but the generic name Malaise trap has been retained for all its variants (Campos et al., 2000; Skvarla et al., 2020). It is a trap based on the observation that most flying insects that encounter an obstacle respond by looking for a way out to escape, either flying up or down or crawling (Matthews & Matthews, 2017). Therefore, it is incredibly efficient in collecting insects that, when their flight is interrupted, exhibit an escape behavior that can be associated with a negative or positive geotropism [or positive or negative heliotropism] (Alexander, 2000; Arnhold et al., 2022). Therefore, entire groups of insects exhibit one or the other behavior and look for escape by the upper part of the trap or, on the contrary, by the lower part (Wilkening et al., 1981). To solve this problem, Wilkening et al. (1981) developed a Malaise trap of the omnidirectional type, "Omnidirectional flight trap", which has separate containers for collecting organisms with positive and negative geotropism (Arnhold et al., 2022).

This study aimed to evaluate the ant fauna sampling efficiency in a cocoa agroforestry system, comparing the strata collection efficiency by an omnidirectional flight trap. Since the foundation of new ant colonies and the development of colonies generally depend on winged ants (males and females), the advantages of using this collection method for assessing the canopy ant community structure were discussed.

Materials and Methods

Study area

The present study was carried out from August to November 2019 in an experimental area of the Cocoa Research Center (CEPEC/CEPLAC) (14°45.3'S, 39°13.9'W), in the municipality of Ilhéus, state of Bahia, Brazil. The cacao (*Theobroma cacao* L., Malvaceae) cultivation is one of the agrosystems that least alters the native biodiversity (Delabie et al., 2011) because it usually requires an association with one or more tree species, which provide controlled shading (Alvim, 1987; Rice & Greenberg, 2000; Novais et al., 2016). This type of plant association forms an agroforestry system where cocoa trees replace the forest understory, and the shading trees form a canopy-like structure. This shading can be composed of trees of native species, which represents the traditional production system ("cabruca"), or planted after the complete elimination of the original vegetation ("total felling") (Delabie et al., 2007; Delabie et al., 2011). Among the planted species, the genus of exotic trees *Erythrina* is commonly found (Delabie et al., 2007; DaRocha et al., 2016). These trees provide favorable conditions for the colonization by epiphytes such as Bromeliaceae, Orchidaceae, Cactaceae, Gesneriaceae, and others, which in turn increase the heterogeneity of the micro-habitat within the canopy, sheltering and providing resources for numerous organisms that live in the tree canopy (DaRocha et al., 2015; 2016). However, removing or replacing native shading trees with one or a few agroforestry species may be responsible for reducing diversity and altering the composition of many insect groups (Novais et al., 2016).

The climate is hot and humid, with the absence of a well-defined dry season ('Af' type on the Köppen scale), with annual precipitation between 1,300 and 2,000 mm (DaRocha et al., 2016). The main regional economic activity is the cultivation of cocoa (*Theobroma cacao* L., Malvaceae); in Bahia, this type of agricultural activity is inserted in the Atlantic Forest biome. The agrosystem is a cocoa plantation in the sampled area, in the system locally known as "total felling", where the shading is almost exclusively warranted by trees of the genus *Erythrina* (Fabaceae).

Sampling design and collection of ants

We selected 40 trees of *Erythrina* sp. with a uniform architectural structure in terms of development. The trees' maximum height was 25 to 30 meters, and the first forked branch was approximately 5 meters above ground level. The selected trees were distributed at minimum intervals of 100 meters to guarantee independence between successive sample units.

Sampling was conducted over three weeks in November 2017, between the 4th and 24th. A single Malaise trap was installed per tree, suspended between 3 and 5 meters from the ground by nylon ropes (Fig 1a-c) fixed on tree branches in a location corresponding to a probable insect flight corridor. The malaise trap is made from fine netting, such as PET (polyester). When assembled, it is 1.15 m wide by 3.0 m high, as shown in Figure 2.

The traps remained in the field for four consecutive days, totaling 96 hours of insect collection by trap (corresponding to 3,744 hours of trap sampling for the whole experiment). Posteriorly, the trapped biological material was packed in vials with alcohol and taken to CEPLAC's Myrmecology Laboratory. The insects were sorted, counting the number of specimens at the order level (see the companion study in Arnhold et al., 2022). The ants were separated from other insects, mounted, and identified using the laboratory reference collection (CPDC, Delabie et al., 2020) and, when necessary, through a query in specialized literature (Bolton, 2021; available online at http://www.antcat.org/catalog).

Statistical analyzes

To evaluate the ant fauna associated with the two trap interception strata, a matrix was constructed with the presence/absence records of the different ant species (considering winged ants, workers, and the two groups together) sampled by each trap and interception strata. This distinction was made to evaluate the records when considering an entire trap and what was found in each interception strata of each malaise.

To determine whether there was a difference in the composition of ant assemblies (considering winged and worker casts together) according to the interception stratum of Malaise traps on the cacao agrosystem studied, an analysis of similarities (ANOSIM) was performed using the Jaccard's distance index.

Fig 2. Approximate view and dimensions of an installed Malaise trap.

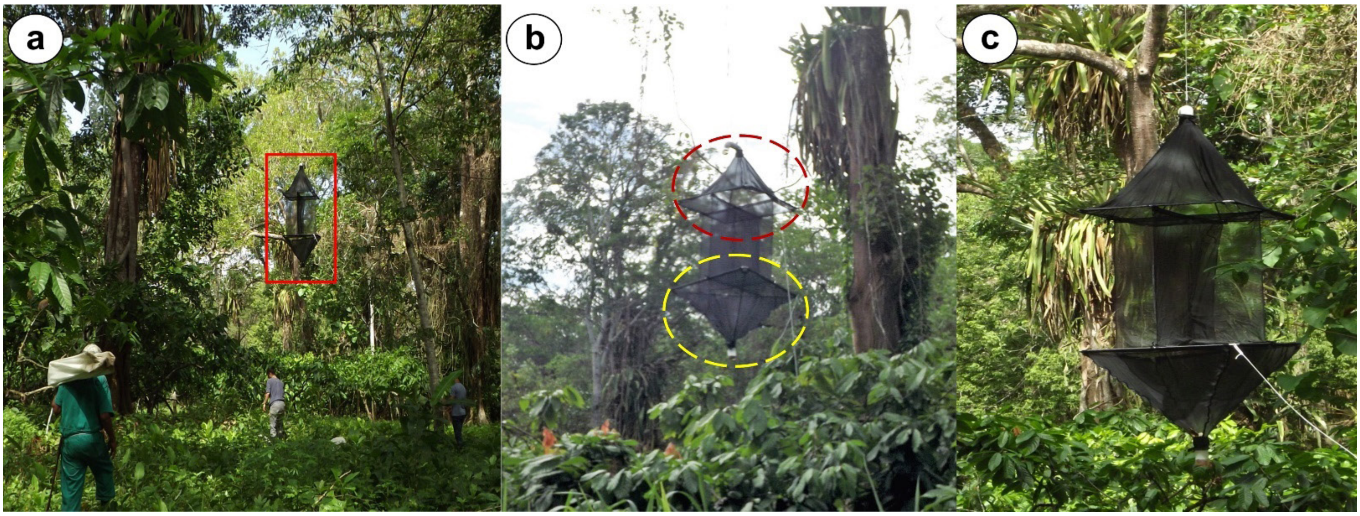

Fig 1. (a) View from a distance of a trap in the study area, (b) Malaise trap installed highlighting the upper (in red) and lower (in yellow) interception stratum, and (c) close-up view of the trap. Experimental fields of the Cocoa Research Center, Ilhéus, Bahia, Brazil.

We evaluated the sampling effort according to the different interception strata, considering winged ants, workers, and the two groups together. Non-parametric estimates were used to construct rarefaction curves, and the theoretical species richness was determined. In each case, the rarefaction curve per interception strata was plotted based on the progression of species richness with sampling effort.

We used a Paired t-test to compare the ant abundance and richness according to the interception stratum. Using Jaccard's index, we also evaluated the similarity in the ant species assemblages sampled according to the interception stratum (Rohlf, 1989). This index considers the presence/absence of species and is one of the similarity indices most used to assess the compositional similarity of species assemblages (Manthey & Fridley, 2009). These analyses considered winged ants, workers, and the two groups together.

Finally, to verify if the ant beta diversity (Sørensen dissimilarity) between the two interception strata of the Malaise traps and according to the different casts of the ants recorded was driven by species turnover or nestedness, the beta diversity was partitioned based on Baselga's family (Baselga, 2010). All analyses were performed in the R software version 4.2.2 (R Development Core Team, 2023) using the packages "betapart" (Baselga & Orme, 2012), "iNEXT" (Hsieh et al., 2016), "vegan" (Oksanen et al., 2019) and "ggplot2" (Wickham, 2016).

Results

Ant fauna

We recorded a total of 374 individuals of 92 species/morphospecies of ants collected belonging to 29 genera and seven subfamilies: Myrmicinae (44.7% of species), Formicinae (15.9%), Dolichoderinae (13.8%), Pseudomyrmecinae (12.8%), Ponerinae (10.6%), Amblyoponinae and Dorylinae (both with 1.1%). The genera with the highest number of species were *Pseudomyrmex* (12 species), *Pheidole* (9), *Camponotus*, *Solenopsis* (7 each), and *Azteca* (5) (Table 1). The species with the highest frequency of occurrence were *Solenopsis* sp.1 (62.5% of the traps), *Crematogaster erecta* (57.5%), *Wasmmania rochai* (35%), *Crematogaster* sp.1 and *Monomorium floricola* (27.5% each). Among all species collected, 68 (72%) are workers, while 42 (44.7%) are winged males or females. Only 15 species (16% of the total) were recorded simultaneously with workers and alates.

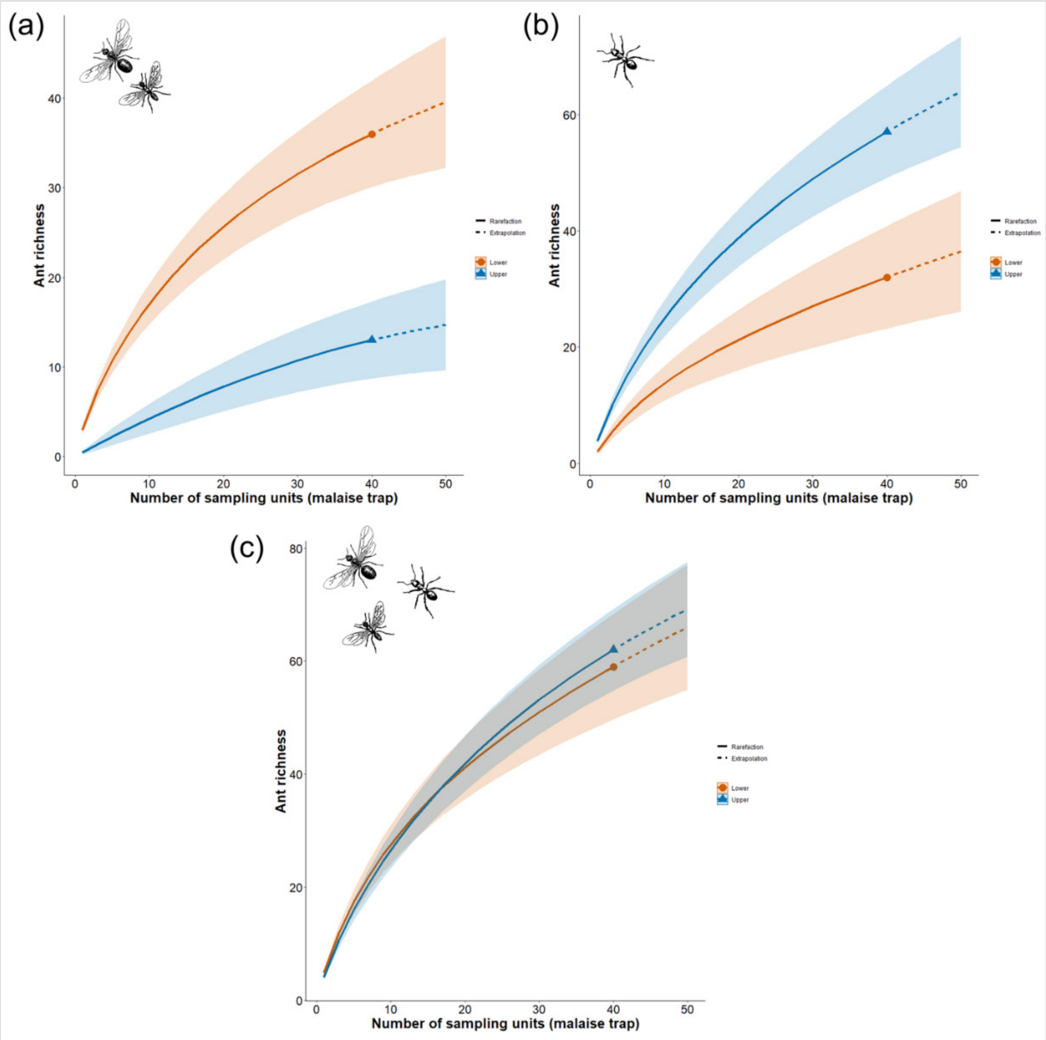

Fig 3. Species accumulation curves based on the number of (a) winged, (b) worker, and (c) all ant species (observed richness) sampled according to the interception strata of Malaise traps on the cacao agrosystem studied, experimental fields of the Cocoa Research Center, Ilhéus, Bahia, Brazil. Dashed lines represent the confidence interval.

A total of 59 ant species (64.1% of all study species) were sampled in the lower interception stratum of the Malaise traps, while 63 (68.5% of the total) were recorded in the upper stratum. Among the whole ants collected in the study, only 29 species (or 31.5% of the total) were recorded in both trap interception strata (Table 1, Fig 3c). The number of exclusive species recorded for the lower and upper interception stratum were, respectively, 27 and 32 (Table 1).

The species composition (considering winged and worker casts together) was significantly different between the interception strata of Malaise traps (ANOSIM R = 0.301; $P < 0.001$). The two strata showed approximately 33% similarity.

Assemblage of winged ants

We recorded a total of 42 species/morphospecies of winged ants. These belong to 23 genera and seven subfamilies: Myrmicinae (54.5% of the species), Formicinae (15.9%), Dolichoderinae (9.1%), Ponerinae (13.6%), Amblyoponinae, Dorylinae and Pseudomyrmecinae (2.1% each) (Table 2). The genera with the highest number of species were *Pheidole*, *Solenopsis* (five spp. each), *Nylanderia* (four spp.), *Azteca*, *Crematogaster,* and *Hypoponera* (three spp. each). The species with the highest frequency of occurrence were *Solenopsis* sp.1 (47.5% of the traps), *Pheidole* sp.4 (45%), and *Crematogaster* sp.1 (27.5%) (Table 1). Only seven species occurred in both interception strata (Table 1). Ant species of the genera *Brachymyrmex*, *Camponotus*, *Cyphomyrmex*, *Dolichoderus*, *Fulakora*, *Hylomyrma*, *Hypoponera*, *Megalomyrmex*, *Neocerapachys*, *Odontomachus*, *Pseudoponera* and *Rogeria* occurred in the lower stratum of the Malaise traps only. Species of the genera *Cardiocondyla*, *Monomorium*, *Neoponera*, *Pseudomyrmex,* and *Wasmannia* were recorded exclusively in the upper stratum of the traps (Table 1). The similarity in the winged ant assemblages collected in the two trap interception strata was 31%.

Assemblage of non-winged (worker) ants

We recorded 68 species/morphospecies of non-winged ants (workers). These belong to 22 genera and five subfamilies: Myrmicinae (45.6% of the species), Dolichoderinae, Pseudomyrmecinae (both 16.2%), Formicinae (14.7%) and Ponerinae (7.3%) (Table 2). The most representative genera were *Pseudomyrmex* (11 spp.), *Pheidole* (seven spp.), *Camponotus* (six spp.), *Azteca*, *Cephalotes,* and *Solenopsis* (five spp. each). The species with the highest frequency of occurrence in the study were *Crematogaster erecta* Mayr, 1866 (57.5%), *Azteca* sp.2 (37.5%) and *Azteca alfari* Emery, 1893 (35%) (Table 1).

We recorded 57 species and 19 genera represented by workers in the upper stratum of Malaise traps, and 31 species and 16 genera were collected in the lower stratum (Fig 4a). A total of 21 species were sampled in both interception strata (Table 1, Fig 4b). Species of the genera *Brachymyrmex*, *Cardiocondyla*, *Linepithema*, *Nesomyrmex*, *Nylanderia*, *Procryptocerus* and *Tapinoma* occurred exclusively in the lower stratum of Malaise traps. In turn, species of the genera *Myrmelachista*, *Odontomachus,* and *Strumigenys* were collected only in the upper stratum of the traps (Table 1).

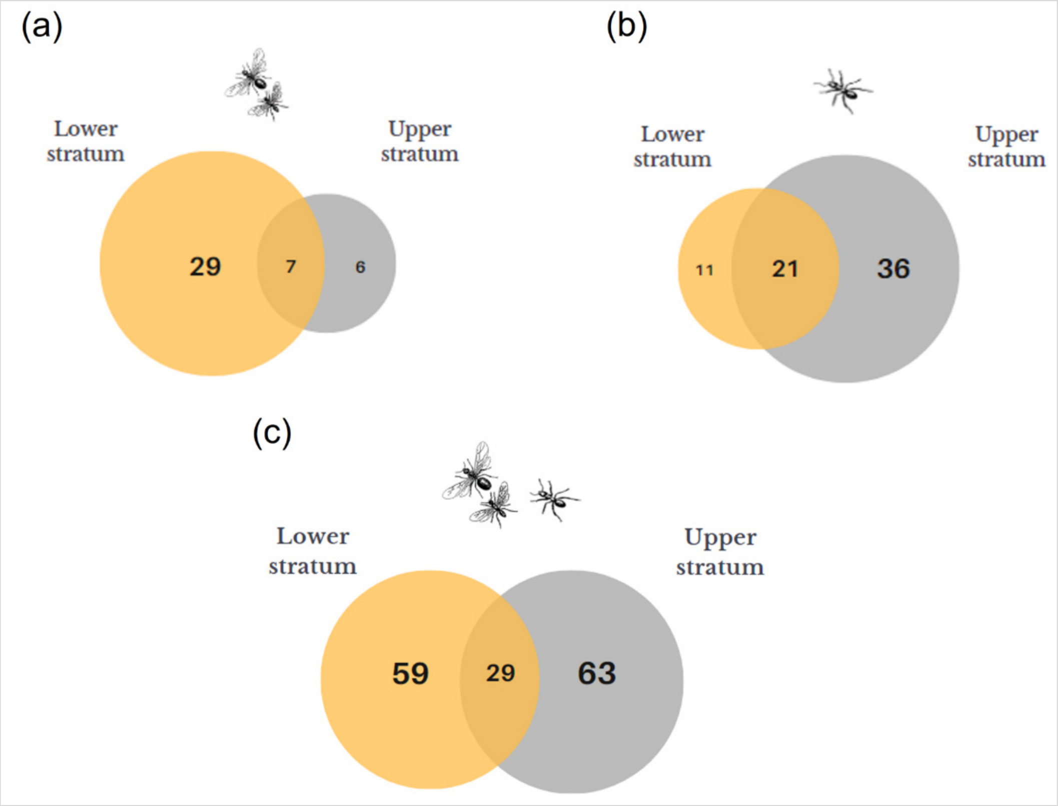

Fig 4. Venn diagrams illustrating the number of ant species considering the different ant castes: (a) winged, (b) worker, and (c) all, recorded according to the interception strata of Malaise traps in trees (*Erythrina* sp.) in the studied cocoa agrosystem, experimental fields of the Cocoa Research Center, Ilhéus, Bahia, Brazil.

Variations in richness and composition according to the ant form and Malaise trap interception stratum

In general, species accumulation curves exhibited ascending patterns, with no indication of reaching stability with the sampling effort employed (Fig 4). The difference between the curves of the two interception strata is evident when looking at the ant castes. The pattern appears to be ascending for winged ants collected in the upper stratum, while the pattern is less ascending and distinct for those collected in the lower stratum. The curves and their respective confidence intervals do not join (Fig 4a). Conversely, a contrasting pattern emerges for ant workers, with both curves exhibiting more remarkable ascendancy (compared to winged ants). Their confidence intervals also do not join (Fig 4b). Finally, when considering the whole ant biological material, there is a substantial overlap in the confidence intervals of the curves from different interception strata, and the pattern is ascending and similar for both curves (Fig 4c).

We observed a significant difference in the average number of winged ant species per trap collected according to the Malaise trap interception stratum (T = 6942, P < 0.001). This number was higher in the lower stratum (3.1 ± 2.2) when compared to the upper one (0.43 ± 0.82) (Fig 5a). For workers, we also observed a significant difference in the average number of wingless species collected according to the interception stratum of Malaise traps (T = -3,245, P = 0.002). However, contrary to what was observed for winged individuals, we recorded, on average, a greater number of workers in the upper stratum (mean ± standard deviation = 3.75 ± 2.9) than in the lower (2.1 ± 1.5) (Fig 5b). When we consider the whole ant biological material, we did not observe the difference in the average number of winged ant species per trap collected according to the Malaise trap interception stratum (T = -1.383, P = 0.175, Fig 5c).

We found that the variation in ant species composition between the two trap interception strata was more pronounced for winged ants, with a higher contribution of nestedness observed.

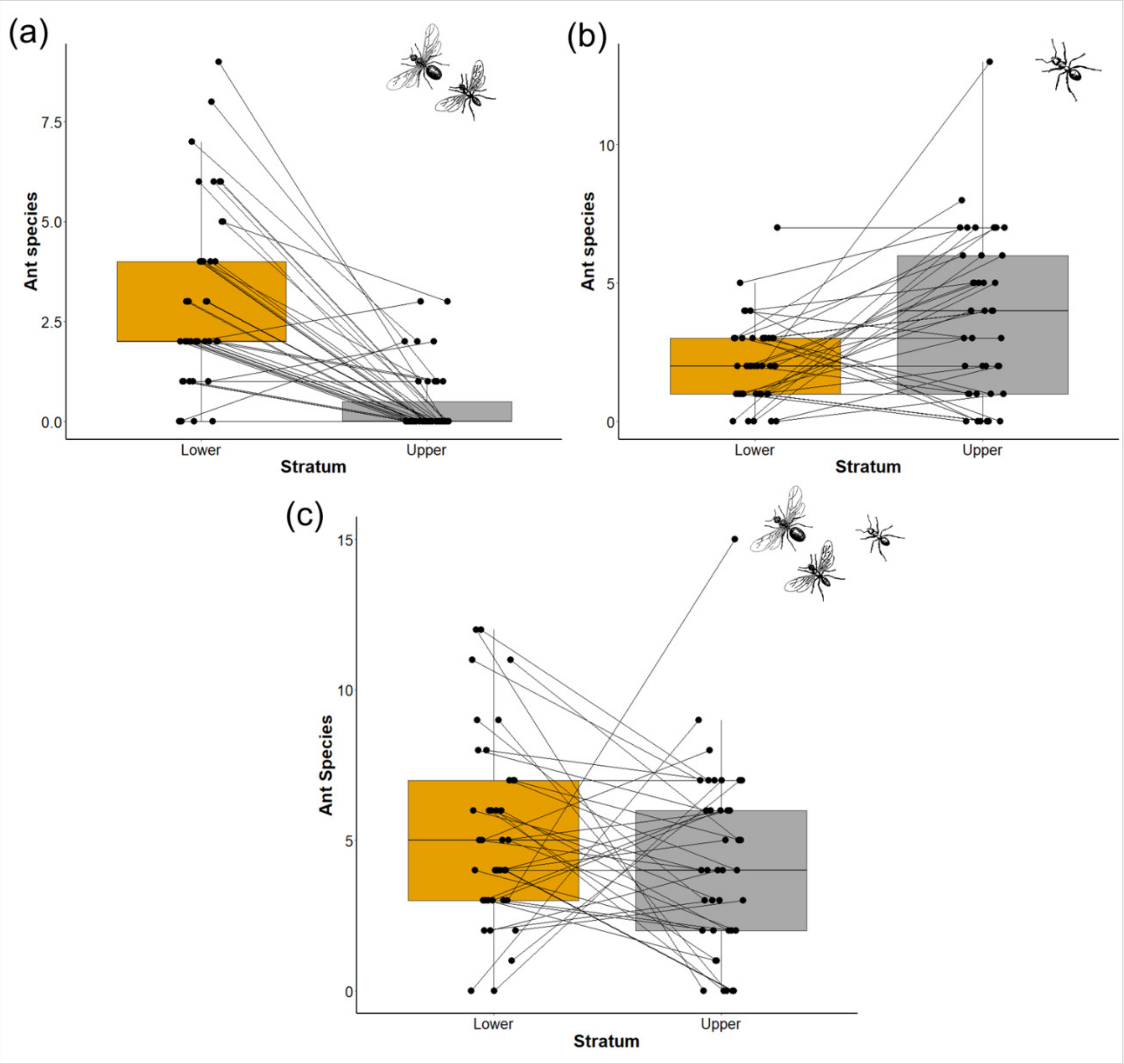

Fig 5. Average number of ant species considering the different ant castes: (a) winged, (b) worker, and (c) all, collected according to the interception strata of Malaise traps in trees (*Erythrina* sp.) in the studied cocoa agrosystem, experimental fields of the Cocoa Research Center, Ilhéus, Bahia, Brazil. The lines link the number of species caught in each collection point (Malaise trap).

The nestedness also explained a significant portion of the beta diversity observed when assessing the difference in the composition of workers when the two interception strata are compared. However, when considering the whole ant biological material, turnover was the primary component explaining nearly all differences in species composition when Malaise trap strata are compared (Figure 6).

Discussion

We observed that the omnidirectional Malaise trap with its two interception strata (upper and lower) enabled the capture of a vast diversity of ants and winged forms of both sexes as workers. In cocoa plantations, trees such as *Erythrina* sp. sustain an impressive diversity of canopy arthropods, as they provide support for vital biomass and diversity of epiphytes, which, consequently, increases the heterogeneity of the microhabitat, allowing it to shelter, for example, a great diversity of ants (DaRocha et al., 2015; 2016; 2021).

When comparing two interception strata (upper and lower), we observed that the similarity in ant assemblages was relatively low. When considering these two strata, a clear understanding of the real diversity of the group in the studied environment was allowed. Shaded cocoa agroforests contribute to maintaining a high diversity of ants, and many species can be found in two or more strata in this environment (Delabie et al., 2007). The general pattern is that some ant species that interact competitively become numerically dominant in a particular location or habitat (Delabie et al., 2007). In the studied environment, the occurrence of epiphytes increases the complexity of the habitat, offering a greater variety of microclimates and microhabitats, which favors the maintenance of the ant community (Delabie et al., 2011; DaRocha et al., 2015). Simultaneously, the local diversity of sap-sucking insects of the order Hemiptera provides a predictable food supply for most arboreal ants (Delabie, 2001; Delabie et al., 2007). The cocoa agrosystem thus allows a rich diversity of interactions between ants and their hemipteran trophobionts (Koch et al., 2020). however, although Hemiptera were abundant in the sampling (see the companion paper Arnhold et al., 2022), only a small fraction of them served as a resource in the form of honeydew or prey to the ants.

In ants, males and winged females actively fly, looking for sexual partners (mates) from mature colonies, and shortly after mating, females search for nesting sites in vegetation or on the ground to fund new colonies (Hölldobler & Wilson, 1990).

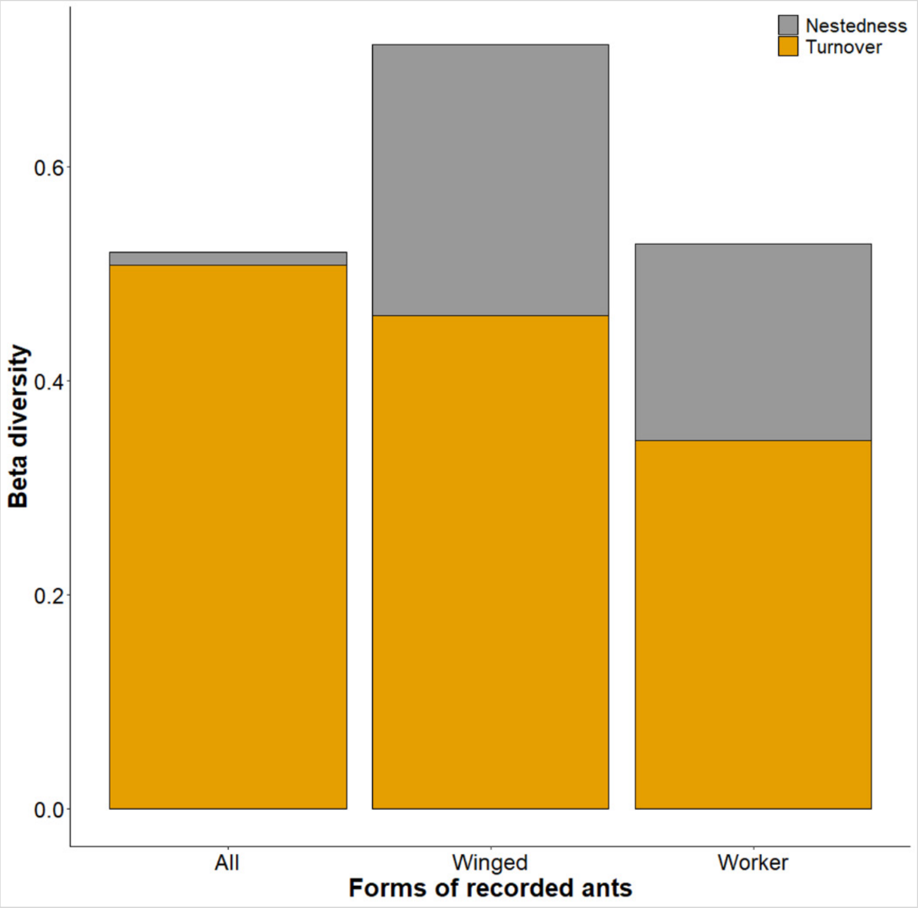

Fig 6. Variation in ant beta diversity and its components considering the two interception strata of the Malaise traps and according to the different cast of the ants recorded.

Here, the number of species represented by alates was higher in the lower stratum, while the number of workers was significantly higher in the upper stratum. Although we could first hope that winged ants are instead attracted to light, with positive phototropism, this is not what we observed here. This instead suggests a positive geotropism, or better, a specific behavior of winged ants which, when they encounter an obstacle (the trap), modifies their behavior and obligates them to land and walk and, therefore, run away to the ground.

Another critical point is that the two groups of ants sampled here may represent two different parts of the community: 1) workers are exclusively represented by species living in the canopy; 2) winged individuals may be represented by both the assemblages of ants of the canopy but also of species living in other strata, such as the leaf-litter or underground.

Our results show a distinction in flight behavior between some ant genera. *Brachymyrmex*, *Cyphomyrmex*, *Megalomyrmex*, *Neocerapachys*, *Rogeria,* and *Hypoponera* exhibited a particular behavior of escaping the trap by running away from dark places (negative geotropism) towards the light (positive phototropism). Conversely, *Cardiocondyla, Neoponera*, and *Pseudomyrmex* exhibited an exclusive behavior of escaping towards the ground or vegetative support (positive geotropism) when trapped. This behavioral variation among different genera deserves attention in further studies since it probably reflects different resource-seeking strategies. Previous studies have examined how ants process visual information to remember a route or identify a resource. For example, Oliveira & Hölldobler (1989) demonstrated that the Neotropical species *Odontomachus bauri* utilizes orientation using a canopy pattern, which is more effective as an orientation cue than horizontal reference points or chemical marks. Lent et al. (2010) evaluated how visual memories of landmarks play a significant role in guiding the habitual feeding routes of *Formica rufa* workers. These authors showed that the ants, before calculating the difference between the desired and current position of a visual feature, such as an edge, and their rotation speed when correcting their path is precisely related to this difference.

In turn, ant workers seem to have a strong tendency to explore in search of new resources. Arboreal species forage throughout the tree canopy in search of any type of resource, such as prey, honeydew from sap-sucking insects, floral or extrafloral nectaries, bird droppings, important nitrogen sources in the form of urea (Hölldobler & Wilson, 1990; Delabie, 2001; Klimes et al., 2012; Del-Claro et al., 2016). The workers captured by the traps correspond to individuals using the ropes that support the traps as bridges, especially foraging in the upper stratum (Basset, 1988). A previous study demonstrated that suspended soils are among the main factors determining the nature of the ants' assemblage associated with epiphytes living on shade trees in cocoa plantations in southeastern Bahia (DaRocha et al., 2015). The structural complexity of epiphytes, particularly bromeliads, explains the variation of animal species associated with them (Armbruster et al., 2002). Notably, most studies using Malaise traps to assess insect diversity disregard sampled non-winged specimens (Delabie & Reis, 2000). However, these ant species, generally considered as "tourists" or curious workers that were accidentally trapped, exhibit greater diversity than species represented by winged individuals and represent an important component of the diversity in the cacao agroecosystems. This high species richness also reinforces the need to conserve tree diversity that provides shade to cocoa plantations and their depending epiphytes (DaRocha et al., 2015; 2016).

Conclusion

Omnidirectional Malaise traps proved elsewhere to be very efficient in sampling flying insects for studying entomological activity in an agroecosystem (Novais et al., 2016; Arnhold et al., 2022). In the particular case of ants, these traps are also interesting for capturing winged individuals of rare species (see Reis & Delabie, 1999; Delabie & Reis, 2000). However, the remarkably high number of worker ants captured (72% of the species collected) until now neglected in biodiversity studies using this sampling methodology, is also able to provide valuable information about the activity of this valuable component of the diversity in the cocoa agroecosystem as, for example, the places reached by predator species, for example.

In summary, our results show that Omnidirectional flight traps, like other types of Malaise traps, are versatile passive net traps (Skvarla et al., 2021; Uhler et al., 2022), capturing not only flying insects but also representatives of an essential component of the canopy diversity: ant workers. Due to their characteristics of sociality, Formicidae is indeed one of the most important groups of organisms in tropical agrosystems, maintaining natural arthropod populations under low economic levels through the stability of their colonies and constant activity of the workers on vegetation (Majer et al., 1994).

It is also worth noting that the trap is a low-maintenance collection technique, making it convenient for long-term use and effective monitoring when the study goal is to sample a representative and sustainable snapshot of the local insect community.

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Table 1. Ant species collected according to cast (winged and worker) and the interception stratum of malaise traps on trees (*Erythrina* sp.) in the studied cocoa agrosystem. (n = 40 traps), experimental fields of the Cocoa Research Center, Ilhéus, Bahia, Brazil.

Subfamily	Species	Winged form			Worker form		
		Malaise	Lower I.S	Upper I.S	Malaise	Lower I.S	Upper I.S
Amblyoponinae	*Fulakora* sp.1	1	1				
Dolichoderinae	*Azteca alfari* Emery, 1893				14	6	10
	Azteca chartifex spiriti Forel, 1912	3	2	1	6	4	3
	Azteca sp.1				3		3
	Azteca sp.2	1	1		15	10	5
	Azteca sp.3	6	6				
	Dolichoderus sp.1	5	5				
	Dolichoderus attelaboides (Fabricius, 1775)				2	2	1
	Dolichoderus bispinosus (Olivier, 1792)				2	1	1
	Dolichoderus lutosus (Smith, F., 1858)				7	4	4
	Linepithema neotropicum Wild, 2007				1		1
	Tapinoma sp.1				3		3
	Tapinoma sp.2				1		1
Dorylinae	*Neocerapachys splendens* Borgmeier, 1957	3	3				
Formicinae	*Brachymyrmex heeri* Forel, 1874				4		4
	Brachymyrmex sp.1	5	5				
	Camponotus atriceps (Smith, F., 1858)	1	1				
	Camponotus balzani Emery, 1894				2	1	1
	Camponotus bidens Mayr, 1870				1		1
	Camponotus fastigatus Roger, 1863				2		2
	Camponotus sexguttatus (Fabricius, 1793)				1		1
	Camponotus sp.1	2	2				
	Camponotus textor Forel, 1899				1		1
	Myrmelachista sp.1				1	1	
	Myrmelachista sp.2				1	1	
	Nylanderia guatemalensis (Forel, 1885)	2	2		2		2
	Nylanderia sp.1	1	1				
	Nylanderia sp.2	3	1	2			
	Nylanderia sp.3	1	1				
Myrmicinae	*Cardiocondyla obscurior* Wheeler, W.M., 1929	2		2	1		1
	Cephalotes angustus (Mayr, 1862)				3		3
	Cephalotes atratus (Linnaeus, 1758)				2	1	2
	Cephalotes maculatus (Smith, F., 1876)				7	3	6
	Cephalotes minutus (Fabricius, 1804)				8		8
	Cephalotes pallidoides De Andrade, 1999				1	1	
	Crematogaster acuta (Fabricius, 1804)	1		1	1		1
	Crematogaster curvispinosa Mayr, 1862				1		1
	Crematogaster erecta Mayr, 1866	2	2		23	7	22
	Crematogaster sp.1	11	10	2			
	Cyphomyrmex rimosus (Spinola, 1851)	1	1				
	Cyphomyrmex transversus Emery, 1894	3	3				
	Hylomyrma sp.1	1	1				
	Megalomyrmex goeldii Forel, 1912	3	3				
	Monomorium floricola (Jerdon, 1851)	1		1	11	4	9
	Nesomyrmex asper (Mayr, 1887)				1		1
	Pheidole group diligens sp.7				1		1

Table 1. Ant species collected according to cast (winged and worker) and the interception stratum of malaise traps on trees (*Erythrina* sp.) in the studied cocoa agrosystem. (n = 40 traps), experimental fields of the Cocoa Research Center, Ilhéus, Bahia, Brazil. (Continuation)

Subfamily	**Species**	**Winged form**			**Worker form**		
		Malaise	**Lower I.S**	**Upper I.S**	**Malaise**	**Lower I.S**	**Upper I.S**
Myrmicinae	*Pheidole* group flavens sp.4				1		1
	Pheidole group tristis sp.5				1		1
	Pheidole group tristis sp.6				1		1
	Pheidole group tristis sp.8	1	1		1		1
	Pheidole sp.1	1	1		1		1
	Pheidole sp.2	1		1			
	Pheidole sp.3	5	4	1	1	1	
	Pheidole sp.4	18	18	1			
	Procryptocerus marginatus Borgmeier, 1948				2		2
	Procryptocerus pictipes Emery, 1896				1		2
	Rogeria blanda (Smith, F., 1858)				1		1
	Rogeria besucheti Kugler, C., 1994				1	1	
	Rogeria foreli Emery, 1894	2	2				
	Solenopsis sp.1	19	19		12	10	4
	Solenopsis sp.2	2	2				
	Solenopsis sp.3	1	1		2		2
	Solenopsis sp.4				1	1	
	Solenopsis sp.5	1	1		1	1	
	Solenopsis sp.6				1	1	
	Solenopsis sp.7	4	3	1			
	Strumigenys elongata Roger, 1863	1	1				
	Strumigenys sp.1	5	4	1			
	Wasmannia auropunctata (Roger, 1863)				1		1
	Wasmannia rochai Forel, 1912				14	7	10
Ponerinae	*Hypoponera* sp.1	2	2				
	Hypoponera sp.2	5	5				
	Hypoponera sp.3	1	1				
	Neoponera crenata (Roger, 1861)	2		2			
	Neoponera curvinodis (Forel, 1899)				2	1	1
	Neoponera inversa (Smith, F., 1858)				2	1	1
	Neoponera villosa (Fabricius, 1804)				1		1
	Odontomachus haematodus (Linnaeus, 1758)				2	2	
	Odontomachus meinerti Forel, 1905	1	1				
	Pseudoponera stigma (Fabricius, 1804)	1	1				
Pseudomyrmecinae	*Pseudomyrmex elongatus* (Mayr, 1870)				3		3
	Pseudomyrmex filiformis (Fabricius, 1804)				2	1	1
	Pseudomyrmex gracilis (Fabricius, 1804)				2		2
	Pseudomyrmex group pallidus sp.1				3	1	2
	Pseudomyrmex group pallidus sp.2	2		2			
	Pseudomyrmex group pallidus sp.3				3	1	3
	Pseudomyrmex group pallidus sp.4				1	1	
	Pseudomyrmex kuenckeli (Emery, 1890)				1		1
	Pseudomyrmex oculatus (Smith, F., 1855)				1		1
	Pseudomyrmex simplex (Smith, F., 1877)				2	1	1
	Pseudomyrmex tenuissimus (Emery, 1906)				1		1
	Pseudomyrmex termitarius (Smith, F., 1855)				1		1

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