RESEARCH ARTICLE

The Effects of Pitfall Trap Spacing on Ant Richness (Hymenoptera: Formicidae), Abundance, and Composition in Dinder National Park, Sudan

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Abstract

Ants play an important role in Sudanese biodiversity and environmental impact assessments, Although baiting is easy and cheap to implement, several considerations, such as the spacing among bait, can affect the estimation of the abundance and richness of ants species. In this study, we evaluated the effects of bait spacing on abundance and the number of ant species. We also demonstrate which distance between baits showed the best relationship between costs and the number of ant species sampled. We sampled 30 transects of 100 m with bait spacing ranging (2.5; 3.3; 5; 6.7; 10 and 20 m), spread over 1 km² into three different type of ecosystems (Wooded grass land, Riverine ecosystem and Maya ecosystem), at DNP located in Sudan. The bait spacing did not affect the ant diversity estimative. Regardless bait spacing, the number of species collected every five baits was around 8, and the average abundance was approximately 50 individuals. However, the number of species per bait was higher in transects with a larger gap between baits. Transects with bait spans of 20 and 10 m captured 50% more species per bait than transects with baits 2.5 and 3.4 m apart. Our study suggest that the most efficient sampling design using only baits in the park would be, to place 450 baits every 10 m and 20 m.

Keywords

PENSOFT.

Introduction

The reports of terrestrial invertebrates in inventories biodiversity and environmental impact have increased rapidly over the last decade (Humle et al. 2009; Bishop et al. 2014). Among the terrestrial invertebrates, ants are often used in these studies because they represent a large portion of the diversity of animal species in tropical forests, constitute one of the largest proportions of animal biomass (Staab et al. 2014; Wang et al. 2018), and are locally dominant over other macro arthropods (Yang et al. 2001). The collection efficiency of such a diverse group abundant, like ants, is a key component in designing rapid inventories of biodiversity or environmental impact reports that aim to meet the specific demands of society (Heath and Claassens 2000; Munya and Foord 2015).

Collecting ants with attractive baits is a simple method, cheap, and easy to implement. This collection method is widely used to investigate ant activity living in soil and vegetation (Kajzer-Bonk et al. 2016; Belskaya et al. 2017; Angelone and Bidochka 2018), and it can not only use to estimating the number of ant species (Walsh et al. 2004) but also a complementary method in inventories (LaPolla et al. 2013). However, the collection with bait usually biased sampling effect of the composition of the ant community. Some ants, called dominants, have aggressive behavior and can displace or prevent other ants from using a particular resource or visiting a bait (Watt et al. 2002; Yeo et al. 2017). In this way, individuals who forage solitarily or species with behavior subordinate can be underestimated (Reznikova 2020). Antagonistic interactions like this can insert a bias in comparisons between treatments in a study or between fauna comparisons that use the only collection with lures. Many studies investigated the effects of the type of bait (Chen et al. 2011; Wang et al. 2014) or environmental variations (Bharti and Sharma 2009; Lei et al. 2019) in the answer behavioral and, consequently, in the efficiency of sampling of species. However, the distance between baits can also affect the foraging of ants and alter the sampling results (Fontanilla et al. 2019). Keeping the area sample size, reducing the distance between baits means increasing its concentration in space. This could affect the number of species and individuals detected by sampling in two different ways. Closer baits can increase the chance to sample more ant species by concentrating the baits' attractive effect or sample in greater detail (more baits per space unit) the leaf /forest soil (Lu et al. 2016). On the other hand, in transects with a lower distance between lures, more lures would be offered within the foraging area of colonies of dominant species (Mauda et al. 2018). The competitive pressure exerted by these species on subordinate species could result in fewer sampled species (Lu et al. 2016). The objective of this work to evaluated the effects of bait spacing on abundance and the number of ant species. We also demonstrate which distance between baits showed the best relationship between costs and number of ant species sampled.

Materials and Methods

Study area

This study was conducted in the Dinder National Park (DNP), Sudan; thise area has increased to 10291 km² (Abdelhameed et al. 1997), and it now lies roughly between latitudes 12˚ – 26 ˚N and 12˚ – 42 ˚N and longitudes 34˚ – 48 ˚E and 35˚ – 02 ˚E (Fig. 1). Geographically the DNP is classified as Dry Savanna with a rainfall of between 600 to 800 milliliters annually. However, the flora and fauna are much richer than in similar habitats in Sudan.

According to (Basheer et al. 2016), the climate is typical of savanna conditions where summer is hot and dry as the temperature reaches 48 C° in March and April. Autumn usually starts early June and annual rainfall reaches 750 – 800 mm. However,
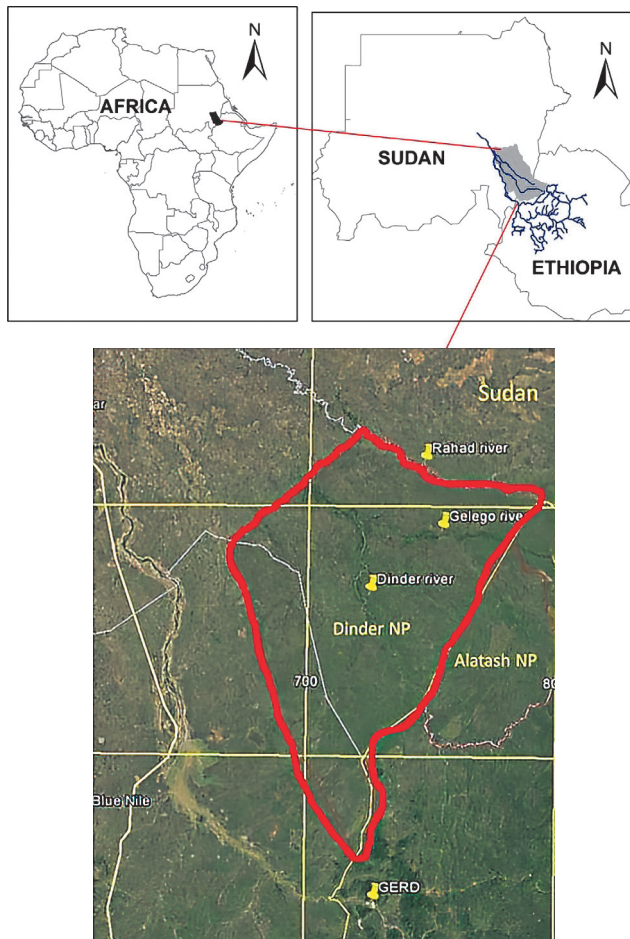

Figure 1. The map shows the location of the Study area (Dinder National Park). Map data 2022 © Google.

over the last ten years, the park witnessed three severe droughts that significantly affected biodiversity there and are thought to considerably contribute to the decline in abundance and diversity of many plants and animals in the park (though there is no empirical research done there yet to confirm/reject this argument).

According to (Basheer et al. 2016), vegetation cover of the DNP into three ecosystems: (1) Wooded grassland: dominated by species of *Acacia seyal*, *Balanites aegyptica* and *Combretum hartmannianum*. (2) Riverine ecosystem: riverine ecosystem occurs in the banks of Dinder and Rahad River. The forest is a multi-layered vegetation, dominated by *Hyphaene thebaica* (L.) Mart., *nilotica nilotica* subsp. *nilotica* and *Zizphus spina* Christi. (3) Maya ecosystem: is wetland (meadows) found along the flooded plains of rivers. They have been formed due to the meandering characters of the channel and nature of flows of their waters. They occupy low lying basin, meanders and oxbows. Mayas are the major parts of water courses that have been separated as Oxbow lake and depressions that get filled in the rainy season by rains or by the flood.

The dominated soil type is heavy, dark cracking clays (cotton soil or vertisols) within which sandy clay and sandy loam (entisols) are interspersed. According to the rating proposed by Abdelhameed et al. (1997), the soil pH of the DNP is moderately acidic in the Maya ecosystem (5.80) but neutral under Wooded grassland ecosystem (7.20), Riverine ecosystem fields (9.83).

Sample design

We set up (0.1 ha, 20 × 50 m plots) between January and August 2020. Using six spacing between baits as treatments (2.5; 3.3; 5; 6.7; 10 and 20 m, see Table 1). The transects and spacing classes among the baits were chosen because they are often (Groc et al. 2007). The transects were distributed within the 1 km² collection grid, with a minimum spacing of 200 m to each other. Drew the collection sequence of the transects to prevent transect with the same spacing between baits were always sampled at the same time, decreasing possible effects resulting from the daily variation of activity ants (Parr and Chown 2001). The transects effects the topography of ant community (Schoeman and Foord 2012), the transects were arranged into three diferent ecosystems (1) Wooded grassland, (2) Riverine, and (3) Maya. We offer at each collection point approximately 5 g of bait composed of the canned sardine mixture (600 g) and guava (500 g) on pieces of plastic card with dimensions of 10 by 7 cm. After 60 minutes, plenty of all species of ants present in the baits was recorded to the scale of richness proposed by Santos et al. 2018): 5.21–50 ants; 6> 50 ants; 4.11–20 ants ; 3.6–10 ants; 2.2–5 ants; 1.1 ants. Between 1 to 5 individuals of each ant species on the card were collected and preserved in 75% alcohol for laboratory. Specimens were identified using a single key to identify subfamilies, a series of keys to identify genera and a series of keys to identify species (Bingham 1903; Holldobler and Wilson 1990; Mathew and Tiwari 2000), and comparison with voucher specimens, comparison with type images available at AntWeb, AntWiki.

Table 1. Number of transects, Number of baits, and distance between baits 100 m transects distributed at DNP.

Number of transects	Number of baits per transect	Distance between baits (m)
5	41	2.5
5	31	3.3
5	21	5.0
5	16	6.7
5	11	10.0
5	6	20.0

Data analysis

We used a method analogous to sample rarefaction to control the effect of different sampling efforts (the number of baits per transect ranged from 6 to 41). For each transect, we calculated the average number of species sampled in 100 draws of five baits. In this way, all transects were left with the same number of subsamples over the comparative analyses, comparing the wealth and abundance between transects and assessing the effect of space between baits on community sampling. The effects of distance between baits on abundance of the ants and the number of species estimated by the draws (from here on denominated relative number of species and abundance relative, respectively) were investigated separately by Analysis of Variance (ANOVA). The possible effects of the distance between baits on the number of species collected by bait and the abundance of species per bait, which are estimates of the collection's efficiency, were also investigated by Analysis of Variance (ANOVA). As one of the objectives of this study is to determine which collection effort has the best relationship between between costs and number of ant species sampled and the number of species sampled, we compared the number of species collected by bait between treatments, and we corrected the level of significance resulting from comparisons multiple by the Bonferroni method. We use analysis to determine whether the distribution of the waste and the models used met the assumptions of the analyzes.

We constructed collector curves by treatment and all samples together to detail the potential effects of distance between bait in the sampling of ant species. Collector curve estimates by the process of rarefaction of samples (or individuals) the number of species expected to be randomized to the data set subsamples. We calculate the estimated number of species (using the Chao 1 indices, Jackknife 1, and Bootstrap) to indicate a minimum collection effort for the study area (Chao and Colwell, 2017). To provide a more comprehensive view of collection efficiency with bait, we compare our results with other works that have used this collection method in the Tropical Forest. The statistical program R (R Project for Statistical Computing) is used in all analyzes and graphs.

Results

In total, 165 species were recorded, distributed in six subfamilies and 42 genera (table 2). Myrmicinae was the most diverse subfamily (101 species), and *Tetramorium* was the most diverse genus (27 species) (occurring in 97 % of the locations).Subfamily Formicinae was the second most diverse (34 species), and it has the second most diverse genus, *Crematogaster* (10 species). Genera *Cataulacus, Monomorium* and *Pheidole* also stand out for having between (10 and 17 species), all belonging to the subfamily Myrmicinae, except for *Brachymyrmex* of the subfamily Formicinae.
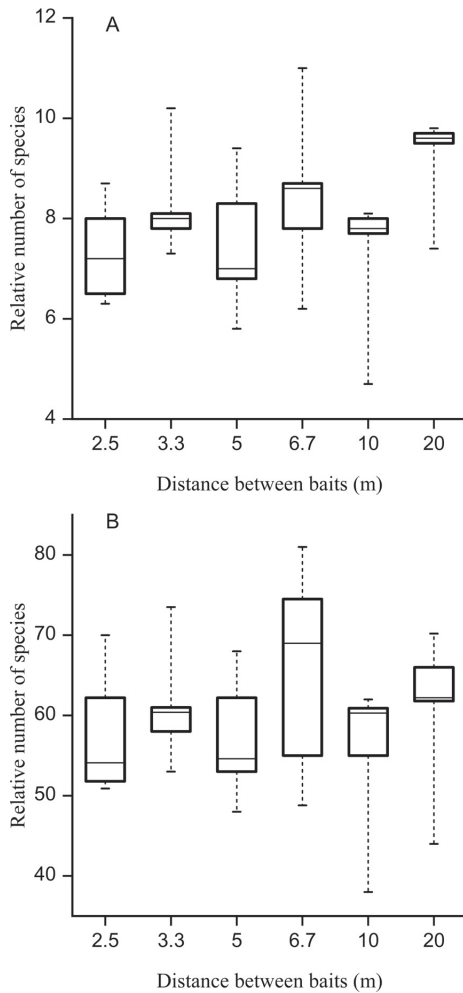

Figure 2. A Relative number of species and **B** relative abundance of ants in five baits in transects with a distance between baits ranging from 2.5 m to 20 m, sampled in Dinder National Park. The thickest horizontal line represents the median, the box the interquartile range, and the dashed lines the extreme values.

Table 2. List of ant species sampled in DNP. Occurrence of each species recorded within each of the three Ecosystem (Wooded grassland, Riverine ecosystem and Maya ecosystem).

Species/ Subfamily	Type of Ecosystems		
	Wooded grass land	Riverine ecosystem	Maya ecosystem
Subfamily Dolichoderinae			
Tapinoma carininotum Weber, 1943	X	X	
Technomyrmex moerens Santschi, 1913			
Technomyrmex pallipes Smith, F., 1876		X	
Subfamily Dorylinae			
Aenictus anceps Forel, 1910		X	
Aenictus bottegoi Emery, 1899		X	X
Dorylus brevipennis Santschi, 1910		X	
Dorylus fimbriatus Santschi, 1919		X	X
Dorylus fulvus Santschi, 1926			
Dorylus nigricans Santschi, 1923	X		
Dorylus nigricans molestus Gerstäcker, 1859			
Dorylus stanleyi Forel, 1909	X		
Dorylus sudanicus Santschi, 1917	X		
Parasyscia lamborni Crawley, 1923	X	X	
Parasyscia sudanensis Weber, 1942	X		
Zasphinctus rufiventris Santschi, 1915	X	X	
Aenictus rotundatus merwei Santschi, 1932		X	
Subfamily Formicinae			
Camponotus acvapimensis Mayr, 1862		X	
Camponotus aegyptiacus Emery, 1915		X	
Camponotus bayeri Forel, 1913		X	
Camponotus brutus Forel, 1886		X	
Camponotus carbo Forel, 1910		X	
Camponotus chapini Weber, 1943		X	X
Camponotus chapini ganzii Weber, 1943	X		
Camponotus cinctellus Santschi, 1939			
Camponotus diplopunctatus Emery, 1915		X	
Camponotus etiolipes Bolton, 1995	X	X	
Camponotus fellah Dalla Torre, 1893	X		
Camponotus hapi Weber, 1943		X	X
Camponotus galla Forel, 1894	X		
Camponotus hapi Weber, 1943		X	X
Camponotus kersteni Gerstäcker, 1871	X	X	
Camponotus maculatus Santschi, 1923	X	X	X
Camponotus pompeius cassius Wheeler, W.M., 1922		X	
Camponotus sericeus Santschi, 1926		X	X
Camponotus tricolor Weber, 1943		X	
Cataglyphis abyssinica Forel, 1904	X	X	
Cataglyphis albicans Roger, 1859		X	X
Cataglyphis aurata Menozzi, 1932		X	
Cataglyphis bicolor Fabricius, 1793		X	
Cataglyphis bicolor sudanica Karavaiev, 1912	X	X	

Table 2. (continued)

Species/ Subfamily	Type of Ecosystems		
	Wooded grass land	Riverine ecosystem	Maya ecosystem
Cataglyphis bombycina Roger, 1859	X	X	X
Cataglyphis savignyi Forel, 1894	X		
Cataglyphis viatica Christ, 1791		X	
Lepisiota canescens Santschi, 1935	X	X	X
Lepisiota capensis Santschi, 1935		X	X
Lepisiota capensis acholli Weber, 1943	X		
Lepisiota capensis issore Weber, 1943	X		
Lepisiota capensis minuta Forel, 1916		X	
Lepisiota capensis thoth Weber, 1943	X		
Lepisiota carbonaria Forel, 1910			X
Lepisiota frauenfeldi Finzi, 1936			
Lepisiota gracilicornis Forel, 1892	X	X	
Lepisiota megacephala Weber, 1943		X	
Lepisiota simplex Forel, 1892		X	
Subfamily Myrmicinae			
Atopomyrmex mocquerysi Santschi, 1923	X		
Calyptomyrmex brevis Weber, 1943		X	
Calyptomyrmex piripilis Santschi, 1923		X	
Cardiocondyla emeryi Bernard, 1948		X	
Cardiocondyla fajumensis Forel, 1913		X	
Cardiocondyla mauritanica Forel, 1890	X	X	
Carebara bartrumi Weber, 1943	X		
Carebara polita Santschi, 1914	X		
Carebara santschii Weber, 1943		X	
Carebara sicheli Mayr, 1862	X		
Carebara sudanensis Weber, 1943		X	X
Carebara sudanica Santschi, 1933	X		
Carebara vidua Santschi, 1912	X		
Cataulacus intrudens Santschi, 1917	X	X	
Cataulacus pygmaeus Santschi, 1911	X		
Cataulacus traegaordhi Weber, 1943		X	
Crematogaster acaciae Santschi, 1916	X		
Crematogaster aegyptiaca Santschi, 1914			X
Crematogaster aegyptiaca robusta Emery, 1877		X	
Crematogaster africana polymorphica Weber, 1943		X	
Crematogaster chiarinii Santschi, 1926		X	
Crematogaster chiarinii subsulcata Santschi, 1914		X	
Crematogaster chlorotica Emery, 1899		X	X
Crematogaster depressa fuscipennis Emery, 1899	X	X	X
Crematogaster flaviventris Santschi, 1910			X
Crematogaster gambiensis Forel, 1914	X	X	
Crematogaster gambiensis transversiruga Santschi, 1914	X		X
Crematogaster inermis Emery, 1926		X	
Crematogaster lango Weber, 1943		X	X

Table 2. (continued)

Species/ Subfamily	Wooded grass land	Riverine ecosystem	Maya ecosystem
	Type of Ecosystems		
Crematogaster latuka Weber, 1943		X	
Crematogaster lotti Weber, 1943			X
Crematogaster menilekii suddensis Weber, 1943			X
Crematogaster mimosae Santschi, 1914			X
Crematogaster nigriceps Consani, 1952	X	X	
Crematogaster pseudinermis Viehmeyer, 1923		X	X
Crematogaster pseudinermis muellerianus Finzi, 1939		X	
Crematogaster senegalensis Forel, 1922		X	
Crematogaster sewellii marnoi Mayr, 1895	X		
Crematogaster sjostedti Mayr, 1907	X	X	
Crematogaster sordidula molongori Weber, 1943		X	
Crematogaster zonacaciae Weber, 1943			X
Melissotarsus emeryi Santschi, 1914	X	X	
Meranoplus inermis Emery, 1895		X	
Meranoplus magrettii André, 1884		X	
Messor arenarius Santschi, 1938	X	X	X
Messor galla Santschi, 1928	X	X	
Monomorium abeillei André, 1884		X	
Monomorium afrum Forel, 1913		X	X
Monomorium arboreum Weber, 1943		X	
Monomorium areniphilum Santschi, 1911	X	X	
Monomorium bicolor Santschi, 1926		X	
Monomorium clavicorne Santschi, 1915	X	X	
Monomorium hercules Viehmeyer, 1923	X	X	
Monomorium kineti Weber, 1943		X	
Monomorium madecassum Forel, 1892	X	X	X
Monomorium mictilis Forel, 1910		X	X
Monomorium nitidiventre Emery, 1893		X	
Monomorium pallidipes Forel, 1910		X	
Monomorium parvinode Forel, 1894	X	X	
Monomorium pharaonis Linnaeus, 1758	X		
Monomorium salomonis Santschi, 1936	X		
Myrmicaria opaciventris congolensis Forel, 1909	X		X
Nesomyrmex angulatus Santschi, 1914	X		
Ocymyrmex celer Weber, 1943	X		
Pheidole aeberlii Emery, 1901			
Pheidole crassinoda ruspolii Emery, 1897		X	
Pheidole decarinata Santschi, 1929			X
Pheidole jordanica Saulcy, 1874	X		
Pheidole megacephala Santschi, 1937		X	
Pheidole megacephala impressifrons Wasmann, 1905	X		
Pheidole punctulata Santschi, 1937		X	X
Pheidole rugaticeps Emery, 1881		X	X
Lepisiota validiuscula Emery, 1897			

Table 2. (continued)

Species/ Subfamily	Type of Ecosystems		
	Wooded grass land	Riverine ecosystem	Maya ecosystem
Strumigenys serrula Santschi, 1910	X		
Temnothorax megalops Hamann & Klemm, 1967		X	
Tetramorium aculeatum Santschi, 1924		X	X
Tetramorium altivagans Santschi, 1914		X	
Tetramorium angulinode Santschi, 1910		X	
Tetramorium boltoni Hita Garcia, Fischer & Peters, 2010		X	
Tetramorium brevispinosum Stitz, 1910	X	X	
Tetramorium caldarium Roger, 1857	X		
Tetramorium cristatum Stitz, 1910	X		
Tetramorium delagoense Forel, 1894			X
Tetramorium eminii Forel, 1894	X	X	
Tetramorium gabonense Santschi, 1937		X	
Tetramorium ghindanum Forel, 1910			X
Tetramorium kestrum Bolton, 1980		X	
Tetramorium laevithorax Emery, 1895		X	
Tetramorium minusculum Weber, 1943		X	
Tetramorium uelense Santschi, 1923	X		
Tetramorium viticola Weber, 1943	X		
Tetramorium weitzeckeri Weber, 1943	X	X	
Tetramorium zonacaciae Weber, 1943	X	X	
Trichomyrmex abyssinicus Forel, 1894	X	X	
Subfamily Ponerinae			
Anochetus sedilloti Forel, 1900		X	
Anochetus sudanicus Weber, 1942	X	X	X
Bothroponera crassa Emery, 1877	X		
Bothroponera pachyderma Santschi, 1920	X		
Bothroponera soror Forel, 1907	X		
Fisheropone ambigua Weber, 1942	X		
Hypoponera dulcis Santschi, 1914	X		
Hypoponera jeanneli Santschi, 1938	X		
Hypoponera punctatissima Forel, 1895	X		
Leptogenys crustosa Santschi, 1914	X	X	
Mesoponera flavopilosa Weber, 1942		X	
Mesoponera ingesta Wheeler, W.M., 1922	X	X	X
Phrynoponera gabonensis Wheeler, W.M., 1922		X	X
Platythyrea cribrinodis Santschi, 1914	X	X	
Platythyrea modesta Emery, 1899		X	
Subfamily Pseudomyrmecinae			
Tetraponera natalensis cuitensis Forel, 1911		X	
Tetraponera natalensis usambarensis Forel, 1911		X	
Subtotal	**73**	**110**	**39**
Total	**222**		

The cumulative species curves tended to become more stable (Fig. 2). This study found that sampling sufficiency was 82.48% in wooded grassland (observed richness: 73; estimated richness: 81.88), 71.99% in the River ecosystem (observed richness: 110; estimated richness: 139.73), and 78.11% in the Maya ecosystem (observed richness: 73; estimated richness: 81.88) (observed richness: 39; estimated richness: 48.43). The relative number of species and the relative abundance of ants were similar between treatments (ANOVA, df = 2, $F_{5.24}$ = 0.723; p = 0.613 and $F_{5.24}$ = 1.601; p = 0.198). On average, the number of species collected with five baits, regardless of the distance between the baits, was approximately 8, and the abundance of ants, estimated by the scale of abundance in five baits per transect, was 35.1 (corresponding to approximately 300 individuals, Fig. 2).

The abundance of ant's per bait was similar in transects with a distance between different baits (ANOVA, df = 2, $F_{5, 24}$ = 0.253; p = 0.934). Regardless of the distance between baits, the average abundance was 6.81 on the abundance scale, that is, more than 50 individuals per bait (Fig. 3). However, the relationship between the numbers of species per collection effort varied between treatments. The number of species collected by bait was higher in transects with a greater distance between baits (ANOVA, df = 2, $F_{5.24}$ = 5.053; p = 0.002). Bait transects 20 m and 10 m apart collected approximately 50% more species per bait than transects with distant baits at 2.5 m and 3.3 m from each other (Fig. 3). Despite this, the number accumulation of species per treatment was similar (Fig. 4). The estimated number of species ranged from 127 to 140 species (Jackknife 1 = 140.0 ± 4.99; Chao1 = 137.3 ± 11.73 and Bootstrap = 127.0 ± 2.89), indicating that between 10 and 31% of the species have not been sampled.

Discussions

The distance between baits did not affect the number of species. Regardless of the distance between baits, five baits offered on the leaflet of this Park attracted an average of 8 species. The increase in new species was also between treatments, suggesting that the number of baits offered varied by magnitude, similarly sampled the local fauna. However, in transects with concentrated baits, the transects with a shorter distance between baits attracted proportionally fewer species per bait. Ant colonies forage more intensely on closer and more abundant resources (Nowrouzi et al. 2016; Maurice Kouakou et al. 2018), mainly in transects with more concentrated baits, the greater foraging intensity and eventual monopoly or dominance could prevent some species from accessing the resource offered. However, proportionately more baits were controlled by dominant species in transects with the highest distance between baits, suggesting a demand conflicting between behavioral response and density resources (see D'Cunha et al. 2013).

The variation in the size of the foraging area of the colonies can explain why we collect more species by bait in transects with more distant baits. In tropical forests,

the size of the foraging area of the colonies varies widely and is usually related to the size of the colonies and the nesting place. For example, ants that nest in usually form small colonies (10–100 individuals) and have a restricted foraging area around the nest (Azhagu et al. 2017). Other species (i.e., *C. tenuicula* and *Wasmannia auropunctata* (Roger), collected in this study) can form "supercolonies" or polyatomic colonies using several independent nesting sites, increasing the size of the colony foraging area (Khot et al. 2013; Subedi and Budha 2020; Eisawi et al. 2022). Like the species that have a habit of breeding polyatomic colonies, *Cataglyphis desertorum*, *Paratrechina longicornis*, and *Monomorium salomonis*, were found in 53% of the baits offered, it is
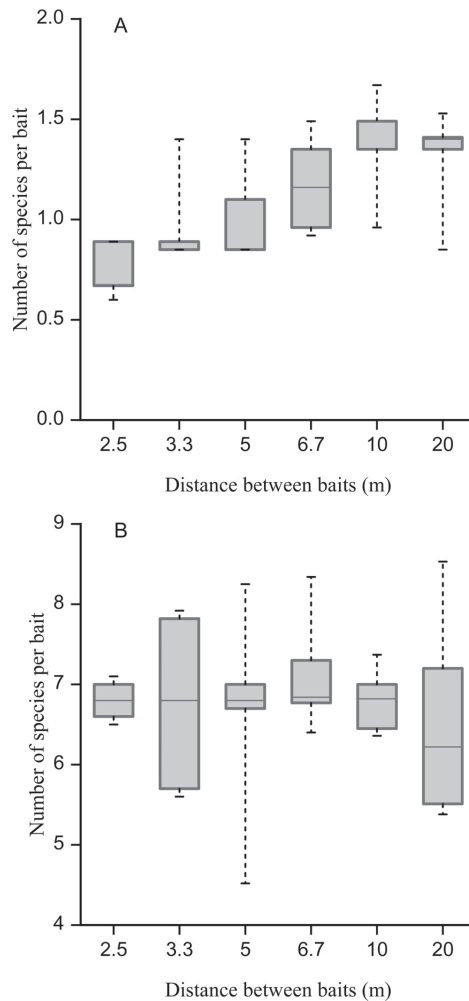

Figure 3. **A** Number of species and **B** abundance of ants per bait in transects with bait spans ranging from 2.5 m to 20 m, sampled in Dinder National Park. The thickest horizontal line represents the median, the box the interquartile range, and the dashed lines the extreme values.
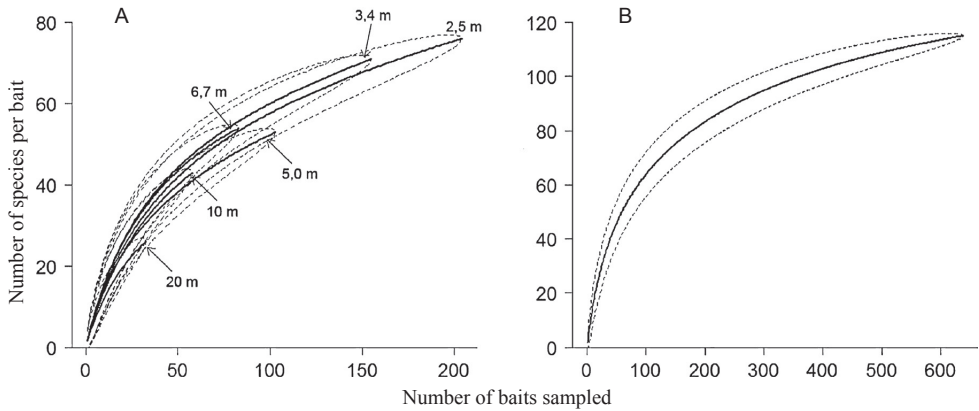
Figure 4. Curves of the collector (rarefaction) by treatment **A** and all combined transects **B**. The dashed lines represent the 95% confidence interval around the estimated values.

likely that in transects with a shorter distance between baits, proportionally more lures were offered within the area foraging of these species. The sampling of individuals from the same colony in several subsamples per transect results in a smaller number of species collected by bait in the transects with greater collection effort, that is, in transects with the shortest distance between baits.

Solitary animals look for available resources and the abundance of some insects is positively correlated with resource density (Amara et al. 2020). However, ants are social organisms and modular, having a relationship with the physical environment relatively similar to plants (Kosgamage 2012; Fotso Kuate et al. 2015). Ant colonies are relatively sessile and do not change locations due to ephemeral resources, as in this case, the baits. However, the energy balance between the amounts of energy needed for the maintenance of the colony and the amount of energy consumed in the food search is done at the colony level. Some species can regulate the foraging intensity depending on the number of available resources, decreasing the foraging in periods with less availability of resources and foraging more intensely in places with abundant resources (Szewczyk and McCain 2016). However, our results suggest that the distance between baits did not affect the abundance estimates of ants. Both in the comparisons with the standardized collection effort, as in the comparisons of the abundance of ants per bait, the number of individuals was similar among treatments. The variation in the density of resources may have regulated the foraging intensity of some species, but at the community level, this effect was imperceptible because the decrease in the abundance of some species can compensate for the increased abundance of other species. Also, the exposure time of lures may have masked possible variations in the number of ants attracted. Usually, competitive interactions stabilize in forest environments after 60 minutes of bait exposure (Fotso Kuate et al. 2015; Garcia et al. 2013). Of that way, the species that recruit en masse, which correspond to most of the species attracted by the baits, had time to concentrate a large number

Table 3. Place of collection, sampled area, number of baits used, and number of species collected available in studies that used attractive baits to collect ants in forest environments in the Tropical Area.

Location	Total sample area	Number of baits	Number of species	Source
savannah mosaic- West African forest	1.59	397	66	Yeo et al. 2017
moist semi-deciduous forest zone, Ghana	1.44	393	222	Stephens et al. 2016
KwaZulu-Natal, South Africa	7500	900	122	Hlongwane et al. 2019
Vhembe Biosphere Reserve, South Africa	127.5	680	115	Munyai and Foord 2015
Gamba, Gabon, central African forest	0.14	108	58	Yanoviak et al. 2008
Kenyan myrmecofauna	2.34	1040	98	Garcia et al. 2013
Southern Cameroon	100	630	112	Fotso Kuate et al. 2015

of individuals, often more than 50 individuals, that is, value 6 (maximum) of the scale of plenty around the bait.

The total number of species sampled in this work was similar to that reported in the literature for other regions' forests in the Africans (Table 2). The difference between the number of species sampled by previous studies (58–122) probably due to the variation in the collection effort and the type of forest environment sampled (Table 2). Inventories with collection effort concentrated in relatively small (Yeo et al. 2017) sampled fewer species than studies with an effort to collect systems distributed in larger areas (Stephens et al. 2016; Hlongwane et al. 2019; Eisawi et al. 2022). This result is expected because areas larger ones are usually more heterogeneous, and more heterogeneous species often harbor more species than areas smaller and more homogeneous (Yanoviak et al. 2008). Ants are often described as thermophilic organism's (Garcia et al. 2013; Munyai et al. 2015). Forests drier may behave less attracted species of ant's baits than more humid forests (Table 2).

Conclusion

Baits are widely used to investigate the activity of terrestrial and arboreal ants, but also can be used to estimate the ant abundance and species richness, the inclusion of terrestrial invertebrates in environmental licensing processes, environmental impact reports, and biodiversity inventories demands greater attention in terms of sampling efficiency. A poorly sized collection effort can unnecessarily collect many invertebrates, burdening the research team to process the collected material and make the final product. On the other hand, if the collection effort is insufficient, the inventory will underestimate the diversity of a location and may lead to misleading

conclusions. One way to estimate the number of species in a location is to conduct random collections and produce a species accumulation curve. However, asymptote or curve stabilization is usually achieved in taxa with reduced species, such as alligators and turtles. Our results suggest that to sample 80% of the species, taking into account the most conservative estimate (Bootstrap), it would be necessary to distribute approximately 450 baits in the soil of this forest. If the study's objective is to quickly inventory and with less collection effort as many species as possible, the most efficient sampling of this collection method would be to distribute 450 baits every 10 m or 20 m across the DNP. This sampling design would be the most efficient in terms of financial cost/number of species sampled.

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