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Biomass and Population Structure of *Constrictotermes cyphergaster* (Silvestri) (Isoptera: Termitidae) in the Dry Forest of Caatinga, Northeastern Brazil

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Biomassa e Estrutura Populacional de *Constrictotermes cyphergaster* (Silvestri) (Isoptera: Termitidae) em Caatinga, no Nordeste do Brasil

RESUMO - A população e a biomassa de *Constrictotermes cyphergaster* (Silvestri) foram analisadas em uma área de caatinga da Paraíba, Nordeste do Brasil. Doze ninhos com tamanhos distintos foram aleatoriamente coletados, sendo seis na estação seca (novembro de 2004 e novembro de 2005) e seis na estação chuvosa (março de 2004). A população de soldados e operários variou de 4880 a 118800 indivíduos/ninho. A razão entre soldados e operários não variou entre as estações seca e chuvosa. A biomassa (peso úmido) de indivíduos variou de 13,9 a 408,8 g/ninho. Os soldados e os operários apresentaram significativamente maiores biomassas na estação chuvosa. A densidade estimada de ninhos de *C. cyphergaster* foi de 59,0 ± 22,53 ninhos ativos/ha. Dados quantitativos das colônias e da abundância de ninhos revelaram que *C. cyphergaster* possuía cerca de 278,2 indivíduos/m^2, com aproximadamente 0,9 g (peso fresco)/m^2. Esses valores populacionais sugerem que *C. cyphergaster* pode participar ativamente do consumo de matéria orgânica vegetal, sendo importante na ciclagem de nutrientes e no fluxo de energia na caatinga.

PALAVRAS-CHAVE: Neotropical, semi-árido, Nasutitermitinae, colônia, abundância

ABSTRACT - Biomass and population structure of *Constrictotermes cyphergaster* (Silvestri) were studied in an area of dry forest of caatinga in the State of Paraiba, northeastern Brazil. Twelve nests of different sizes were randomly collected, being six during the dry season (November 2004 and 2005) and six during the wet season (March 2004). Soldier and worker populations varied between 4880 and 118800 individuals per nest. The ratio between soldiers and workers did not significantly vary between seasons. Biomass (measured as fresh weight) of individuals varied between 13.9 and 408.8 g per nest, and soldiers and workers had significantly greater biomass during the wet season. The estimated density of nests of *C. cyphergaster* was 59.0 ± 22.53 active nests/ha. Quantitative data of the study colonies and data on the nest abundance showed that *C. cyphergaster* encompassed some 278.2 individuals/m^2, with approximately 0.9 g (fresh weight)/m^2. These data suggest that *C. cyphergaster* is an important consumer of vegetal matter and, therefore, an important species affecting the nutrient cycling and energy flow in the caatinga vegetation.

KEY WORDS: Neotropical, semi-arid, Nasutitermitinae, colony, abundance

Termites play an important role in tropical ecosystems, acting as mediators in the process of decomposition of litter and in the transfer of materials of pedologic and organic origins, given their foraging habits and building behavior (Lee & Wood 1971, Wood & Sands 1978, Black & Okwacol 1997). In arid and semi-arid environments, termites are considered keystone organisms for the maintenance of the structural and functional integrity, playing an important role in the nutrient cycling and maintenance of soil moisture (Holt 1987, Holt & Coventry 1990, Whitford 1991).

The quantification of abundance and biomass in ecological studies represent two of the most important aspects for the evaluation of the functional role of a species, or an assemblage, of termite in a given environment. Nevertheless, quantitative data on termite populations, such as density, are scarce in Neotropical ecosystems in general, and also in areas of

Savanna such as the Brazilian caatinga and cerrado (Martius 1994). The caatinga vegetation is a mosaic of xerophytic, deciduous, scrub and forest that covers some 735,000 km^2 of the Brazilian northeastern region. This formation is surrounded by the forested regions of the Amazon Forest to the west, the Atlantic Forest to the east and the savannas of the cerrado to the south.

The Neotropical termite *Constrictotermes cyphergaster* (Silvestri) is known to occur in the Savanna of central Brazil, Paraguay, Bolivia and northern Argentina (Mathews 1977, Constantino 1998). Studies have reported the occurrence of this species in some areas in the Brazilian caatinga (Godinho *et al*. 1989, Mélo & Bandeira 2004). In the caatinga, this is the main termite species that builds conspicuous nests (Mélo & Bandeira 2004). Their active nests can harbor many individuals, including other species of termites, such as *Inquilinitermes fur* (Silvestri) or *I. microcerus* (Silvestri), which are considered obligatory inquilines (Mathews 1977, Cunha & Brandão 2000).

This study aims to quantify the population and the biomass of soldiers and workers of 12 colonies of *C. cyphergaster* and, in association with data on nest abundance, estimate the size of the population of this species in an area of caatinga in the Northeast of Brazil.

Materials and Methods

This study was performed at the Reserva Particular do Patrimônio Natural Fazenda Almas (RPPN Fazenda Almas) (07° 28' S; 36° 52' W), a private reserve located in an area of caatinga in the State of Paraiba, Northeast Region of Brazil. The RPPN Fazenda Almas encompasses an area of 3505 ha at an altitude ranging between 600 m and 720 m a.s.l, and the annual average precipitation is 560 ± 230 mm. Rainfall is concentrated between February and April, and the average annual temperature and humidity are 25°C and 65%, respectively (Governo do Estado da Paraíba 1985).

Twelve nests of *C. cyphergaster* with different sizes were randomly collected, being six (A, B, C, D, E and F) during the dry season (November 2004 and 2005) and six (G, H, I, J, L and M) during the wet season (March 2004). Nest volume was estimated using formula for the hemiellipsoid: $V = 2/3\ \pi\ h \cdot D \cdot d$, where h = nest height, D = ½ of the wider diameter and d = ½ of the narrower diameter. In cases where the nest was build surrounding a tree trunk, the volume of the trunk was also estimated and subtracted from the nest volume.

Upon removal, the nests were weighed, fragmented and aspersed with alcohol 96%, to euthanize and partially dehydrate the termites. The nest fragments were exposed to the sun for about 2h to allow the individuals to be further dehydrated. Then, the nest fragments were put in water and the individuals were removed after floatation, and preserved in alcohol (Bandeira & Vasconcellos 2002). Although this technique was successful for the extraction and quantification of soldiers and workers, it was ineffective for the extraction of eggs and larvae. Furthermore, the presence of two species of termites (*C. cyphergaster* plus *I. fur* or *I. microcerus*) within the same nest does not allow the species larvae to be separated efficiently. On the other hand, nymphs, alates and reproductives were easily distinguished, given that the mandibles of *Constrictotermes* and *Inquilinitermes* are very different.

Population size per nest was quantified based on five sub-samples of 3.5 ml randomly taken from each nest collected after they were homogenized. The sub-samples were weighed and had the individuals counted to estimate the population size and biomass per nest. One sample per nest, with 100 individuals of each caste (soldiers and workers) of *C. cyphergaster*, was weighed in an analytical scale to estimate the mean fresh weight of each caste.

Nest density was estimated in 10 parcels of 100 m x 20 m, assigned randomly throughout the RPPN Fazenda Almas. Within each parcel, all nests with volume ≥ 0.1 L were counted and had their volume estimated. Therefore, the association between data on population size and biomass per nest and data on density of nests on each parcel enabled the estimation of the population size of *C. cyphergaster* throughout the study area.

Differences in the biomass of soldiers and workers between the dry and wet season were evaluated through the Student´s t-test. The ratio between soldiers and workers was tested with the chi-square test. We also regressed the values of volume x population, volume x biomass and volume x weight in order to obtain the equation for these data. All tests were done using the *Statistica* for Windows 5.5 (Statistica for Windows 1995).

Results

The studied nests of *C. cyphergaster* presented a range of coloration that varied from reddish brown to grayish brown, depending on the color of the nearby soil and the nest developmental stage. Nests were usually built on trees, but rocks can also be used as a substrate for nest construction (Fig. 1). Study nests had an average volume of 24.0 ± 18.15 L and an average weight of 19.7 ± 17.27 kg. Nest volume and weight were significantly correlated ($r = 0.98$; $P < 0.01$) (Fig. 2).

Kings and queens of *C. cyphergaster* were found in nine nests and were absent in nests A, D and I (Table 1). Nymphs were observed during both dry and wet seasons, but alates were found only during the wet season. Soldier and worker populations varied between 4,880 and 118,800 individuals/nest. The ratio between soldiers and workers did not vary between the dry and wet seasons ($X^2 = 0.63$; $P = 0.43$).

The average biomass of soldiers (wet season: 3.4 ± 0.41 mg of fresh weight; dry season: 2.6 ± 0.58 mg of fresh weight) and workers (wet season: 3.4 ± 0.50 fresh weight; dry season: 2.5 ± 0.50 fresh weight) was significantly different between seasons, being higher during the wet season than during the dry season (soldiers: t test = -3.8; df = 10; $P < 0.05$; workers: t test = -3.2; df = 10; $P < 0.05$). The population size and biomass of colonies were significantly correlated with nest volume ($r = 0.80$; $P < 0.01$ and $r = 0.72$; $P < 0.01$, respectively) (Fig. 3).

The estimated density of nests of *C. cyphergaster* with volume larger than 0.1 L was 59.0 ± 22.53 active nests/ ha

Fig. 1. Nests of *C. cyphergaster* in the RPPN Fazenda Almas, Paraiba State, Brazil. Ruler: 30 cm.

and 40.0 ± 14.14 abandoned nests/ ha. Quantitative data on population and biomass of colonies and abundance of nests revealed that *C. cyphergaster* has approximately 278.2 individuals/m^2 and 0.9 g (fresh weight)/ m^2, corresponding to some 2,782,000 individuals/ ha and 9 kg (fresh weight)/ha.

Discussion

The quantification of nest population has often been used as a tool to estimate termite abundance (Bandeira & Torres 1985, Martius & Ribeiro 1997). However, because the population of a nest may be spread over different microhabitats (e.g. soil, logs, litter), estimative from nest population alone may be conservative, as they are likely to target portions of the overall termite population (Martius & Ribeiro 1997). Nevertheless, in the case of *C. cyphergaster,* the quantification of colony size based on nests provides valuable population data, as long as it is done during daylight. The foraging of the colonies of this species occurs at night and all individuals involved in foraging events are back to the nest during early morning (Moura *et al*. 2006a).

In the present study, the relationship among nest volume and the colony´s population size and biomass indicates that most of the population was actually quantified. A positive correlation between volume and population size or biomass in the nests has been observed in other studies (see Darlington & Dransfield 1987, Martius & Ribeiro 1997). Nevertheless, the absence of such relationship can occur due to at least three factors: (i) when a great portion of the population is foraging out of the nest (Petersen & Luxton 1982, Martius & Ribeiro 1997); (ii) when a colony is in populational decline, or (iii) when polycalism is present in the colony, and two or more interconnected nests harbor a single colony (Vasconcellos & Bandeira 2006). In the latter, the migration of individuals to nests nearer food resources may lead to the population decline in nests farther from such resources.

Nymphs or alates were found in most nests, indicating that most colonies were mature. The king and the queen were not found in three nests, with volume smaller than 7 L. According to Noirot & Darlington (2000), arboreal termites, such as *Constrictotermes cavifrons* (Holmgren) and *Astalotermes*

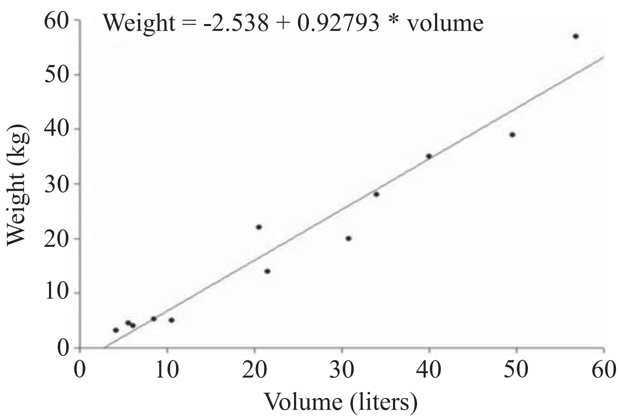

Fig. 2. Simple regression between volume and weight of 12 nests of *C. cyphergaster* in the RPPN Fazenda Almas, Paraiba State, Brazil.

Table 1. Population size and biomass (fresh weight) of 12 colonies of *C cyphergaster* during the dry and wet seasons in the RPPN Fazenda Almas, Paraiba State, Brazil.

Season	Nest	Nest weight (kg)	Nest volume (L)	Workers		Soldiers	
				Population size	Biomass (g)	Population size	Biomass (g)
Dry	A	3.2	4.2	2,937	9.05	1,943	5.60
	B	35.0	40.0	53,400	122.29	23,734	48.20
	C	20.0	30.8	30,006	69.01	13,417	26.30
	D	4.0	6.1	26,795	84.67	10,954	32.75
	E	14.0	21.5	7,388	25.56	2,036	5.44
	F	22.0	20.5	5,260	10.15	2,053	3.82
Wet	G	28.0	34.0	28,748	88.54	10,606	32.10
	H	39.0	49.6	91,194	287.26	27,604	85.00
	I	4.5	5.6	26,868	106.67	7,262	26.51
	J	5.0	10.5	24,336	67.17	8,296	24.64
	L	5.2	8.5	34,194	133.36	13,523	53.90
	M	57.0	56.8	83,030	309.70	30,289	99.10
Average		19.7 ± 4.9	24.0 ± 5.2	34,513.0 ± 8,158.9	109.5 ± 28.0	12,643.1 ± 2,825.2	36.9 ± 8.7
SD		17.3	18.2	28,263.6	97.2	9,786.8	30.3

Season	Individual weight (mg)		Ratio soldiers: workers	Reproductives	Nymphs	Alates	*Inquilinitermes* spp.
	Workers	Soldiers					
Dry	3.08	2.88	1.0:1.5				
	2.29	2.03	1.0:2.3	X	X		X
	2.30	1.96	1.0:2.2	X	X		X
	3.16	2.99	1.0:2.2		X		
	1.90	2.30	1.0:3.6	X			X
	2.30	3.40	1.0:2.5	X			X
Wet	3.08	3.03	1.0:2.7	X	X	X	X
	3.15	3.08	1.0:3.3	X	X		X
	3.97	3.65	1.0:3.7		X		X
	2.76	2.97	1.0:2.9	X	X		
	3.90	3.99	1.0:2.5	X	X	X	X
	3.73	3.41	1.0:2.7	X	X		X
Average	3.0 ± 0.2	3.0 ± 0.2	1.0:2.7				
SD	0.7	0.6					

spp., first establish the colony on the soil and, only after that, move to the tree, including the queen and king.

The record of 12 alates of *I. fur* (seven females and five males) in nest I with 5.6 L indicates that the colony of this species can be started in recently built nests of *C. cyphergaster*. In a study by Godinho *et al.* (1989), in a Cerrado area, *Inquilinitermes* spp. were observed only in nests with volume larger than 10 L.

In the caatinga, the swarming period of *C. cyphergaster* is usually between March and May (Moura *et al.* 2006b). That explains the fact that, in the present study, the alates were only found during the wet season, despite the fact that larvae and nymphs of several instars development were found during both seasons.

The difference in biomass of the soldiers and workers between dry and wet seasons is likely to be related to the

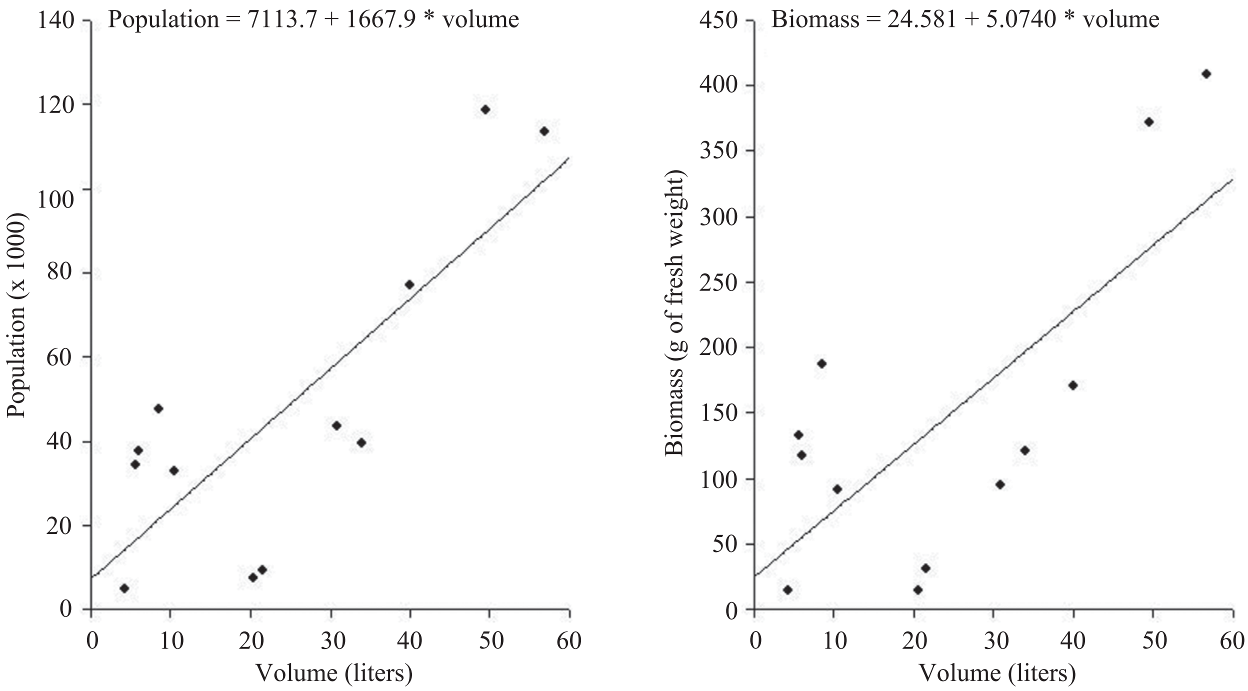

Fig. 3. Simple regression between volume and population size and volume and biomass of 12 nests of *C. cyphergaster*, in the RPPN Fazenda Almas, Paraiba State, Brazil.

seasonal variation in food resource availability and in the intensity of foraging activities, leading to the increase in weight of the castes during the wet season. Moura *et al.* (2006b) observed in the same area where this study was performed, that during the wet season, colonies of *C. cyphergaster* showed a significant increase in the recruitment of workers and in the frequency of foraging events. According to Buxton (1981), in the Savannas of Kenya, the foraging activity of termites is intensified during the wet season, leading to a higher consumption of wood.

The density of conspicuous nests with volumes larger than 0.1 L was within the range recorded in other ecosystems in the Neotropical region (Mathews 1977, Gontijo & Domingos 1991, Martius 1994). Apparently, the nests of *C. cyphergaster* represent an important structural element in the studied area of caatinga. According to Cunha & Brandão (2000), in an area of cerrado, active nests of *C. cyphergaster* may harbor organisms of several trophic levels. In the caatinga, the abandoned nests of *C. cyphergaster* are used as a refuge or spots for nidification and/or predation by a great variety of invertebrates, such as spiders, scorpions, ants, bees and even other species of termites (e.g. *Amitermes* sp. and *Diversitermes* sp.). There are also records of lizards and birds using active and inactive termite nests.

Besides *C. cyphergaster*, four other species of termite build conspicuous nests in the study area: *Microcerotermes strunckii* (Sörensen) (0.3 nests/ ha), *Microcerotemes* sp. (20 nests/ ha), *Nasutitermes corniger* (Motschulsky) (1.0 nest/ ha) and *N. macrocephalus* (Silvestri) (0.5 nests/ ha).

Overall, the abundance and biomass of *C. cyphergaster* were high, given the aridity of the study environment. In the more humid Neotropical forests, the abundance and biomass of termites (including species inhabiting the soil, wood, nests and litter) were estimated at 2,060-4,845 individuals/m^2 and 13-17 g (fresh weight)/m^2, respectively (Martius 1994, 1998; Bandeira & Vasconcellos 2002). In other systems termite populations are able to remove 20% to 50% of the annual production of litter, reaching almost 100% in some arid regions (Holt 1987, Whiford 1991). Thus, the population size of *C. cyphergaster* indicates that this species actively participates in the consumption of organic vegetal matter and nutrient cycling in the studied area of caatinga, significantly so in areas with high density of nests. The role of *C. cyphergaster* in the process of decomposition may be enhanced during the dry period, when the activity of decomposer microorganisms is limited due to the lack of water.

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