

Trap-nesting bees (Hymenoptera, Apoidea) in areas of dry semideciduous forest and caatinga, Bahia, Brazil

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ABSTRACT. In this study were examined the species richness and seasonal abundance of cavity-nesting bees in areas of dry semi-deciduous forest and caatinga in the State of Bahia, Brazil. Sampling was done employing two types of trap-nests: bamboo canes and tubes made of black cardboard with dimensions of either 58 x 6 mm or 105 x 8 mm. The traps were inspected once a month. One hundred and forty-six nests of 11 bee species were collected in the forest, and 121 nests of seven species were collected in the caatinga. Five species of cleptoparasitic bees were also reared from these nests. The highest nesting frequencies occurred in the wet season in both areas. Nests parasitism was important only for *Centris tarsata* Smith, 1874, and was higher at the caatinga site than in the forest. The mortality of pre-emergent adults was high, especially in *C. tarsata*, *Tetrapedia diversipes* Klug, 1810 and *Euglossa cordata* (Linnaeus, 1758). Information on the number of cells per nest, the size, shape, and arrangement of brood cells in the nests, as well as the number of adults produced and the number of generations per year are also presented. Species richness, temporal patterns of nesting, and percentage of parasitism were compared with other habitats. **KEY WORDS.** Nesting biology, solitary bees, South American dry forests, trap-nests.

RESUMO. **Abelhas (Hymenoptera, Apoidea) que nidificam em ninhos-armadilha em áreas de floresta semi-decídua e caatinga, Bahia, Brasil.** Neste estudo foram investigadas a riqueza de espécies e a abundância sazonal de abelhas que nidificam em cavidades em áreas de Floresta estacional semi-decídua e Caatinga na Bahia. A amostragem foi realizada com dois tipos de ninhos-armadilha (= N.A.): gomos de bambu e tubos de cartolina preta (58 x 6 mm e 105 x 8 mm). Os N.A. foram inspecionados uma vez por mês. Foram coletados 146 ninhos de 11 espécies de abelhas na floresta e 121 ninhos de sete espécies na caatinga. Além disso, cinco espécies de abelhas cleptoparasitas foram criadas a partir destes ninhos. As freqüências de nidificação mais altas ocorreram na estação úmida em ambas as áreas. Parasitismo de ninhos foi importante apenas para *Centris tarsata* Smith, 1874, e foi mais alto na caatinga do que na área de floresta. A mortalidade de adultos pré-emergentes foi alta, especialmente em *C. tarsata*, *Tetrapedia diversipes* Klug, 1810 e *Euglossa cordata* (Linnaeus, 1758). Informações sobre o número de células por ninho, tamanho, forma e arranjo das células nos ninhos, assim como o número de adultos produzidos e o número de gerações por ano foram também apresentados. A riqueza de espécies, os padrões temporais de nidificação e o percentual de parasitismo foram comparados com outros habitats.

PALAVRAS CHAVE. Abelhas solitárias, biologia de nidificação, florestas secas sul-americanas, ninhos-armadilha.

The use of trap-nests in studies with solitary bee species that nest in preexisting cavities has provide a considerable increase on the knowledge of biology of those species. Some of the studies were made to obtain information on the nesting biology (KROMBEIN 1967, STRICKLER *et al.* 1996, PEREIRA *et al.* 1999, MORATO *et al.* 1999, JESUS & GARÓFALO 2000, SILVA *et al.* 2001, AGUIAR & GARÓFALO 2004, ZILLIKENS & STEINER 2004), whereas other provide information on population dynamics (JAYASINGH & FREEMAN 1980), preferred habitats (FRANKIE *et al.* 1988, GATHMANN *et al.* 1994), reproductive biology of parasites which hosts nest in

trap-nests (SCOTT *et al.* 2000, GAZOLA & GARÓFALO 2003) and composition and seasonal patterns of communities (CAMILLO *et al.* 1995, GARÓFALO 2000, VIANA *et al.* 2001, AGUIAR & MARTINS, 2002; ALVES-DOS-SANTOS 2003). More recently, trap-nesting bees and wasps have been used in researches designed to evaluate the habitat quality (FRANKIE *et al.* 1998, TSCHARNTKE *et al.* 1998), the effects of habitat fragmentation and of the landscape complexity on community composition and predator-prey interactions (MORATO & CAMPOS 2000, MORATO 2001, STEFFAN-DEWENTER 2002, KRUESS & TSCHARNTKE 2002).

In this study we examine the richness and abundance of bee species that nest in preexisting cavities in relation to two different habitat types: caatinga (dry savana) and dry semi-deciduous forest. Furthermore, we provide information on several bionomical aspects of the species that occupied the traps.

MATERIAL AND METHODS

The study was conducted in an area of caatinga of Sempre Verde Farm, Ipirá (12°13'09"S, 39°49'53"W), Bahia, and in a dry semi-deciduous forest of Olhos d'Água Farm, Baixa Grande (12°00'29"S, 40°17'21"W), Bahia. The climate in Ipirá is semi-arid, with an average annual temperature of 23.7 °C (average maximum of 28.9°C and average minimum of 19.9 °C) and an average annual rainfall of 754 mm (range 157-1560 mm/year) (BAHIA 1994). During this study, the dry season extended from February/March to September/October. The rainy season started in October/November and continued until January/February, although it was interrupted by intermittent dry periods. The vegetation in the area is an open arboreal caatinga, often converted to pasture. In Baixa Grande, the climate ranges from dry to sub-humid. The average annual temperature is 23.6° C (average maximum of 29° C and average minimum of 19.7°C) and the average annual rainfall is 820 mm (range 368 - 1204 mm/year) (BAHIA 1994). During the study period, the rainy season began in October and extended until March/April, while the dry season started in April/May and ended in August/ September. The trap-nests were placed in a forest fragment surrounded by bean crop fields.

As described by CAMILLO *et al.* (1995), the trap-nests used consisted of hollow bamboo canes, which were cut so that a nodal septum closed one end of the cane, and tubes of black cardboard, with one end closed with the same material. The bamboo canes varied in internal diameter from 5.0 to 25.0 mm and had variable lengths. The tubes were of two sizes (length x internal diameter): 10.5 x 0.8 cm (= large tubes) and 5.8 x 0.6 cm (= small tubes). These tubes were inserted into horizontal holes drilled into wooden plates (54 holes per plate). The canes and the wooden plates were placed along steel shelves covered with a plastic tarpaulin in order to protect them from the sun and the rain. Two sampling sites were established in each area: one in a forest fragment (BG-I) and the other in a farm shed (BG-II), 600 m far from BG-I, in Baixa Grande; and one in a pasture (IP-III) and the other far 700 m, in an area of caatinga (IP-IV) in Ipirá. A total of 270 cardboard tubes of both sizes plus 100 bamboo canes were set up at each sampling site, except for site BG-II where 108 small tubes, 54 large tubes, and 50 bamboo canes were set up.

The trap-nests were inspected once a month from September 1999 to February 2001 in Ipirá, and from November 1998 to February 2001 in Baixa Grande. Each inspection was made with the aid of an otoscope. When traps contained complete nests, they were collected and replaced with empty ones. The traps occupied by females were marked and left at their

original places. If completed, such nests were removed to the laboratory in the next inspection. In the laboratory, each trap-nest was introduced into a transparent glass or plastic tube, 4.0-5.0 cm longer than the trap, with one end closed with a cork. As adult emerged into the glass/plastic tube, the trap was removed and the individuals were collected. The nests were kept at room temperature and observed daily until the adults emerged. A few days after the last emergence from any given nest occurred, the nest was opened and its contents analyzed. Cells and nests from which nothing emerged were also opened, and the cause and stage of mortality were recorded. Voucher specimens of bees are deposited in the CUFS collection, Universidade Estadual de Feira de Santana, Bahia.

Statistical tests follow ZAR (1984) and were performed by using the statistical package SigmaStat for Windows (1994-Jandel Corporation, San Rafael, CA). Chi-square tests were used to compare number of nests by area, immature mortality, and sex ratio. Pearson correlation analysis was performed to verify the intensity of association between frequency of nesting in each area and monthly rainfall. Throughout the text all means (x) are given \pm SD.

RESULTS

Bee species richness and abundance

The number of species that occupied the traps in Baixa Grande was higher than that observed in Ipirá (Tab. I). In addition to the listed species in table I, other five unidentified species used the traps: one species of *Centris* Fabricius, 1804 (one nest, at site BG-I) and one species of *Megachile* Latreille, 1802 (two nests at site BG-I and one nest at site BG-II) nested in Baixa Grande, one species of *Anthodiocetes* Holmberg, 1903 (one nest at site IP-IV) and one species of *Megachile* (*Dactylomegachile*) (five nests at site IP-III) nested in Ipirá, and one species of *Ephantidium* Moure, 1947 nested in both areas (two nests at BG-I, one nest at IP-III and four nests at IP-IV).

In Baixa Grande, of the 146 nests built by 11 bee species, 104 were collected at site BG-I and 42 at site BG-II. There was no difference between the frequencies of occupation of traps in relation to the number of exposed trap in each site ($\chi^2 = 1.18$; $df = 1$; $p = 0.277$). Of the 121 nests obtained from Ipirá, 52 were established at site IP-III and 69 at site IP-IV. These nests were built by females of seven bee species. Similar to found in Baixa Grande, there was no difference between the number of nests established in each site ($\chi^2 = 2.34$; $df = 1$; $p = 0.126$). Only four species nested in both areas and *Centris tarsata* Smith, 1874 was the most abundant species in Baixa Grande (37% of total nests) and also in Ipirá (55% of total nests) (Tab. I). The natural enemies associated with the nests were *Mesocheira bicolor* (Fabricius, 1804), *Coelioxoides waltheriae* Ducke, 1908, and one unidentified species of *Coelioxys* Latreille, 1809 in Baixa Grande, and *M. bicolor* and two unidentified species of *Coelioxys* in Ipirá.

In general, in both areas nesting occurred mainly from November to March (Tabs II and III), which corresponds to the

Table I. Trap-nesting bees and number of nests obtained in each sampling site in Baixa Grande (BG-I and BG-II), from November 1998 to February 2001, and Ipirá (IP-III and IP-IV), from September 1999 to February 2001.

Species	Number of nests per site			
	BG-I	BG-II	IP-III	IP-IV
Apidae				
<i>Centris tarsata</i> Smith, 1874	35	18	27	39
<i>Centris analis</i> (Fabricius, 1804)	3	6	–	–
<i>Euglossa cordata</i> (Linnaeus, 1758)	7	3	11	16
<i>Tetrapedia diversipes</i> Klug, 1810	24	3	–	–
<i>Xylocopa grisescens</i> Lepeletier, 1841	–	1	–	–
<i>Xylocopa frontalis</i> (Oliver, 1789)	24	–	1	5
Megachilidae				
<i>Dicranthidium arenarium</i> (Ducke, 1907)	5	9	–	–
<i>Dicranthidium luciae</i> Urban, 1992	1	1	–	–
<i>Megachile lissotata</i> Moure, 1943	–	–	7	4

Table II. Number of nests obtained monthly, from November 1998 to February 2001, in Baixa Grande, Bahia.

Species	Number of nests/month/year											
	J	F	M	A	M	J	J	A	S	O	N	D
	99/00/01	99/00/01	99/00	99/00	99/00	99/00	99/00	99/00	99/00	99/00	98/99/00	98/99/00
<i>Centris tarsata</i>	0/0/2	5/2/0	5/2	3/1	2/0				1/3	4/0	1/10/1	5/5/1
<i>Centris analis</i>						0/1	0/4	0/3			0/1/0	
<i>Euglossa cordata</i>	0/0/1		0/1			0/2		0/1			0/3/1	0/1/0
<i>Tetrapedia diversipes</i>	0/4/1	0/10/0	0/6	0/4							0/1/0	0/1/0
<i>Xylocopa grisescens</i>											0/0/1	
<i>Xylocopa frontalis</i>		0/4/0	0/4	0/2	0/2		0/3		0/1	0/1	0/0/6	0/0/1
<i>Dicranthidium arenarium</i>	0/5/1	0/4/0	0/3									0/1/0
<i>Dicranthidium luciae</i>			0/1									0/1/0

Table III. Number of nests obtained monthly, from September 1999 to February 2001, in Ipirá, Bahia.

Species	Number of nests/month/year											
	J	F	M	A	M	J	J	A	S	O	N	D
	00/01	00/01	00	00	00	00	00	00	99/00	99/00	99/00	99/00
<i>Centris tarsata</i>	5/4	10/4	4						0/2	0/1	10/5	11/10
<i>Euglossa cordata</i>	0/4	5/5	7		3				3/0			
<i>Xylocopa frontalis</i>	0/1	0/1		1					1		0/1	0/1
<i>Megachile lissotata</i>		3/1				1	2					4/0

period of greatest rainfall. In Baixa Grande, however, no significant correlation was found between the number of nests and the monthly rainfall during both years ($r = 0.39$; d.f. = 11; $p = 0.206$, for 1999 and $r = 0.33$; d.f. = 11; $p = 0.298$, for 2000), while in Ipirá the correlation was highly significant ($r = 0.72$; d.f. = 11; $p = 0.008$) for the period from January to December 2000.

Bionomical aspects of the species

Centris tarsata occurred in both areas (Tabs I, II and III). Females of this species used all types of trap establishing 72% of the nests in large tubes, 25% in bamboo canes and 3% in small tubes. The bamboo canes utilized by the bees ranged from 8 to 13 mm in diameter, but most nests (87%) were established in

canes either 9 mm or 10 mm. The bees constructed their nests with a mixture of sand and oil. Completed nests had two to three cells in small tubes, one to seven cells in large tubes, and two to 13 cells in bamboo canes. The analyses of the contents of 266 cells (133 from each area) showed a similar total mortality between Baixa Grande (52.6 % of the cells) and Ipirá (58.6 %) ($\chi^2 = 0.97$; d.f. = 1; $p = 0.323$). *M. bicolor* and two species of *Coelioxys* were the insect parasites associated with the nests. The parasitism rates were 11% and 16% in Baixa Grande and Ipirá, respectively. In Baixa Grande, *M. bicolor* was the main enemy, accounting for 73.3 % of all cells parasitized, while in Ipirá, other parasitic bees were the most destructive enemies, accounting for 63.6 % of all cells parasitized. In Baixa Grande, the sex ratio (4.5 males: 1 female) was significantly males biased ($\chi^2 = 36.5$; d.f. = 1; $p = 0.00$), while in Ipirá, it was not significantly different from 1:1 (1.1 males: 1 female; $\chi^2 = 0.15$; d.f. = 1; $p = 0.691$).

Centris analis Fabricius, 1804 nested in Baixa Grande only (Tabs I and II). Of the nine nests obtained, five were established in large tubes, three in small tubes, and one in bamboo cane. The cells were constructed with a material similar to fine wood chips. Completed nests had three cells in small tubes ($n = 3$) and four ($n = 3$) or five ($n = 2$) brood cells in large tubes, arranged linearly beginning at the back of the trap. The nest established in a bamboo cane had one cell only. The measurements of the cells ranged from 10 to 14.9 mm in length ($x = 12.7 \pm 1.8$ mm; $n = 7$) and from 6.8 to 7.6 mm in maximum width ($x = 7.3 \pm 0.3$ mm; $n = 8$). The nests constructed in small tubes and two of them constructed in large tubes had an empty vestibular cell at the entrance. In these nests the plug had been built at the entrance of the trap. From two nests six individuals emerged before the nests being removed to the laboratory. Of the remaining nests emerged five males and seven females, and seven cells contained dead immatures. These immatures died in the egg stage (1 cell), larval stage (1 cell), and pre-emergent adults (5 cells).

Xylocopa frontalis (Olivier, 1789) occurred in both areas (Tabs I, II and III) and nested in bamboo canes only. The traps utilized by bees had diameter higher than 18 mm, and 75% of the nests occupied traps ranging from 20 to 22 mm in diameter. The females scraped the inner walls of the bamboo cane with their mandibles producing sawdust, used to make the cell partitions.

Nests of *Tetrapedia diversipes* Klug, 1810 were obtained from Baixa Grande only (Tabs I and II). Of the 27 nests obtained, eight had been established in small tubes and 19 in large tubes. The bees constructed their nests with a mixture of sand and oil, and the number of cells per nest ranged from two to nine. The interval between collection date of the nests and adult emergence was about 8 weeks, but in two nests there were larva and pupa 8 months after they have been removed from the field. Of the 92 cells analysed, 43 cells produced males and females, one cell produced a male *C. waltheriae*, and 48 cells contained dead immatures that had died of unknown causes. The immatures

died in the egg stage (6 cells), larval stage (3 cells), pupal stage (9 cells), and as pre-emergent adults (30 cells). Of these 30 pre-emergent adults found dead in the cells, 22 of them were identified as male or female. These individuals together with those emerged from the 43 cells resulted in a total sex ratio not significantly different from 1:1 ($\chi^2 = 0.13$; df = 1; $p = 0.709$).

Euglossa cordata (Linnaeus, 1758) occurred in both areas (Tab. I) but nested with higher frequency in Ipirá (27 nests) (Tab. III) than Baixa Grande (10 nests) (Tab. II). The bamboo canes utilized by bees ranged from 12 to 26.5 cm in length and from 1 to 2 cm in diameter. All of the nests had a resinous wall recessed from the trap entrance in which was a small circular hole just large enough for the female to pass. The distance from resinous wall to bamboo cane entrance ranged from 2 to 9.3 cm. In most cases, however, that distance was smaller than 5 cm. The nests did not show any inner wall coating; some of them had resinous particles deposited near the nest entrance. The number of cell per nest ranged from 1 to 12, but 88.6% of the nests contained 1-6 cells only. The cells were made of dark or pale brown resin and 11.2 – 15 mm long ($x = 12.6 \pm 0.8$ mm; $n = 16$) by 7.2 – 10 mm in maximum diameter ($x = 7.9 \pm 0.6$ mm; $n = 16$). The cells were constructed in rows (two parallel rows in the nest with 12 cells) with the long axes tending to be vertical or inclined. They could be found in isolated series with the cells of each series built in close contact or some cells could be isolated and other cells could be together. In general, adults emerged 7 to 8 weeks after nests were removed from the field, and 59 days was the maximum interval between collection date of the nest and adult emergence. In Baixa Grande, adult bees emerged from 22 of 28 constructed cells in the nests; the six remaining cells contained dead pre-emergent adults. The sex ratio of 28 individuals produced in the nests, emerged ($n = 22$) and dead in the cells ($n = 6$), was 53.6% females to 46.4% males, which is not significantly different from a 1:1 sex ratio ($\chi^2 = 0.14$; df = 1; $p = 0.705$). In addition to the 14 males and 8 females that were produced from the nests collected in Ipirá, 7 males and 15 females were found dead in the cells. Considering the live and dead individuals together, the sex ratio was 52.3 females to 47.7 males, which is not significantly different from a 1:1 sex ratio ($\chi^2 = 0.09$; df = 1; $p = 0.763$).

Dicranthidium luciae Urban, 1992 and *Dicranthidium arenarium* (Ducke, 1907) were recorded in Baixa Grande only (Tabs I and II). *D. luciae* nested in small tubes. Three females and six males emerged from the two nests. *D. arenarium* established its nests in small tubes ($n = 13$) and bamboo cane ($n = 1$). The cells of both species were constructed with a hardened resinous material, pale brown in colour, and arranged in a linear series, forming a continuous cylindrical structure. In most nests there was a single row of cells, but two parallel rows were found in some nests. For both species, emergence of adults occurred 28-32 days after nests were removed from the field. Of the 46 brood cells built in the 14 nests of *D. arenarium*, only 25 (54.3%) produced adult bees: 15 males and 10 females. The

remaining cells ($n = 21$) contained dead immatures from unknown causes. The immatures died in the egg stage (4 cells), larval stage (9 cells), and pre-emergent adults (8 cells). The individuals emerged together with the males and females found dead in the cells, resulted in a total sex ratio not significantly different from 1:1 ($\chi^2 = 1.48$; $df = 1$; $p = 0.223$).

Megachile lissotata Moure, 1943 occurred in Ipirá only (Tabs I and III). The nests were established in bamboo canes 10.2-19.1 cm long and 0.7-1.1 cm in diameter. The first cell was always constructed in the end of the trap. Subsequent cells were constructed with their bases adjoining the closing of earlier cells so the cells formed a continuous linear series. The inner end of the cell and the cell walls were made with overlapping leaf pieces. The number of brood cells per nest ranged from two to five and they were 8-12.5 mm long ($x = 10.4 \pm 1.3$ mm; $n = 17$) by 5.7-6.8 mm in outer diameter ($x = 6.2 \pm 0.4$ mm; $n = 17$). The cells were closed by up to six circular leaf pieces. The nest plugs were usually made with 12-14 circular leaf pieces, and they were built recessed from the trap entrance. The distance from nest plug to trap entrance was usually longer than 8 cm.

DISCUSSION

Species richness and abundance

In the studies carried out in Brazil with trap-nests, the species richness of bees nesting in such cavities has been highly variable. This variation, however, must be interpreted cautiously because, in addition to the potential diversity of species in the study area (ALVES-DOS-SANTOS 2003), the results can be affected by different man-made nesting materials (BOSCH 1995), trap-nest diameter (VANDENBERG 1995), height of trap-nests in relation to ground level (MORATO 2001), exposure of trap-nests to sun (FRANKIE *et al.* 1988), availability of natural preexisting cavities (VIANA *et al.* 2001), and by the period of sampling. Irrespective of these variables, some general patterns has emerged from the studies made. As observed in the present study, the community structure shows most species with few nests and few species with many nests, and forested habitats have shown higher species richness than habitats with open vegetation (CAMILLO *et al.* 1995, GARÓFALO 2000, MORATO & CAMPOS 2000, VIANA *et al.* 2001). Although the period of sampling in Baixa Grande was larger than in Ipirá, the species richness found for the period in which both areas were simultaneously sampled was highest in Baixa Grande. Therefore, the differences between habitats may be associated with corresponding differences in plant species number in each of them since habitats with high floral diversity offer better and richer food resources for the bees, thereby supporting more bee species (HEITHAUS 1979, GATHMANN *et al.* 1994, TSCHARNIKE *et al.* 1998).

The highest trap-nesting bee species richness has been found in studies made in mesophilic semi-deciduous forests in the state of São Paulo. From two sampling sites in Cajuru, CAMILLO *et al.* (1995) reported the occurrence of 25 and 21 species nest-

ing in those habitats, and in Serra do Japi (Jundiá), 17 species nested in the traps (GARÓFALO 2000). These figures as also that found by MORATO & CAMPOS (2000) in Amazonic forest (Central Amazonia, 14 species), are higher than that obtained in this work in a dry semideciduous forest (Baixa Grande, 11 species). On the other hand, the species richness in the caatinga in Ipirá (7 species) was similar to that found for sand dunes areas in Salvador, Bahia (7 species) by VIANA *et al.* (2001), and higher than those reported by AGUIAR & MARTINS (2002) for habitats of open savanna (5 to 8 species) and closed forest at Guaribas Biological Reserve (2 species, in Mamanguape, Paraíba). The low species richness of bees found in the caatinga and in the sand dunes coincides with the patterns observed from collecting of bees at flowers (MARTINS 1994, AGUIAR & MARTINS 1997, VIANA 1999, VIANA & ALVES-DOS-SANTOS 2002, AGUIAR & ZANELLA 2005). According to some authors (GARÓFALO 2000, VIANA *et al.* 2001) the species richness found in their studies may be underestimated because not all species present in the habitats were attracted to nest in the traps. Considering that *C. analis*, *T. diversipes*, *D. arenarium* and *D. luciae* are species that occur in the caatinga (ZANELLA 2000), the absence of them in the samples from Ipirá indicates that the species richness found in this work can be also underestimated. Thus, as pointed out by GARÓFALO (2000), multiple sampling stations within habitat are necessary to a better knowledge on the number of species present in that habitat.

The studies made in Brazil have shown that *Centris* species are usually those that nest at highest frequency in trap-nests (CAMILLO *et al.* 1995, MORATO & CAMPOS 2000, VIANA *et al.* 2001, AGUIAR & MARTINS 2002). In northeastern region has been observed a predominance of nesting by *C. tarsata* in semi-deciduous forest (37% of the total of nests in this work), in the Atlantic forest (58%) and coastal savanna (39% - 52%) (AGUIAR & MARTINS 2002) as well as in sand dunes (58%) (VIANA *et al.* 2001) and caatinga (55% in this work) areas. These data reveal, thus, that *C. tarsata* is successful in nesting in hot and open vegetation, in forest areas and in agricultural (as site BG-II) and human disturbed areas (as site IP-III) since there are available cavities. On the other hand, *C. analis* nested only in coastal savanna and in closed forest (AGUIAR & MARTINS 2002) and, as observed in this study, in forested areas. Although this species showed low nesting frequency in Baixa Grande, it was the second most abundant species at Guariba Biological Reserva (AGUIAR & MARTINS 2002). It is important to observe that while *C. tarsata* is a predominant species in some areas of the northeastern part of Brazil (VIANA *et al.* 2001, AGUIAR 2002, AGUIAR & MARTINS 2002, AGUIAR & GARÓFALO 2004), *C. analis* is, usually, the most abundant *Centris* species in forest fragments of the southeastern part (CAMILLO *et al.* 1995, GARÓFALO 2000).

Of the sampled species in the caatinga (this work), in sand dunes (VIANA *et al.* 2001) and in coastal savannas (AGUIAR & MARTINS 2002), only *E. cordata* e *C. tarsata* occurred in the three habitats. These environments share some similarities as the open vegetation, high temperatures and insolation and can

be characterized by showing low species richness (7 or 8 species nesting in traps) and a high nesting frequency by *C. tarsata*. Although the total number of nests in the caatinga was twice higher than that found in the sand dunes, the number of nests per species was similar, each area showing most nests distributed by two species while the remaining species nested few times (usually less than six nests each).

Nesting season

Fluctuations in annual frequencies of nesting, as occurred in this study, have also been reported by other authors (FRANKIE *et al.* 1993, 1998, MORATO *et al.* 1999, PEREIRA *et al.* 1999, VIANA *et al.* 2001, AGUIAR & GARÓFALO 2004) working with trap-nests. FRANKIE *et al.* (1998) suggested that such fluctuations would be a regular characteristic of cavity-nesting bee species, and that different species would be affected differently by climatic changes between years. According to FRANKIE *et al.* (1998), the yearly variations in nesting frequency could be driven by factors such as differential natural mortality, extreme annual climatic patterns (drought or above normal rainfall), or the disturbance of marginal habitats.

Although there was a tendency of the nesting activities occur in highest frequencies during the wet season in both areas, only in Ipirá the association between the two variables, frequency of nesting and monthly rainfall, was strongly positive. The absence of a similar association in Baixa Grande indicates, as observed in this study, that the duration of the favorable nesting period in this area is larger than that of Ipirá. *C. tarsata*, *E. cordata*, and *X. frontalis* showed long reproductive seasons, producing more than one generation per year. Other species were more seasonal, such as *T. diversipes* and *D. arenarium*. The great variation (from 8 weeks up to 8 months) in the egg-to-adult period of *T. diversipes* indicates that some of the progeny produced at the end of the reproduction season (March, April) enter diapause. Similar observations were reported by ALVES-DOS-SANTOS *et al.* (2002), for *T. diversipes*, and CAMILLO (2000), for *Tetrapedia curvitaris* Friese 1899, nesting in the state of São Paulo. Some of the progeny of *C. tarsata* also undergo diapause in at least one of the generations during the year (AGUIAR & GARÓFALO 2004). The occurrence of diapause in mature larva and pupa can be viewed as a survival strategy during unfavourable environment periods, and can reduce the risk of local population extinctions (MARTINS *et al.* 2001). The temperature was high throughout the year (above 20° C) at both study sites, and probably did not directly affect the reproductive activities of solitary bees. It is possible that a low abundance of floral resources in the dry season (autum/winter) restrains reproduction, but more research is needed on the temporal fluctuations of this resource in order to fully test this hypothesis.

Some aspects of the nests

Nests of most of the species recorded in this study have been previously described by other authors who also studied aspects of the nesting biology of these bees, as for example

CAMILLO & GARÓFALO (1982) (*Xylocopa grisescens* Lepeletier, 1841 and *X. frontalis*), GARÓFALO (1992) (*E. cordata*), JESUS & GARÓFALO (2000) (*C. analis*), SILVA *et al.* (2001), AGUIAR & GARÓFALO (2004) (*C. tarsata*), and ALVES-DOS-SANTOS *et al.* 2002 (*T. diversipes*).

Considerable intraspecific variation in the number of cells per nest in different species was observed in this study. This variation may be related to the space available for cell construction (MICHENER & LANGE 1958), to the diameter of the trap-nest (VANDENBERG 1995, PARKER 1986), changes in quality or abundance of floral resources along the nesting season, and/or to the decline of the foraging capacity of older females (TORCHIO & TEPEDINO 1980). Variation in the fecundity of solitary bees also depends on the availability of floral resources and the duration of the nesting season (BOSCH 1994a, b, c).

Studies of tropical bees have shown that *C. analis* constructs from 1 to 3 nests, producing up to 9 cells per female (JESUS & GARÓFALO 2000), while *Centris vittata* Lepeletier 1841 produces a maximum of 11 cells per female (PEREIRA *et al.* 1999). In the present study, the maximum number of cells recorded in a nest of *C. tarsata* was 13, considerably greater than previous reports for this species (8 cells) (SILVA *et al.* 2001). At another site (Monte Santo, Bahia), a nest of *C. tarsata* had 15 cells which produced 11 males and 4 females (AGUIAR, personal observation). However, it will be necessary to mark the females and follow them through the nesting season in order to make more definitive evaluations of their reproductive capacity. The maximum number of cells observed for *E. cordata* nests was lower than the maximum recorded by BENNETT (1966) (13 cells), but greater than that reported by GARÓFALO (1992) (10 cells). Most nests had cell numbers within the variation reported by GARÓFALO (1992).

Several species only nested in bamboo canes, while *T. diversipes* preferred cardboard tubes. This suggests that the used material to build the trap-nests may also influence the choice of nesting cavities. Some species have shown variations in their acceptance of different kinds of trap-nests in different studies. In the present study, *E. cordata* established no nests in cardboard tubes, although this species has reportedly used cardboard trap-nest in sites where bamboo canes were not available (such as in Mamanguape, Paraíba) (AGUIAR & MARTINS 2002). GARÓFALO *et al.* (1993) noted a preference of *Euglossa* Latreille, 1802 females for bamboo canes. This species will also nest in other cavities, such as old nests of *Xylocopa* Latreille, 1802 dead tree trunks, and wooden boxes (GARÓFALO 1992). *Xylocopa* females need sawdust to construct cellular partitions and this restricts the use of traps that do not provide this material. The nests of these species have been reported in tree trunks (CAMILLO & GARÓFALO 1982) and in pieces of sawn wood (VIANA *et al.* 2001, OLIVEIRA-FILHO & FREITAS 2003). Besides allowing the observation of intra-nest behaviour, trap-nests made of bamboo canes can be a cheap alternative for rearing and managing *Xylocopa* populations used in crop pollination.

The utilization of different kinds of materials as trap-nests as well as a variety of cavity dimensions mainly of bamboo

canes, allowed nesting by bee species of many sizes, and with different preferences for nesting cavities. So the sampling technique efficiency is improved with the use of several kinds of trap-nests.

Some of the native pollinators observed in this study, mainly *C. tarsata* and *X. frontalis*, show a potential for management as crop pollinators (FREITAS 1997, FREITAS et al. 1999, FREITAS & OLIVEIRA-FILHO 2003), increasing the importance of further studies to elucidate details of their nesting biology and resource requirements, as well as techniques for their management and breeding.

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