ECOLOGY, BEHAVIOR AND BIONOMICS

Diversity of Social Wasps (Hymenoptera: Vespidae) in *Cerrado* fragments of Uberlândia, Minas Gerais State, Brazil

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Diversidade de Vespas Sociais (Hymenoptera: Vespidae) nos Cerrados de Uberlândia, MG

RESUMO - Estudos de levantamento de espécies são importantes para o conhecimento dos recursos naturais além de contribuírem com informações de características ecológicas de uma determinada região. Não há estudos dessa natureza abordando vespas sociais no Triângulo Mineiro. O presente estudo investiga a diversidade das espécies encontradas em fragmentos de cerrado em Uberlândia, MG, e sua distribuição temporal. O trabalho de campo foi conduzido de outubro de 2003 a setembro de 2004, realizando-se 43 amostragens utilizando as metodologias de busca ativa e amostragem pontual. Foram encontradas 29 espécies em 10 gêneros, destacando-se *Polybia* e *Polistes* com 51,7% dos espécimes coletados. *Mischocyttarus cerberus styx* Richards representou 26,5% do total de indivíduos registrados para busca ativa e *Agelaia pallipes* (Olivier) correspondeu a 57,6% para amostragem pontual. Duas espécies apresentaram primeiro registro para Minas Gerais: *Polybia striata* (Fabricius) e *M. cerberus styx*. Os fragmentos estudados apresentaram elevado índice de diversidade (H' = 0,66 a 1,16), grande quantidade de espécies raras e poucas espécies comuns. O método de amostragem pontual foi satisfatório para coletar as espécies mais comuns enquanto a busca ativa foi importante para a coleta de espécies raras. A metodologia de busca ativa foi mais eficiente, em termos de abundância, que a amostragem pontual, embora algumas espécies só tenham sido coletadas pelo método de amostragem pontual. Esses fatores revelaram que para efetuar um levantamento de vespas uma combinação de diferentes metodologias de coleta parece ser o mais indicado.

PALAVRAS-CHAVE: Vespa enxameante, método de amostragem, inventário

ABSTRACT - Sudies of species survey are important to know the available natural resources and to get useful information about the ecological characteristics of a specific area. There are not studies, on this issue, related to social wasps, in the Triângulo Mineiro region. The present study describes the diversity of species found in fragments of the *cerrado* region in Uberlândia, MG, and their temporal distribution. The field study was conducted from October 2003 to September 2004, and 43 samplings were carried out using active searching (24) and point sampling (19) methodologies. Twenty-nine species were found in 10 genera, *Polybia* and *Polistes* corresponding to 51.5% of the total listing. *Mischocyttarus cerberus styx* Richards represented 26.5% of the total individuals recorded by active searching and *Agelaia pallipes* (Olivier) corresponded to 57.6% by point sampling. Two species had their first record for the state of Minas Gerais: *Polybia striata* (Fabricius) and *M. cerberus styx*. The studied fragments presented a high level of diversity (H' = 0.66 to 1.16), a large number of rare species and a few common species. To collect the more common species the point sampling method was satisfactory while active searching was better to collect the rarer species. The active searching methodology was more efficient than point sampling, however some species could only be collected by point sampling. These factors showed that in order to carry out a wasp survey, a combination of different collection methodologies seems to be more appropriate.

KEY WORDS: Swarm founding wasp, sampling method, inventory

Survey and identification studies of genera and species, both for animals and plants, are important to make known the available natural resources in a specific area, besides contributing to the study of the ecological characteristics of an ecosystem. Species richness and diversity calculus can only be applied after the relative occurrence and abundance of the species in a specific area are assessed (Marques *et al*. 1993, Ricklefs 2003).

Though Brazil has one of the largest entomofauna in the world, its hymenopterans, including wasps, are not well known, mainly when species diversity is concerned (Diniz & Kitayama 1994, 1998; Raw 1998a; Lima *et al*. 2000; Silveira 2002). There are not studies related to this issue in the Triângulo Mineiro region, in Minas Gerais State.

According to Carpenter (1993) and Carpenter & Marques (2001), the Vespidae family is composed by seven monophyletic subfamilies, being one yet extinct (Priorvespinae). The family includes solitary wasps (Euparigiinae, Masarinae and Eumeninae) and wasps with some degree of socialization (Stenogastrinae, Polistinae and Vespinae). The major part of filogenetic studies based on morphology and behavior point out that Stenogastrinae is directed linked to Polistinae and Vespinae (Carpenter 1993, Brothers 1999). Schmitz & Moritz (1998) worked with molecular taggers and suggested a parafiletic relationship between Vespidae and Apidae. Members of Masarinae, Eumeninae and Polistinae occur in Brazil; they constitute the richest fauna of wasps in the world with more than 302 species, being 104 endemic (Carpenter & Marques 2001).

Originally the Cerrados occupied 25% of the Brazilian territory (Goodland 1971, Eiten 1972), being the biome with the largest biodiversity among the savannas. Nevertheless, there are only a few studies on the distribution, colony density and species seasonality of social wasps from the *cerrado*. The few existing studies were carried out in the state of Mato Grosso (Diniz & Kitayama 1994, 1998), Distrito Federal (Henriques *et al.* 1992, Raw 1998b) and São Paulo (Mechi 1996, Mechi & Moraes 2000).

Generally, surveys of animal species from the *cerrado* are rare, even though it is one of the most endangered ecosystems in the world (Oliveira & Marquis 2002). The present study aimed mainly at contributing to a better understanding of the social wasp species present in the *cerrado* region, testing methodologies for their finding and recording. Data were also obtained in order to understand how the different species are distributed along the *cerrado* fragments in the Triângulo Mineiro region.

Material and Methods

Study area. The work was conducted in *cerrado* areas at the Reserva Ecológica do Clube de Caça e Pesca Itororó de Uberlândia (CCPIU) (15º57'S, 48º12'W; altitude 863 m; 640 ha); at the Estação Ecológica do Panga (EEP), of the Universidade Federal de Uberlândia (UFU), registered in IBAMA as a Natural Patrimony Private Reserve – (RPPN), Uberlândia, MG (19º09'S, 48º23'W; altitude 840 m; 400 ha); at the Fazenda Experimental do Glória, UFU) (1000 m^2 study area); and in a *cerrado* fragment inside the urban perimeter (19º11'S, 48º27'W, 1000 m^2).

The vegetation at the ecological reserve of the CCPIU is characterized by the presence of *vereda*, humid field, *sensu-stricto cerrado*, mesophilic forest and gallery forest (Appolinario & Schiavini 2002). At the Estação Ecológica do Panga, *vereda*, humid field, dirty field, *cerrado* field, *sensu-stricto cerrado*, *cerradão*, semideciduous mesophilic slope forest and gallery forest are found (Schiavini & Araujo 1989). The Fazenda Experimental do Glória has sensu-stricto *cerrado* areas, orchards, pastures and gallery forests (Santos 2002). The vegetation inside the urban perimeter (Karayba neighborhood, in the city's south side) is constituted of *sensu-stricto cerrado*.

The region's climate is classified as Aw, megathermal, according to the Köppen scale, with two well defined seasons, a cold and dry one between April and September and a hot and humid one from October to March (Rosa *et al*. 1991). Meteorological data were provided by the weather station of the Universidade Federal de Uberlândia, Instituto de Geografia.

Species study, collection and recording period. Forty-three samplings were made, from October 2003 to September 2004, distributed regularly per season, on clear and sunny days, at the hottest times of day (9:00 am to 3:00 pm) corresponding to the highest wasp activity period (Prezoto *et al*. 1994, Andrade & Prezoto 2001, Lima & Prezoto 2003, Elisei *et al*. 2005).

Wasp species were collected by mean of active searching and point sampling methods. With the active searching methodology the sighted animals were captured by using an insect net. The collections (24, six per season) were done along trails, streams, investigations in the floral resources, tree trunks, leafs and termite colonies, being the samples performed in a randomly way. While with the point methodology, non-toxic baits were used, with orange juice, water and sugar based solution put in PET plastic bottles (Santos 1996). The wasps attracted by this resource fell into the solution and their wings became wet preventing their flight. Each trap was kept in the field for seven consecutive days; the material was gathered at the end of this period and packaged in moist form. Nineteen collections were done using this method.

The insects were taken to the laboratory for assembling and identification with the keys proposed by Richards (1978) and Carpenter & Marques (2001) and for comparisons between the entomological collections. Non identified species were sent to taxonomists (MCT – Pará e UNESP – Rio Claro). Voucher specimens are deposited in the collection of the Museu de Biodiversidade do Cerrado, Instituto de Biociência of the Universidade Federal de Uberlândia and in the collection of the Museu Emílio Goeldi - MCT, Belém, PA.

Statistical analyses. The data obtained in the present study were grouped per season for a better interpretation and comparison of the results (spring – October to December; summer – January to March; fall – April to June and winter – July to September).

For the diversity analyses, the Simpson's Index (λ) was used for finite populations, besides the Shannon-Wiener index (H') (Ludwig & Reynolds 1988). The values found for the Shannon-Wiener index were compared using the Student's T test (Ludwig & Reynolds 1988).

The species accumulation curve (Coleman's curve) was obtained by the EstimateS 7.0 program (Colwell 2004). Were used non-parametric estimators ACE (Abundance-based Coverage Estimator), ICE (Incidence-based Coverage Estimator), Jack-Knife 1, Jack-Knife 2 e Bootstrap. The data were randomized 100 times to remove the order effect in the sample, allowing a more suitable comparison of estimators and the curve of species accumulation (Colwell 2004). For the similarity coefficient the Jaccard Index was used (Ludwig & Reynolds 1988).

Results

Twenty-nine social wasps species distributed in 10 genera from Subfamily Polistinae were registered (Table 1). Five species were recorded during all seasons *Mischocyttarus cerberus styx* Richards, *Parachartergus pseudapicalis* Willink, *Polybia occidentalis occidentalis* (Oliver), *Polybia ignobilis* (Haliday), and *Polybia sericea* (Haliday). Only five species colonies were found (Table 1). The most frequent species collected with the

Table 1. Social wasp species (Polistinae) found in the Cerrado in Uberlândia, MG and their occurrence per season. The classification follows Carpenter (1993) and reviews in Carpenter & Marques (2001) (S – spring; Su – summer; F – fall; W – winter; + presence; - absence).

Tribe	Species	Season			
		S	Su	F	W
Polistini	*Polistes* (*Aphanilopteris*) *ferreri* de Saussure	+	+	-	+
	Polistes (*Aphanilopteris*) *versicolor* (Oliver)	+	-	-	-
	Polistes (*Aphanilopteris*) *simillimus* Zikán	+	+	-	-
	Polistes (*Epicnemius*) *cinerascens* de Saussure	-	-	+	-
	Polistes (*Epicnemius*) *subsericeus* de Saussure	-	-	+	-
	Polistes (*Epicnemius*) *billardieri ruficormis* de Saussure	-	-	-	+
	Polistes sp. 01	+	-	-	-
Mischocyttarini	*Mischocyttarus* (*Mischocyttarus*) *drewseni* de Saussure	+	+	-	+
	Mischocyttarus (*Kappa*) *latior* (Fox)	+	-	-	+
	Mischocyttarus (*Kappa*) *atramentarius* Zikán	-	-	+	-
	Mischocyttarus (*Monocyttarus*) sp. prox. *marginatus* (Fox)	-	-	+	-
	Mischocyttarus (*Monocyttarus*) *cassununga* (R. Von Ihering)	-	+	-	-
	Mischocyttarus (*Haplometrobius*) *cerberus styx* Richards†	+	+	+	+
Epiponini	*Polybia* (*Polybia*) *striata* (Fabricius)	-	-	-	+
	Polybia (*Apopolybia*) *jurinei* de Saussure	-	+	+	-
	Polybia (*Myrapetra*) *occidentalis occidentalis* (Oliver) †	+	+	+	+
	Polybia (*Myrapetra*) *ruficeps xanthops* Richards †	-	-	+	-
	Polybia (*Myrapetra*) *paulista* (H. Von Ihering) †	+	+	+	-
	Polybia (*Myrapetra*) *scutellaris* (White)	+	+	-	-
	Polybia (*Myrapetra*) *platycephala sylvestris* Richards	-	-	+	-
	Polybia (*Trichothorax*) *ignobilis* (Haliday)	+	+	+	+
	Polybia (*Trichothorax*) *sericea* (Oliver)	+	+	+	+
	Brachygastra lecheguana (Latreille)	-	-	-	+
	Synoeca surinama (L.)	-	-	+	-
	Parachartergus pseudapicalis Willink	+	+	+	+
	Chartergellus communis Richards	-	-	-	+
	Pseudopolybia vespiceps (de Saussure)	+	-	-	-
	Agelaia pallipes (Olivier)	+	+	-	+
	Apoica (*Apoica*) *pallens* (Fabricius) †	+	+	-	-

† Colonies found

active searching method was *M. cerberus styx* (26.5% of the total), followed by *Polybia paulista* (H. Von Ihering) (8.5%). For the traps, *Agelaia pallipes* (Olivier) represented 57.6%, followed by *P. sericea* (15.2%). Sixteen species were collected using only the active searching method and five species using only the point sampling method (Table 2).

The Fig. 1 shows the number of individuals and the number of species collected by active searching and point sampling methods compared to climatic data. During winter, an increase in the number of individuals and social wasp species collected by the point sampling method was seen (Fig. 1 c, d). Perhaps the dry season benefits nest foundation, considering that the strong rains of the early Springer in *cerrados* are enough cause the fall of leaves, trunks and sometimes trees.

The diversity indexes of the two sampling methods are presented in Table 3 showing significant differences between the Shannon-Wiener indexes for the active searching and point sampling ($t = -9.20\%$, $P < 0.05$).

Through the species accumulation curve (Coleman´s curve) (Fig. 2), it is possible to observe that the species richness for the two sampling types tends to increase with the addition of samples, not reaching an equilibrium point. The

Table 2. Social wasp species frequency in the Cerrado in Uberlândia, MG, Brazil, collected through active searching and point sampling.

Species	Frequency (absolute, relative)					
	Active searching		Point sampling		Total	
Agelaia pallipes (Olivier)	8	(0.68)	72	(5.76)	80	(3.31)
Mischocyttarus (*Haplometrobius*) *cerberus styx* Richards	31	(2.65)	-	-	31	(1.28)
Polybia (*Trichothorax*) *sericea* (Oliver)	7	(0.59)	19	(1.52)	26	(1.07)
Polistes (*Aphanilopteris*) *ferreri* de Saussure	5	(0.43)	9	(0.72)	14	(0.58)
Polybia (*Trichothorax*) *ignobilis* (Haliday)	7	(0.59)	6	(0.48)	13	(0.54)
Polybia (*Myrapetra*) *occidentalis occidentalis* (Oliver)	6	(0.51)	6	(0.48)	12	(0.50)
Polybia (*Myrapetra*) *paulista* (H. Von Ihering)	10	(0.85)	-	-	10	(0.41)
Parachartergus pseudapicalis Willink	9	(0.77)	-	-	9	(0.37)
Polistes (*Aphanilopteris*) *simillimus* Zikán	3	(0.26)	3	(0.24)	6	(0.25)
Polybia (*Myrapetra*) *scutellaris* (White)	6	(0.51)	-	-	6	(0.25)
Apoica (*Apoica) pallens* (Fabricius)	4	(0.42)	1	(0.08)	5	(0.21)
Polybia (*Apopolybia*) *jurinei* de Saussure	1	(0.08)	4	(0.32)	5	(0.21)
Mischocyttarus (*Mischocyttarus*) *drewseni* de Saussure	4	(0.34)	-	-	4	(0.17)
Polybia (*Myrapetra) ruficeps xanthops* Richards	4	(0.34)	-	-	4	(0.17)
Mischocyttarus (*Kappa*) *atramentarius* Zikán	2	(0.17)	-	-	2	(0.08)
Mischocyttarus (*Kappa*) *latior* (Fox)	2	(0.17)	-	-	2	(0.08)
Brachygastra lecheguana (Latreille)	-	-	1	(0.08)	1	(0.04)
Mischocyttarus (*Monocyttarus*) sp. prox. *marginatus* (Fox)	1	(0.08)	-	-	1	(0.04)
Mischocyttarus (*Monocyttarus*) *cassununga* (R. Von Ihering)	1	(0.08)	-	-	1	(0.04)
Chartergellus communis Richards	1	(0.08)	-	-	1	(0.04)
Polistes (*Aphanilopteris*) *versicolor* (Oliver)	1	(0.08)	-	-	1	(0.04)
Polistes (*Epicnemius*) *cinerascens* de Saussure	1	(0.08)	-	-	1	(0.04)
Polistes (*Epicnemius*) *subsericeus* de Saussure	1	(0.08)	-	-	1	(0.04)
Polistes sp. 01	1	(0.08)	-	-	1	(0.04)
Polistes (*Epicnemius*) *billardieri ruficormis* de Saussure	-	-	1	(0.08)	1	(0.04)
Polybia (*Myrapetra*) *platycephala sylvestris* Richards	1	(0.08)	-	-	1	(0.04)
Polybia (*Polybia*) *striata* (Fabricius)	-	-	1	(0.08)	1	(0.04)
Pseudopolybia vespiceps (de Saussure)	-	-	1	(0.08)	1	(0.04)
Synoeca surinama (L.)	-	-	1	(0.08)	1	(0.04)

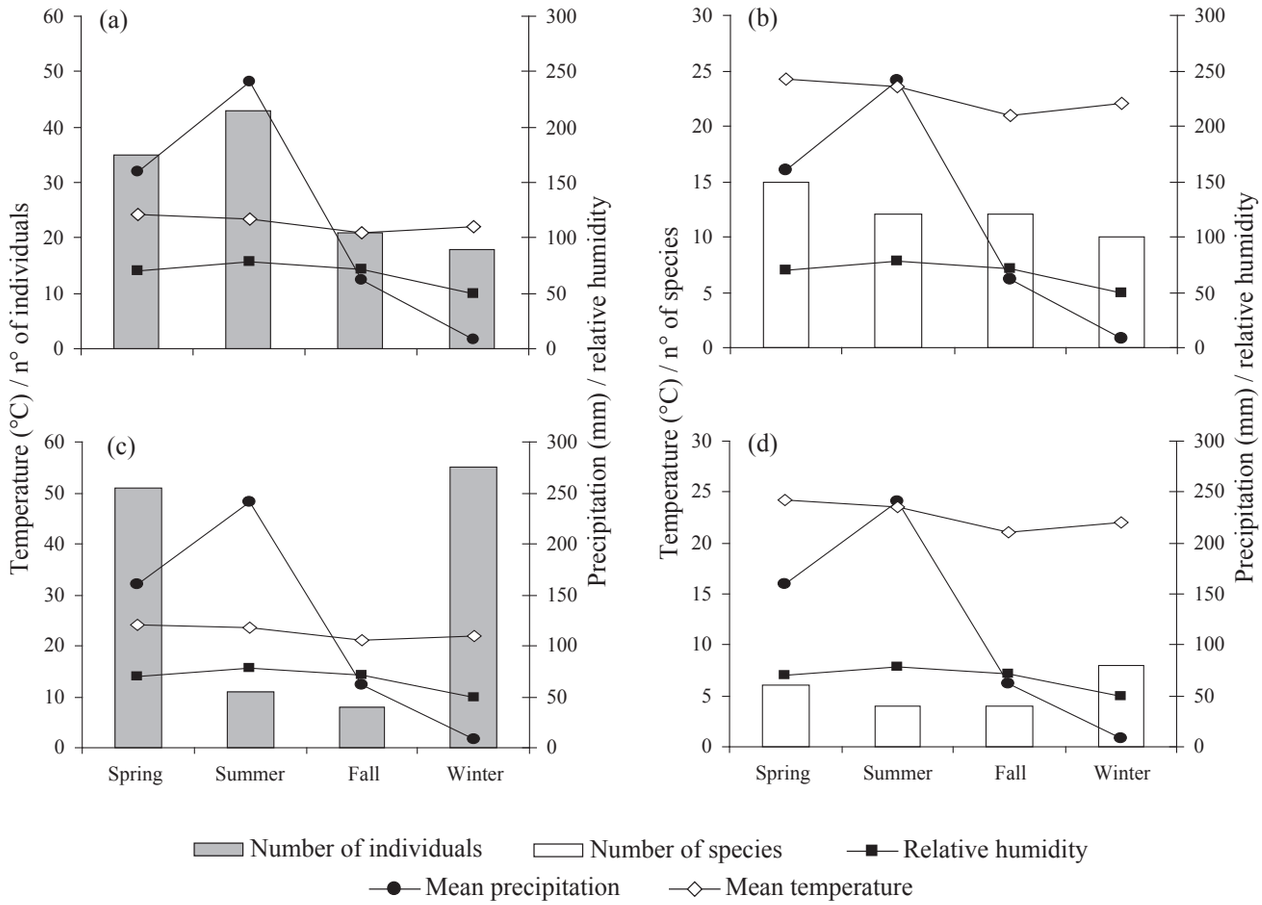

Fig. 1. Number of social wasps individuals and species collected, during each season, using the active searching method – (a) and (b) – and point sampling – (c) and (d), in *cerrado* fragments in Uberlândia, MG. (Climatic data: weather station of the Universidade Federal de Uberlândia, Instituto de Geografia – UFU).

estimation of species richness based on the activity sample varied in 28 to the Bootstrap estimator and 42 species to Jack-Knife 2. The estimation of richness by point sampling varied between 16 and 30 species, being the lowest estimation in Bootstrap and the highest in ACE. The ACE and ICE curves showed an inner growing tending to stability with the sample accumulation. To active sampling the estimators followed the collector's curve. The Fig. 3 shows the similarity index of this study related to other works concerning the Brazilian social wasp richness and diversity.

Table 3. Richness and diversity indexes calculated by active searching and point sampling of the social wasp species in the *cerrado* in Uberlândia, MG, Brazil.

	Active searching	Point sampling
Species Richness (S)	24	13
Simpson's Index (λ)	0.11	0.37
Shannon-Wiener Index (H')	1.16	0.66

Discussion

In different habitats at national park Chapada dos Guimarães, in the state of Mato Grosso, Diniz & Kitayama (1994) found 30 species in 15 genera, with a sampling effort of five weeks. For a sampling effort of 50 collections, Diniz & Kitayama (1998) working in the same region obtained 36 species. Raw (1998b) studying the colonies of social wasps from the Apa-Gama-Cabeça de Veado (Environmental Protection Area), Brasília, DF, sampled 13 species during 18 collections. However, the species similarity of these works with the present one was just 20-25% (Jaccard Index – Fig. 3), probably due to the conservation state of these study areas, area size, sampling effort, food resources availability, nesting sites and climatic season (Jeanne 1991, Ricklefs 2003). Diniz & Kitayama (1998) were the only ones to present diversity index (Shannon's Index = 0.058 to 1.004), depending on the season and vegetation type studied. The other studies did not present general diversity indexes calculus for comparison.

Also working with wasp diversity in cerrado areas of Brazil, São Paulo state, Mechi (1996) verified in two ecological stations the common occurrence of Vespidae,

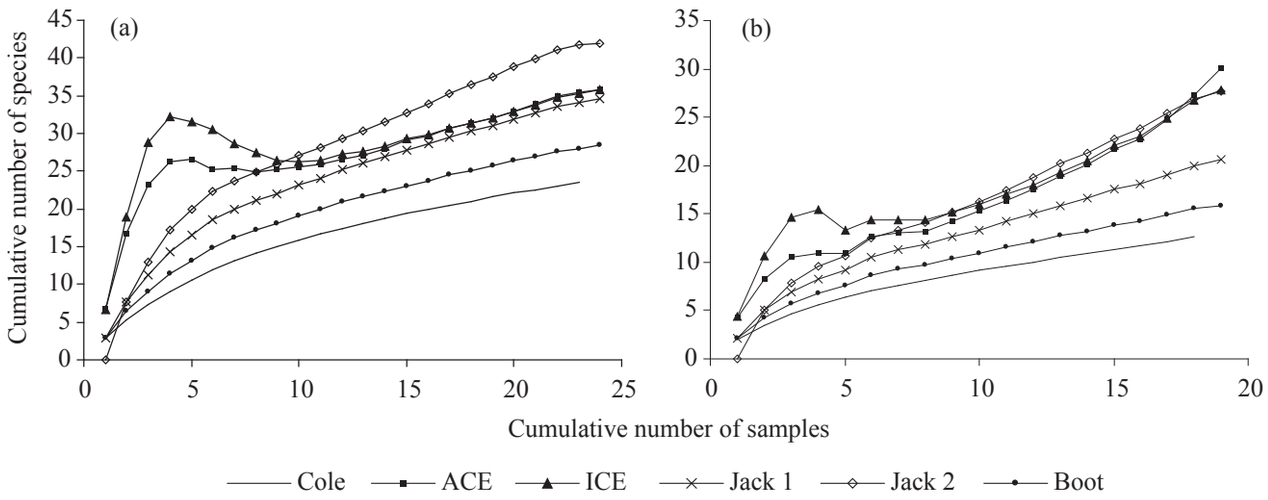

Fig. 2. Species accumulation curve and estimators to the social wasps collected through the active searching (a) and point sampling methods (b) in Cerrado fragments in Uberlândia, MG. The acronym means: ACE – Abundance-based Coverage Estimator; Boot – Bootstrap; Cole – Coleman´s Rarefaction; ICE – Incidence-based Coverage Estimator ; Jack 1 – Jack-Knife 1; e Jack 2 – Jack-Knife 2.

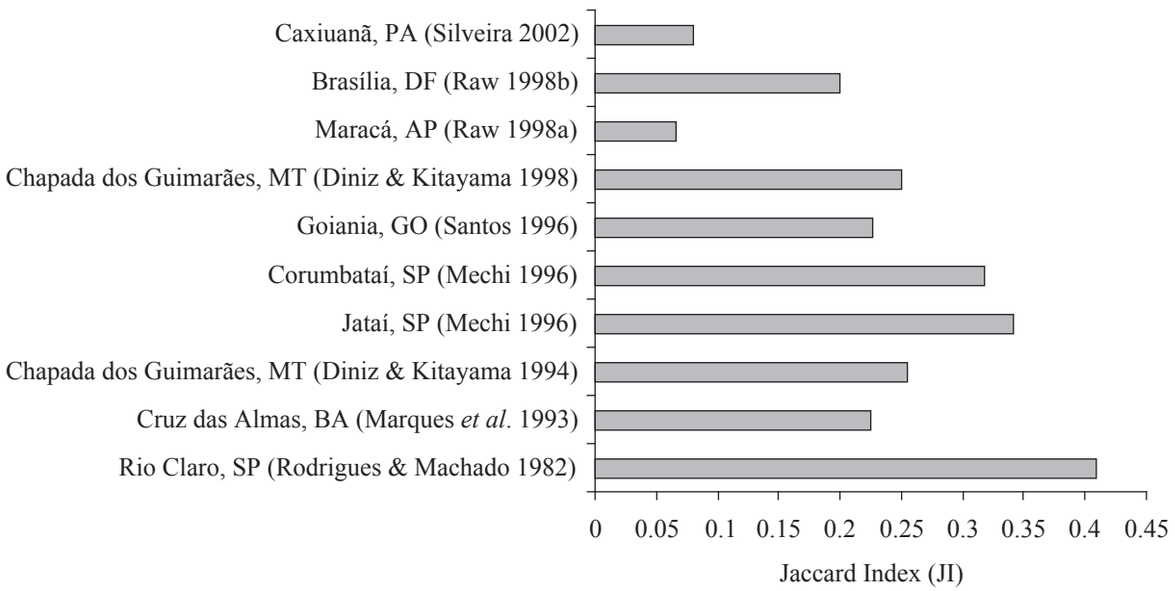

Fig. 3. Jaccard's Similarity Index, comparing species composition of the present study to works on social wasps surveys available in the literature.

26 species in nine genera at Jataí station and 25 species in nine genera at Corumbataí station. These areas also present secondary vegetation in distinct stages of regeneration and species composition presenting 34% (Jataí) and 32% (Corumbataí) of similarity with Uberlândia (Fig.3).

Rodrigues & Machado (1982) verified the occurrence of 33 species in 10 genera in the study conducted at the Navarro de Andrade Tree Nursery in the city of Rio Claro, SP, which is an area of mixed vegetation with eucalyptus and secondary forests, which is different from the typical *cerrado*. However, that area presented 41% of species composition similarity with Uberlândia (Fig. 3). This probably occurred because it is a secondary preservation area with successive reforestations and annual fires in the neighboring areas (Rodrigues & Machado 1982). Similar conditions were verified for the present study areas, conducted in cerrado fragments that have already gone through anthropical changes (intentional fires, deforestation and cultivation) or natural alterations (fire).

Fires are common events in the *cerrado* and necessary for the ecological balance of this ecosystem, when they occur

in a natural regime (Oliveira & Marquis 2002). However, when they occur at a continuous rate and through frequent anthropical action, they can easily decrease the diversity of the area. During the study period three fires occurred in the collection sites. This might explain the low number of colonies found for most species collected. Of the colonies found, the genera belonging to the Epinonini tribe, also called swarm-founding wasps, have a large number of individuals per colony, which can be medium to large sized (Richards 1978, Zucchi *et al*. 1995). The wasps of the genera *Polistes* and *Mischocyttarus* have a small number of individuals and small sized colonies. *M. cerberus styx* was the most abundant species found with the active searching (26.5%, Table 2), increasing the probability to find its colonies. Henriques *et al*. (1992) found seven colonies of four species - *P. paulista*, *Polistes satan* Bequaert, *Parachartergus fraternus* (Gribodo) and *Mischocyttarus marginatus* (Fox) – in a *cerrado* area in Brasília, DF, where frequent fires took place in the dry season and there was short water availability.

During the dry and cold winter, water availability becomes a determinant factor in the survival of individuals, due to a decrease of food resources (nectar and insects). The traps became a new resource to be explored during this period of the year (water, orange juice, sugar, attraction for other insects). The water used by the wasps is connected to the thermoregulation of the colony, while the nectar, as the other sugary substances (fruit juice), constitute the wasps main food item in their adult stage (Prezoto *et al*. 1994, Andrade & Prezoto 2001, Prezoto & Gobbi 2003).

An estimator should consider to reach (or almost reach) stability with less samples than needed to stabilize the curve of species accumulation observed. The final result should not differ widely from others; and it must present estimations similar to that visually accepted to the observed curves of species accumulation (Toti *et al*. 2000). The estimations used in the present study showed good performance. To point sampling the estimations got by Jack-Knife (1 e 2) and Bootstrap showed satisfactory. Independent of the sampling method, the curves of estimators ACE and ICE showed high inner growing, followed by a fall, getting stability to the active sample and pronounced growing to the point sample. These results suggest that ACE and ICE are not much reliable estimators. Depending on the number of samples they can superestimate the number of species (e.g. Bragagnolo & Pinto-da-Rocha 2003).

The active searching methodology, considering the total number of collected species, was more efficient than the point sampling one. However, some species were only collected by the point sampling method, so proving its methodological value. Silveira (2002) observed that the traps were a satisfactory procedure to collect the more common species, since it is a passive collecting method and is extremely dependent on the general abundance and size of the colonies and season.

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