



RESEARCH ARTICLE - WASPS

The Social Wasp Fauna of a Riparian Forest in Southeastern Brazil (Hymenoptera, Vespidae)

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Article History

Edited by

Gilberto M M Santos, UEFS, Brazil

Received 23 August 2013

Initial acceptance 21 November 2013

Final acceptance 23 March 2014

Keywords

Richness, abundance, Polistinae, attractive traps, active sampling

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An inventory of social wasps was carried out on a monthly basis, from March 2010 to March 2011 in a section of riparian forest along the Passa-Cinco River in Ipeúna, São Paulo state, Brazil. Two active collecting methods (active collecting and point sampling using a liquid bait) and one passive method (baited PET bottle trap) were used. The results increased the data on the diversity of social wasps of the State and were used to compare richness, equitability and diversity obtained with several collecting methods which have been employed to social wasps. Thirty-one species belonging to eight genera were recorded; the most abundant were *Agelaia vicina* (de Saussure) and *Agelaia pallipes* (Olivier). Both species belong to the tribe Epiponini, which was dominant in the sample. Regarding sampling methods, the active collecting ones sampled the greatest richness value and the highest Shannon-Wiener diversity index and also presented the largest number of exclusive species. However, the other methods have also obtained exclusive species.

Introduction

Native forests have been exploited for years in a degrading manner, resulting in a number of environmental problems such as species extinctions, local climate change, soil erosion, siltation and eutrophication of watercourses (Ferreira & Dias, 2004). In order to monitor the effects of changes in the environment, to develop conservation strategies on a local scale, information on biodiversity of an area is essential. The concept of diversity can be divided into *alpha*, *beta* and *gamma*, namely the biological diversity in natural and changed communities, the biodiversity exchange rate between different communities, and the species richness of all the communities which integrate a landscape, respectively (Moreno, 2001). An inventory of a local fauna which generates data on alpha diversity is the first step in conservation biology.

Brazil hosts a great diversity of social wasps, reaching a total of 319 species, about 33% of the social wasp species described worldwide (Prezoto et al., 2007). Due to this high diversity and the importance that has been assigned to this

group of insects, researches related to diversity of social wasps in this country are increasing in number and have covered different regions, environments and biomes (Richards, 1978; Rodrigues & Machado, 1982; Marques, 1989; Marques et al., 1993; Diniz & Kitayama, 1994; Mechi, 1996; Santos, 1996; Lima et al., 2000; Raw, 2003; Marques et al., 2005; Mechi, 2005; Melo et al., 2005; Hermes & Köhler, 2006; Santos et al., 2006; Silva-Pereira & Santos, 2006; Souza & Prezoto, 2006; Elpino-Campos et al., 2007; Santos et al., 2007; Morato et al., 2008; Ribeiro Junior, 2008; Silveira et al., 2008; Souza et al., 2008; Gomes & Noll, 2009; Santos et al., 2009a; Santos et al., 2009b; Alvarenga et al., 2010; Auad et al., 2010; Lima et al., 2010; Prezoto & Clemente, 2010; Santos & Presley, 2010; Souza et al., 2010; Pereira & Antonialli-Junior, 2011; Silva et al. 2011; Souza et al., 2011; Tanaka Junior & Noll, 2011; Jacques et al., 2012; Silveira et al., 2012; Simões et al., 2012; Auko & Silvestre, 2013; Grandinete & Noll, 2013; Togni et al. 2014). In the State of São Paulo, studies on diversity of social wasps are still scarce, mainly focusing on the North-western region, with studies in localities such as Paulo de



Faria, Pindorama and Neves Paulista (Gomes & Noll, 2009), Patrocínio Paulista (Lima et al., 2010), Magda, Bebedouro, Matão and Barretos (Tanaka Junior & Noll, 2011); on the Central Eastern region, with researches in Rio Claro (Rodrigues & Machado, 1982), Luíz Antônio, Corumbataí (Mechi, 1996), and Santa Rita do Passa Quatro (Mechi, 2005); and finally at the Littoral in Ubatuba (Togni et al., 2014).

According to the above information, this study aimed to conduct an inventory of the diversity of social wasps in an area of Riparian Forest in the Central Eastern region of São Paulo State, increasing the data on the diversity of social wasps of the State and to compare richness, equitability and diversity obtained through the several methods used.

Materials and Methods

Social wasps (Vespidae, Polistinae) were sampled monthly from March 2010 to March 2011 along the western edge of a riparian forest fragment (semideciduous alluvial forest, according to Rodrigues, 1999) by the margins of the Passa-Cinco River, in a landscape with the surrounding matrix composed by sugarcane plantations, in the rural municipality of Ipeúna - State of São Paulo (22 ° 24'52 .55 "S, 47 ° 43'35 .55" W). The Passa-Cinco is one of the main rivers of the Corumbataí River Basin, in a region that presents a subtropical climate (Köppen Cwa type) characterized by dry winter and rainy summer, with an average temperature in the warmest month of up to 22°C (Palma-Silva, 1999). Originally, the watershed vegetation was mainly composed of semideciduous forests, and "cerrado" vegetation spots in smaller areas (Koffler, 1993 as cited in Valente & Vettorazzi, 2002). According to Valente and Vettorazzi (2002) the sub-basin of Passa-Cinco River had in year 2000 51.72% of its surface occupied by pasture areas, 14.3% by sugarcane, 15.67% native forest, 10.5% planted forest, 0.74% Cerrado, 0.5% urban areas and 6.47% by others.

Three different methods were used for sampling the wasps: baited PET bottle trap, active collecting, and point sampling using a liquid bait. The baited PET bottle trap method consisted in 10 attractive traps made with 2 L PET type bottles (Polyethylene Terephthalate Bottles) installed along a 1000 meter trail bordered by riparian vegetation and sugarcane plantation. The traps were set on the edge of the vegetation at a height of approximately 1.5 meters (Ribeiro Junior, 2008), with a 100 meters interval between traps (Togni et al., 2014). Each bottle had four circular orifices at the middle, and contained 200 ml of attractive liquid (modified from Souza & Prezoto, 2006) consisting of natural industrialized guava juice and sugar solution (Togni et al., 2014). After a week, traps were removed, the attractive liquid sifted and all social wasps encountered were fixed in 70% ethanol.

Active collecting (without the use of any attractive) consisted in active searching for individuals along the same 1000 meter trail mentioned before collected with an entomo-

logical net, at the time of greatest foraging activity between 10:00 am to 3:00 pm (see Prezoto et al., 2008). Rounds of active collecting were made at two different days each month by four independent collectors on the same transect where the bottle traps were placed. The collected individuals were associated with the nearest trap point for further analysis and comparisons.

The method of point sampling using a liquid bait was made with a sucrose solution (1: 4, commercial sugar: water) with 2 cm³ of salt for each half liter of solution which was sprayed over the vegetation at 10 marked points along the sampling trail (with a distance of 100 meters between points). At least 30 minutes after spraying, active searching was performed by two independent collectors on the vegetation for 3 minutes with the aid of an entomological net (modified from Liow et al., 2001; Lima et al., 2010; Tanaka Junior & Noll, 2011).

The species relative abundances were computed by dividing the number of collected individuals of each species by the total abundance found (expressed as percentage) and the richness value is the total number of species encountered.

The richness value obtained by each method was divided by the total richness sampled to evaluate the efficiency of each of them. We calculated the Shannon-Wiener index and Equitability of samples obtained by each method according to the formulas from Krebs (1998) in order to compare the diversity sampled by each of them.

The rarefaction curve based on samples was obtained using the Mao Tau estimator (Colwell et al., 2004) calculated with EstimateS- version 8.2 (Colwell, 2009) and used to compare the three methods based on the monthly richness sampling effort. The species accumulation curve for months of collection was calculated through the addition of new species found every month.

To analyze the equality of samples obtained from each sampling method, the Kruskal-Wallis test (BioEstat 5.0 version 5.0 (Ayres et al., 2007)) was used. For the test, the raw abundance data of each species, and the relative abundances (percentage), were used.

Results and Discussion

Social wasps community in Ipeúna - SP

After 13 months of sampling activity in the rural area in Ipeúna, São Paulo state, 31 species of eight genera of social wasps were found. A total of 954 individuals was collected and 86.58% belonged to the Epiponini tribe, while only 9.43% belonged to the tribe Polistini and 3.98% to the tribe Mischocyttarini (Table 1). Other studies have also noted the predominance of Epiponini in the total abundance of social wasps found. Representatives of this tribe constituted more than 70% in many studies conducted in Brazil (Santos, 1996; Mechi, 2005; Hermes & Köhler, 2006; Santos et al., 2006;

Elpino-Campos et al., 2007; Morato et al., 2008; Gomes & Noll, 2009; Santos et al., 2009b; Silva & Silveira, 2009; Auad et al., 2010; Alvarenga et al., 2010; Lima et al., 2010; Pereira & Antonialli-Junior, 2011; Tanaka Junior & Noll, 2011; Simões et al., 2012; Grandinete & Noll, 2013; Togni et al., 2014). However, when only nests are the targets of surveys, the abundance of Epiponini is often smaller, as observed in Juiz de Fora, Minas Gerais (Lima et al., 2000), with only 11.03% of the colonies belonging to this tribe and in Biritinga, Bahia, were 67.43% of the total abundance found was of Epiponini, yet only 25.71% of the nests found belonged to this tribe (Santos & Presley, 2010). This is probably due to greater depredation of Epiponini nests by humans because of their large size, to destruction by rain and also by the greater facility of finding Mischocytarini and Polistini nests next to human constructions. Differently from the other polistine tribes in the Neotropics, Epiponini is composed of swarming species that may construct large nests and consequently have greater abundance of individuals (Jeanne, 1991; Carpenter & Marques, 2001), a factor that certainly concurs to the high occurrence of specimens from this group in active and passive collections, highlighting the importance of this tribe to the ecosystem studied.

The species with greater abundances (Table 1) were *Agelaia vicina* (404 individuals, relative abundance = 42.35%) and *A. pallipes* (138 individuals, relative abundance = 14.47%). *Agelaia vicina* is known as the polistine species with the largest nests and colonies, and Zucchi et al. (1995) reported the existence of a colony with more than one million adult individuals and nest with over 7.5 million cells. Oliveira et al. (2010) added that the high growth rate, large population and high number of queens provide nests with such proportions. The magnitude of these colonies certainly explains the larger abundance of individuals of this species in the present work, which might in fact be produced by just a few colonies in the area. Oliveira et al. (2010) suggest that *A. vicina* should be considered in many environments as a keystone species, i.e. as populations which determine the stability (integrity and persistence over time) of a community through their activities and abundances (Paine, 1969). In addition to having very large colonies and nests, *A. vicina* presents elevated offspring production rate, requiring therefore a large amount of prey, consisting of a large diversity of arthropods, and severely impacting their populations locally (Oliveira et al., 2010). Among the species belonging to the tribe Mischocytarini, that with the greatest abundance was *Mischocyttarus drewseni* with 26 individuals collected, i.e. 2.73% of the total. *M. drewseni*, which is widely distributed in Brazil (Richards, 1978), rarely presents colonies with more than 30 individuals (Jeanne, 1972), and was diagnosed by Souza et al. (2010) as an indicator of degraded areas and strong human pressure in riparian forest of Rio das Mortes, in Barroso, Minas Gerais. The species with the greatest abundance belonging to the Polistini tribe was *Polistes versicolor* with 37 specimens (3.88%). *Plt. versicolor*

is another species with a wide distribution in Brazil (Richards, 1978), which has been suggested as a biological control agent in certain crops, such as for control of the eucalyptus defoliator (Elisei et al., 2010). A colony of *Plt. versicolor* can collect around 4015 preys during a year, consisting in a majority (but not exclusively) of lepidopteran larvae (Prezoto et al., 2006).

Among the species found in the area, only *Apoica pallens* had not been recorded by Richards (1978) in the State of São Paulo, but it has been sampled in other inventories (Rodrigues & Machado, 1982; Mechi, 1996; Togni et al., 2014). While recorded by Richards (1978) for São Paulo, *Polistes ferreri* and *Mischocyttarus mattogrossoensis* were not found by other authors. These species may be rather easily misidentified due to close similarity with other more abundant species. The wasp *M. mattogrossoensis* is apparently restricted to cerrado areas (Raw, 2003) as shown by the recorded occurrences in Brazil: Mato Grosso (Richards, 1978; Diniz & Kitayama, 1994; 1998), Goiás (Raw, 2003) and Mato Grosso do Sul (Grandinete & Noll, 2013). However this species was also recorded in an urban environment in Cruz das Almas, Bahia (Marques et al., 1993).

Comparing the studies on diversity of social wasps carried out in the State of São Paulo (Rodrigues & Machado, 1982; Mechi, 1996; Mechi, 2005; Gomes & Noll, 2009; Lima et al., 2010; Tanaka Junior & Noll, 2011; Togni et al., 2014) a survey accomplished at Rio Claro (Rodrigues & Machado, 1982; in an environment comprised of *Eucalyptus* plantations with secondary regrowth of semideciduous seasonal forest, approximately 25 kilometers away from Ipeúna) showed the greatest richness (33 species), with the present study coming next with 31 species. The survey at Rio Claro, although using a quite distinct sampling method (active search for colonies during 13 years) and being performed in a area with a much larger area with 2230 hectares, showed 21 species in common with that of Ipeúna. Nine species (*Polybia bifasciata*, *Pseudopolybia vespiceps*, *Agelaia vicina*, *Mischocyttarus mattogrossoensis*, *Polistes acteon*, *Plt. ferreri*, *Plt. geminatus*, *Plt. lanio* and *Plt. subsericeus*) were exclusive to Ipeúna, whereas 12 species (*Polybia platycephala*, *Protonectarina sylveirae*, *Protopolybia exigua*, *P. sedula*, *Parachartergus pseudapicalis*, *Apoica flavissima*, *Mischocyttarus araujoi*, *M. cerberus*, *M. labiatus*, *M. lator*, *Polistes canadensis* and *Plt. consobrinus*) were exclusive to Rio Claro. Despite these differences, it is important to emphasize that 63.63% of the species sampled more than 30 years ago in Rio Claro were found in Ipeúna (even considering the distinctly smaller collection effort), thus showing a noticeable similarity between those social wasps communities.

It is truly remarkable that even a small fragment of riparian vegetation with very strong anthropic influences due to nearby large plantations, has also obtained a very impressive species richness. It is noteworthy that the idea of high diversity in this degraded area, may in fact be indicative of

Table 1. Abundance of wasp species collected with the three methods (AC - Active collection, PS - Point Sample using a liquid bait and BT - attractive PET bottle traps), total abundance and relative abundance (%) of species collected in Passa Cinco River's riparian forest in Ipeúna. (AC - Active collection, PS - Point Sample, BT - Bottle Traps).

Species	AC	PS	BT	Total	Relative Abundance
<i>Agelaia multipicta</i> (Haliday, 1836)	1	2	0	3	0.31
<i>Agelaia pallipes</i> (Olivier, 1791)	20	32	86	138	14.47
<i>Agelaia vicina</i> (de Saussure, 1854)	159	93	152	404	42.35
<i>Apoica pallens</i> (Fabricius, 1804)	0	0	1	1	0.1
<i>Brachygastra augusti</i> (de Saussure, 1854)	1	1	0	2	0.21
<i>Brachygastra lecheguana</i> (Latreille, 1824)	3	1	0	4	0.42
<i>Polybia chrysothorax</i> (Lichtenstein, 1796)	4	0	10	14	1.47
<i>Polybia dimidiata</i> (Olivier, 1791)	33	5	17	55	5.77
<i>Polybia fastidiosuscula</i> de Saussure, 1854	0	9	32	41	4.3
<i>Polybia ignobilis</i> (Haliday, 1836)	19	4	23	46	4.82
<i>Polybia jurinei</i> de Saussure, 1854	0	0	3	3	0.31
<i>Polybia</i> gr. <i>occidentalis</i> sp 1 (Olivier, 1791)	12	16	2	30	3.14
<i>Polybia</i> gr. <i>occidentalis</i> sp 2 (Olivier, 1791)	7	12	7	26	2.73
<i>Polybia paulista</i> H. von Ihering, 1896	10	10	3	23	2.41
<i>Polybia sericea</i> (Olivier, 1791)	12	5	3	20	2.1
<i>Polybia bifasciata</i> de Saussure, 1854	0	1	0	1	0.1
<i>Pseudopolybia vespiceps</i> (de Saussure, 1864)	7	4	0	11	1.15
<i>Synoeca cyanea</i> (Fabricius, 1775)	4	0	0	4	0.42
Epiponini's total	292	195	339	826	86.58
<i>Mischocyttarus cassununga</i> (von Ihering, 1903)	5	0	0	5	0.52
<i>Mischocyttarus drewseni</i> de Saussure, 1857	22	4	0	26	2.73
<i>Mischocyttarus mattogrossoensis</i> Zikán, 1935	3	0	0	3	0.31
<i>Mischocyttarus rotundicollis</i> (Cameron, 1912)	3	0	1	4	0.42
Mischocyttarini's total	33	4	1	38	3.98
<i>Polistes actaeon</i> Haliday, 1836	2	0	0	2	0.21
<i>Polistes billardieri</i> Fabricius, 1804	3	2	1	4	0.42
<i>Polistes cinerascens</i> de Saussure, 1854	6	0	0	8	0.84
<i>Polistes lanio</i> (Fabricius, 1775)	0	0	2	2	0.21
<i>Polistes ferreri</i> de Saussure, 1853	4	1	3	8	0.84
<i>Polistes simillimus</i> Zikán, 1951	7	5	3	15	1.57
<i>Polistes geminatus</i> Fox, 1898	4	0	0	4	0.42
<i>Polistes subsericeus</i> de Saussure, 1854	6	4	0	10	1.05
<i>Polistes versicolor</i> (Olivier, 1791)	6	14	17	37	3.88
Polistini's total	38	26	26	90	9.43
Total abundance	363	225	366	954	100
Total richness	26	20	18	31	
Exclusive richness	6	1	3		

an impoverishment of the social wasps fauna of the state of São Paulo that may be happening for a long time, making thirty-one species appear to be a high diversity when compared with other inventories carried out in the state.

Comparison of sampling methods

With regard to the methods used for sampling social wasps (active collecting, point sample using liquid bait, and baited bottle traps), a remarkable aspect to note was their large complementarities, with only 38.71% of the species being collected by all three methods (Table 1).

By using the active collection method, 363 individuals belonging to 26 species (seven genera) were obtained. Six species were captured exclusively by this method: *Synoeca cyanea*, *Mischocyttarus cassununga*, *M. mattogrossoensis*, *Polistes actaeon*, *Plt. cinerascens* and *Plt. geminatus*. Among these species, *Plt. actaeon* and *M. cassununga* have already been collected by attractive PET bottle traps by Souza et al. (2011) e Jacques et al. (2012) respectively. *Synoeca cyanea*, as well as *M. cassununga* were also previously sampled by passive trapping, actually with Malaise trap by Auad et al. (2010). The other species were captured in other studies with different active collecting methods, as active collecting with liquid bait (*Plt. geminatus* (Tanaka Junior & Noll, 2011), *S. cyanea* and *M. cassununga* (Lima et al., 2010), *M. mattogrossoensis* (Grandinete & Noll, 2013)) and active collection in quadrants and point sampling (*M. cassununga* and *Plt. cinerascens*, (Souza & Prezoto, 2006)).

The method of point sampling using a liquid bait was responsible for the capture of 225 individuals belonging to 20 species (six genera), with only *Polybia bifasciata* being exclusive. This species was previously captured by Souza and Prezoto (2006) with the method of point sampling, while Togni (2009), Jacques et al. (2012) and Simões et al. (2012) obtained specimens using attractive traps.

The method of baited PET bottle traps collected 366 specimens belonging to 18 species (five genera), of which *Apoica pallens*, *Polybia jurinei* and *Polistes lanio* were exclusives to this technique. These species, however, had already been sampled by different methods in other studies: *Apoica pallens*, though being a species with nocturne foraging habit (Hunt et al., 1995), which would explain absence in the active collections during daytime, was otherwise captured actively during the day by Mechi (1996), Souza and Prezoto (2006), Elpino-Campos et al. (2007), Silveira et al. (2008), Clemente (2009), Silva and Silveira (2009) and Souza et al. (2011). *Polybia jurinei* was found by active collection by Souza and Prezoto (2006), Elpino-Campos et al. (2007), Silva and Silveira (2009) and Jacques et al. (2012); by active collection in flowering plants by Mechi (1996; 2005), and by active collecting with the use of liquid bait by Noll and Gomes (2009), Lima et al. (2010) and Grandinete and Noll (2013). *Polistes lanio* was collected by active collection by Simões et al. (2012) and by

active collection while scanning flowering plants by Mechi (1996; 2005).

The most efficient method, regarding the number of species collected, was the active collection, responsible for capturing 83.87% of the species, followed by point sampling using a liquid bait (64.52%) and baited PET bottle traps (58.06%). When adding the samples obtained through active collection and point sample using liquid bait, quite different from the method that uses attractive PET bottle traps which is characteristically passive, 28 species were sampled (90.32% of total richness) with 13 being exclusive of those methods.

The diversity index of Shannon-Wiener (H') for the total sample was 2.248 and the evenness (J') was 0.655. Comparing the methods employed regarding these indexes, it was noted that the highest Shannon-Wiener index was obtained by active collection ($H' = 2.297$), which is even higher than that obtained for the entire sample, whereas the lowest index was obtained by the attractive PET bottle traps method ($H' = 1.854$). The equitability obtained in the area was very similar between active collection ($J' = 0.705$) and point sampling using a liquid bait ($J' = 0.717$) and was lower for samples collected using attractive PET bottle traps ($J' = 0.641$). In this way, we note that the attractive PET bottle traps were responsible for less homogeneous samples regarding the species abundance, with a less equity in these samples and therefore a lower diversity index.

When the methods are analyzed as a sole group regarding the difference of abundance sampled, there is no significant difference between them ($H' = 5.202$, $df = 2$, (p) Kruskal-Wallis = 0.0742) and the same occurs when using the species relative abundance of each method in the analysis ($H' = 4.348$, $df = 2$, (p) Kruskal-Wallis = 0.114).

By comparison of the curves of species accumulation with the rarefaction curves (Figure 1) it is possible to see that the curve of richness accumulation obtained through active collection is that closest to an asymptote, seeming to stabilize in the last four collection days. It is worth noting that the curve obtained for the rarefaction of baited bottle traps tends to an asymptote in a similar way to the curve of active collection, although with a smaller number of species than that obtained by the other techniques, indicating a false idea of good sampling.

Therefore, the method shown to be more efficient was the active collection, since it was responsible for the largest number of species obtained exclusively by one method, for the highest Shannon-Wiener index and a rarefaction curve compatible with the curve of expected species. This method had already been reported as the most efficient in respect of richness by other researches (Souza & Prezoto, 2006; Elpino-Campos et al., 2007; Silva & Silveira, 2009; Souza et al., 2011; Jacques et al., 2012; Simões et al., 2012). The low equitabilities and richness obtained for attractive traps, indicate the need for additional sampling with other methods. However, the occurrence of exclusive species demonstrates the importance

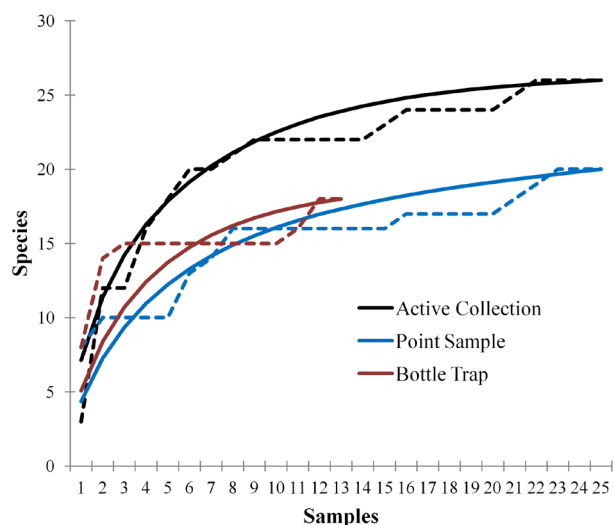


Fig 1. Species accumulation curves (dashed line) and rarefaction curves (continuous line) through samples (collecting days), for each methodology employed in the surveying of the Ipeúna social wasp fauna: Active collecting (Active Collection), Point sampling using a liquid bait (Point Sample), and attractive PET bottle trap (Bottle Trap).

of this technique. Therefore the use of more than one collection method is indicated in conducting inventories of social wasps, as proven in other studies (Silveira, 2002; Souza & Prezoto, 2006; Ribeiro Junior, 2008; Clemente, 2009; Togni, 2009; Souza et al., 2011; Jacques et al., 2012; Simões et al., 2012).

Acknowledgments

We thank the Brazilian National Council for Scientific and Technological Development (CNPq) for financial support and the Brazilian Institute for the Environment and Renewable Natural Resources (SISBIO / IBAMA) for the authorization for collection and transport of specimens, number 22250-1.

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