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REVIEW

Studies of social wasp diversity in Brazil: Over 30 years of research, advancements and priorities

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Abstract

The first records of social wasps in Brazil were made during expeditions focused on the taxonomy and distribution of the species throughout the country. From the 1970s the essence of publications on the diversity of social wasps has been changing, with studies focusing on specific areas and incorporating the use of sampling methodologies and analysis of results through ecological indexes. Since then, the neotropical social wasps have gained more prominence due to the acknowledgement of their decisive role in the trophic balance of ecosystems, which has been increasing the interest in studying these insects. Therefore, we aimed to make a detailed analysis of the social wasp diversity studies published in Brazil over the past 33 years, looking to build knowledge on the research history of the group. For the literature review, selected publications must have attended to the following criteria: including keywords addressing the matter and being indexed in databases within the defined period. We found 78 publications, most of them (70.52%) published in scientific journals. Diversity studies featured in publications in a regular basis from the year 2005 on, and the years 2010, 2012 and 2014 were the most productive; there was also a concentration of studies in the BA, MG and SP states. There were 11 different collection methods used, from which the Active Search and Attractive Trap methods stood out as most common; however, we found no pattern regarding study duration or collection methodology. The contribution of this analysis is to extend the current status of knowledge of social wasps research, as well as to guide and encourage future studies in unexplored areas.

Introduction

In the last decade, neotropical social wasps have stood out as role models in studies on ecology, biology and animal behavior (Prezoto et al., 2011; Prezoto & Souza, 2015). This growing interest in the group is due to the acknowledgement of the wasps' role in the trophic balance of ecosystems, since they can contribute both as pollinators (during the collection of nectar and pollen) and as predators (during their search for the animal protein used in the nourishment of their larvae); thus, wasps show potential as possible agriculture pest control agents (Hunt, 2007; Prezoto et al., 2008; Elisei et al., 2010; Clemente et al., 2013; Clemente et al., 2012, Barbosa et al., 2014). Furthermore, some species are sensitive to environmental changes, being acknowledged as effective indicator organisms (Urbini et al., 2006; Souza et al., 2010).

The first records on social wasps in Brazil were made during expeditions focused on taxonomy and species distribution by Von Ihering (1904), Ducke (1904, 1905, 1907, 1918), Zikán (1949, 1951) and Araújo (1944, 1946, 1960). In 1978, Richards publishes the book "The Social Wasps of the Americas, Excluding the Vespinae", which comprehends an extensive review on the neotropical species, with details on their distribution, morphology and biology; this publication instantly became a milestone for posterior studies on the group, and references to it can still be found in recent publications (e.g. Melo et al., 2015; Jacques et al., 2015).

After the publishing of Professor Vilma Maule Rodrigues's paper in 1982 on the wasps in the Horto Florestal Navarro de Andrade garden in the city of Rio Claro/SP, Brazil, there was a major change in the essence of publications regarding social wasps; researchers began to focus their sampling effort on a chosen locality, and, as years went by, applied sampling methodologies and data analysis through ecological indexes.

It is estimated that we know less than 10% of the Brazilian insect species (Lewinsohn & Prado, 2005) and although diversity studies are essential to the conservation of species, particularly for social wasps, these efforts must be carried out as to enhance the existing knowledge, thus allowing the comparison between studies and providing information to guide future investigations on the matter.

Therefore, we aimed to analyze in detail the publications on social wasps diversity in Brazil for the last 30 years, aiming to increase the knowledge on these studies through a discussion on the advancements and research priorities regarding the methods applied and the attained results.

Methods

Method and Data Search Criteria

On this study we followed the protocol suggested by the PRISMA method for systematic studies and meta-analysis (Moher et al., 2009) adapted by Moher et al. (2015). The methodological approach included the development of the selection criteria, the definition of search strategies, the evaluation of the studies' quality and the extraction of relevant data.

The criteria for selection and inclusion of publication were: publications approaching the matter; publications indexed on the Google Scholar, Scientific Electronic Library Online (SCIELO), Scopus and Web of Science databases; papers published in journals within the period limited between January 1982 and October 2015. The key words used to search publications were 'social wasps' and 'diversity'. Publications such as monographies, theses and books were added through cross-referencing.

We recorded the following data from each publication: study area, focus, duration, sampling methods and identified social wasp species. Based on this information, we generated: (1) a map of the distribution of the publications by state and (2) a table of social wasp species and the methods used to sample them, also sorted by state.

Data analysis

In order to assess social wasp species richness, we generated species rarefaction curves (*sensu* Gotelli & Colwell, 2001) in the software EstimateS 9 (Colwell, 2013) with 5000 randomizations. This software generates 5000-species accumulation curves by randomizing the order of samples; this way, each point along the curve represents the mean of the accumulated richness for the 5000 curves and is associated to a standard deviation value. Each publication was considered a sample, therefore resulting in 76 samples; two studies were not considered since their authors did not identify organisms to species-level.

We calculated the Constancy Index suggested by Bodenheimer (1955) in order to assess social wasp species constancy recorded in studies in the Brazilian territory. To perform the calculations, once again, each publication was considered a sample. Species present in more than 50% of the samples were considered constant; the ones present in 25% to 50% of the samples were considered accessory; species present in less than 25% of the samples were considered accidental.

Results and Discussion

We selected 78 publications, from which eight (10.25%) were books, 15 (19.23%) were unpublished studies (Monographies and Theses) and 55 (70.52%) were papers publishedin scientific journals (Table 1). Regarding the papers, 25 distinct journals were used, most of them being Brazilian (n= 16). The most used journals were: Socibiology (n= 13), Revista Brasileira de Entomologia (n= 5), Neotropical Entomology, MGBiota and EntomoBrasilis, these last four featuring a single publication each (Table 1); altogether, they make up 54.54% (n= 30) of the published papers (n= 55). Almost one quarter of the papers (23.63%) were published on the Sociobiology journal.

The first publication on social wasp diversity in Brazil dates from 1982 (Rodrigues and Machado, 1982); from 1985 to 2002, 12 more studies werepublished on an uneven frequency. From 2005 on, however, some publication regularity started to appear, the years of 2010, 2012 and 2014 being the most productive (with eight, eight and 12 publications respectively) (Fig 1, Table 1). In this chronological sense, it stands out that most papers (n= 45; 57.69%) were published in the last six years (from 2010 to 2016) (Fig 1).

The distribution of publications throughout the Brazilian states showed a concentration in the states of Minas Gerais (n= 24), São Paulo (n= 13) and Bahia (n= 10), which together make up more than half of all studies (Fig 2), while nine states still haven't had any published studies on their social wasp fauna.

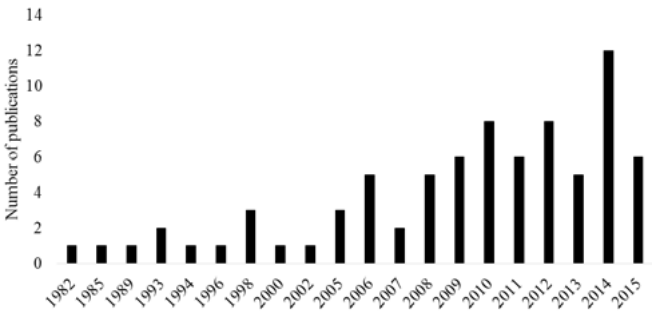

Fig 1. Number of publications per year, in national and international journals, on Brazilian social wasp diversity, in the period between 1982 to 2015.

Table 1. Papers, mean of publication, study duration, sampling methods, study area (states) and number of genera and species recorded in Brazilian social wasp diversity studies from 1982 to 2015: AS – Active Search; BT – Bait Traps; F – Fogging Technique; FS – Flower Search; LB - Liquid Bait; LT – Light Traps; MO – Möericke; MT – Malaise Trap; Q – Quadrant; ST –Shuey Trap; TT – Tray Traps; I – Study state; II – Nº of species found; III – Nº of genera found; IV – Nº of swarming species and V – Nº of independent species.

Paper nº	Author/year	Journal	Study duration (months)	Sampling methods	I	II	III	IV	V
1	Rodrigues and Machado, 1982	Naturalla	144	AS	SP	33	10	20	13
2	Lorenzato, 1985	Agron. Sulriograndense	16	BT	SC	12	5	9	3
3	Marques, 1989	M.Sc Dissertation	16	BT	BA	13	8	11	2
4	Marques et al., 1993	Insecta	63	AS, FS	BA	20	10	14	6
5	Marques and Carvalho, 1993	Insecta	52	AS	BA	17	10	12	5
6	Diniz and Kitayama, 1994	J. Hymenopt research	5	Q	MT	30	15	22	8
7	Santos, 1996	Agrárias	13	BT	GO	9	5	9	0
70	Diniz and Kitayama, 1998	Rev. de Biologia Tropical	4	AS	MT	36	12	26	10
8	Raw, 1998a	Rev. Brasileira de Zoologia	47 days*	AS	DF	13	8	9	4
74	Raw, 1998b	Book	-	AS	RR	36	13	26	10
9	Lima et al., 2000	Rev. Bras. Zoociências	13	AS	MG	X	5	X	X
10	Silveira, 2002	Papéis Avulsos de Zoologia	7	AS, MT	PR	79	18	51	28
62	Mechi, 2005	Book	-	FS	SP	28	8	17	11
11	Melo et al., 2005	Book	8	AS, FS	BA	23	10	14	9
12	Silveira et al., 2005	Entomological Science	8	BT	PR	6	2	6	0
53	Hermes and Kohler, 2006	Rev. Bras. Entomologia	32	FS	RS	25	7	13	12
75	Mechi and Moraes, 2006	Book	25	FS	SP	26	8	17	9
13	Santos et al., 2006	Sociobiology	13	FS	BA	13	5	7	6
14	Silva-Pereira and Santos, 2006	Neotropical Entomology	8	FS	BA	11	6	8	3
15	Souza and Prezoto, 2006	Sociobiology	15	AS, BT, FS, Q	MG	38	10	20	18
16	Elpino-Campos et al., 2007	Neotropical Entomology	12	AS, BT	MG	29	10	16	13
18	Santos et al., 2007	Neotropical Entomology	37	AS	BA	21	11	14	7
19	Lima, 2008	M.Sc Dissertation	27	AS, FS, LB	SP	31	11	21	10
20	Morato et al., 2008	Acta Amazonica	24 days*	MT	AC	20	7	16	4
21	Ribeiro-Junior, 2008	M.Sc Dissertation	12	AS, BT	MG	12	6	6	6
22	Silveira et al., 2008	Acta Amazonica	-	AS, BT	AM/AP	46	15	38	8
23	Souza et al., 2008	MG.Biota	24	AS, BT, FS, Q	MG	42	12	23	19
61	Carbonari, 2009	Ph.D Thesis	23	AS, MT, TT	MS	19	8	11	8
24	Clemente, 2009	M.Sc Dissertation	12	AS, BT	MG	21	8	12	9
25	Gomes and Noll, 2009	Rev. Bras. Entomologia	6	BA, LB	SP	14	7	11	3
26	Santos el al., 2009a	Neotropical Entomology	8	AS	BA	19	13	15	4
68	Santos et al., 2009b	Environmental Entomology	6	AS	BA	17	10	11	6
27	Silva and Silveira, 2009	Iheringia Série Zoologia	6	AS, MT	PR	63	12	40	23
29	Alvarenga et al., 2010	Sociobiology	2	AS	MG	X	5	X	X
63	Arab et al., 2010	Sociobiology	37	ST	SP	10	4	7	3
30	Auad et al., 2010	Sociobiology	24	MT	MG	13	4	11	3
31	Coró, 2010	M.Sc Dissertation	12	MT	SP	20	9	16	4
32	Lima et al., 2010	Sociobiology	15	AS, FS, LB	SP	30	10	20	10
33	Prezoto and Clemente, 2010	MG.Biota	12	AS, BT	MG	23	10	14	9
45	Souza et al., 2010	MG.Biota	12	AS, BT, BF	MG	32	9	15	17
50	Ribeiro, 2010	Monography	6	AS	PR	13	5	7	6
66	De Souza et al., 2011	J. Economic Entomology	12	BT, AS	MG	17	9	13	4

Table 1. Papers, mean of publication, study duration, sampling methods, study area (states) and number of genera and species recorded in Brazilian social wasp diversity studies from 1982 to 2015: AS – Active Search; BT – Bait Traps; F – Fogging Technique; FS – Flower Search; LB - Liquid Bait; LT – Light Traps; MO – Möericke; MT – Malaise Trap; Q – Quadrant; ST –Shuey Trap; TT – Tray Traps; I – Study state; II – Nº of species found; III – Nº of genera found; IV – Nº of swarming species and V – Nº of independent species. (Continuation)

Paper nº	Author/year	Journal	Study duration (months)	Sampling methods	I	II	III	IV	V
35	Henrique-Simões et al., 2011	CheckList	12	AS, BT, MT	MG	34	10	16	18
36	Pereira and Antonialli-Jr, 2011	Sociobiology	27 days*	AS, BT, LB	MS	18	6	10	8
37	Silva el al., 2011	Rev. Bras. Entomologia	13	AS	MA	31	13	25	6
69	Silva, 2011	M.Sc Dissertation	6	AS, BT	MG	13	7	9	4
34	Tanaka and Noll, 2011	Psyche	25	AS, LB	SP	29	10	21	8
60	Bomfim et al., 2012	Sociobiology	6	AS, BT	MS	18	6	10	8
38	Henrique-Simões et al., 2012	Iheringia Série Zoologia	12	AS, BT	MG	32	10	15	17
39	Jacques et al., 2012	Sociobiology	3	AS, BT	MG	25	10	16	9
72	Noll et al., 2012	Book	9	AS, MT, LB	SP	32	11	25	7
41	Silva, 2012	M.Sc Dissertation	12	AS, BT	MG	20	7	11	9
42	Silveira et al., 2012	Rev. Bras. Entomologia	44 days*	MT, AS	PA	30	6	21	9
43	Somavilla, 2012	M.Sc Dissertation	5	AS, BT, F, LT, MT	AM	86	17	70	16
44	Souza et al., 2012	MG.Biota	12	AS, BT	MG	38	10	21	18
76	Auko et al., 2013	Book	11 days*	AS, MT	MS	8	6	7	1
55	Auko and Silvestre, 2013	Biota Neotropica	11	AS, MT, MO	MS	18	9	10	8
71	Gomes, 2013	Ph.D Thesis	8	BT, LB	RO	76	15	67	9
47	Grandinete and Noll, 2013	Sociobiology	12	AS, BT, LB	MS	22	8	14	8
46	Silva et al., 2013	EntomoBrasilis	4	AS, BT	MG	10	4	7	3
48	Almeida et al., 2014	Sociobiology	10	AS	MT	14	8	13	1
51	Andena and Carpenter, 2014	Book	-	MT	X	74	17	45	29
59	Brugger, 2014	M.Sc Dissertation	12	AS, BT	MG	23	8	17	6
40	Locher et al., 2014	Sociobiology	13	AS, BT, LB	SP	31	8	18	13
54	Rocha and Silveira, 2014	EntomoBrasilis	-	AS	PI	12	6	10	2
28	Togni et al., 2014	CheckList	13	AS, BT	SP	21	8	14	7
67	Klein, 2014	Monography	13	AS, BT, LB	RS	16	7	10	6
77	Silvestre et al., 2014	Book	17	AS, BT, MT, TT, MO	MS	31	8	13	18
56	Somavilla et al., 2014a	Rev. Bras. Entomologia	16 days*	AS	AM	58	13	46	12
57	Somavilla et al., 2014b	EntomoBrasilis	17	BT, MT, LT	MA	38	12	36	2
49	Souza et al., 2014a	Bioscience Journal	12	AS	MG	38	10	22	16
52	Souza et al., 2014b	Acta Sciemtiarum	24	AS	MG	29	10	16	13
64	Barbosa, 2015	M.Sc Dissertation	32	AS, BT	MG	36	10	21	15
65	Clemente, 2015	Ph.D Thesis	6	AS, BT	SP	31	8	17	14
73	Freitas et al., 2015	Revista Agrogeoambiental	4	BT	MG	19	8	14	5
78	Jacques et al., 2015	Sociobiology	26	AS, BT	MG	29	8	15	14
17	Melo et al., 2015	Checklist	12	FS	BA	8	5	5	3
58	Somavilla et al., 2015	EntomoBrasilis	7 days*	AS, LT, MT	AM	49	14	42	7

This asymmetry regarding publications may be explained by the fact that Minas Gerais, São Paulo and Bahia host some of the core social wasp research groups in Brazil, present in universities, research institutes and technology centers; these groups perform important roles not only by carrying out studies on the group, but also by developing human resources which would organize new research groups dispersed in other Brazilian states.

However, the increased amount of studies in the states of Minas Gerais e São Paulo does not grant the southeastern region the status of most studied in the country, since the states of Espírito Santo and Rio de Janeiro still have, on their territories, 10.5% and 18.6% (respectively) of the original fragments of the Atlantic Rainforest, which is considered one of the most endangered of the Brazilian biomes (SOS Mata Atlântica, 2013); therefore, it is surprising that there aren't any publications on their social wasp fauna.

Data on the duration of studies was present on 73 (93.58%) publications and ranged from a few days to 144 months, being 12 months the most usual duration (n= 15). In 28 publications the duration was superior to 12 months (from 13 to 144 months), while in other studies (n= 30) the duration was less than 12 months (from 7 consecutive days to 11 months) (Table 1). It is evident that there is no uniformity in the duration of the sampling period, and there is a necessity to create a pattern for study duration in order to enable data comparison between studies.

One of the consequences of the variable duration of studies can be observed when a Species Accumulation Curve is generated (Fig 3). Taking the 24 months-long study performed by Barbosa (2015) as role model, we can relate the curve's behavior to the potential of species to be sampled through time. The Species Accumulation Curve is asymptotic and grows in a decreasing rate, since for each sampling event the potential for finding new species decreases. On the first six months of study this rate is very high, which shows a possibility of sampling a greater number of species in the area. This rate is noticeably lower between six and 12 months, and is minimum after this period (between 12 and 24 months). This curve pattern shows that short-term studies tend to underestimate the number of species in an area, thus reassuring the precision of long-term studies. For the social wasps, it is evident that studies with 12 or more months of samplings have a better estimation of the species diversity when compared to the expected value.

Regarding the sampling, we recorded 11 different methods used to capture of social wasps: Active Search (n= 60), Bait Trap (n= 35), Malaise Trap (n= 14), Flower Search (n =13), Liquid Bait (n= 9), Quadrant (n= 3), Light Trap (n =3), Tray Trap (n= 2), Möericke Trap (n= 2), Shuey Trap (n= 1)

Fig 2. Geographical representation of the number of publications on social wasp diversity per Brazilian state from 1982 to 2015.

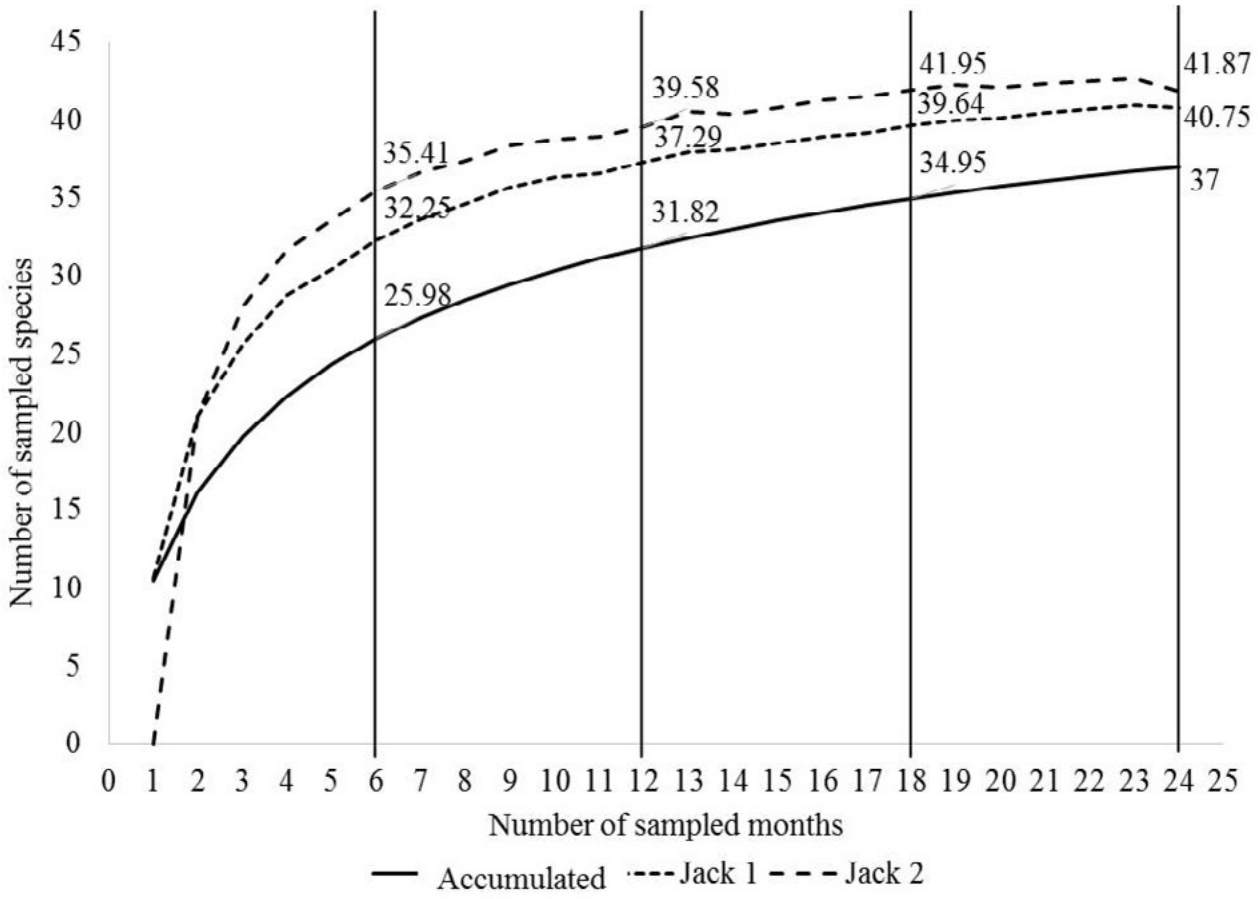

Fig 3. Species Accumulation Curve model based on Barbosa (2015), with 24 months of sampling of social wasps. The vertical lines separate the sampling intervals in six, 12 and 18 months.

and Fogging Technique (n= 1) (Table 1). Furthermore, most publications (55.12%, n= 43) used more than one sampling method, which became a trend after 2006; before that, the use of a single sampling method prevailed on most studies. This trend agrees with many studies (Silveira, 2002; Souza & Prezoto, 2006; Togni et al., 2014) that highlight the importance of conciliating methods in order to better record the fauna of wasps in an area.

Sampling through Bait Traps was the second most used method (present in 35 studies), right after Active Search, and was also the method that varied most on its way of application. There were different kinds of baits used, usually made of various fruit juices or sardine-based protein broths; the amount, disposition, duration and confection of traps also varied a lot (e.g. Santos, 1996; Souza & Prezoto, 2006; Clemente, 2009; Locher et al., 2014). This methodological diversity observed for bait traps is mainly due to the lack of a study that tests the best layout for this method; such possibility would generate data to optimize the distance between traps, the setting height for them, the kind of bait used (natural or industrialized juice), the setting duration on field, the container size, and so on. This standardization would bring direct benefits for a more fitting comparison of sampling efforts in future studies, and also to optimize time and money costs to set the traps on the field.

Almost half of the sampling methods used (45.45%, n= 5) recorded exclusive species (recorded by means of a single method). Among those, the methods that recorded the most exclusive species were: Active Search (n= 23) and Malaise Trap (n= 15) (Table 2). Curiously, sampling through Light Traps, recorded for only three studies and characterized as effective for capturing species with night habits, stood out for sampling eight species in the *Apoica* genus, which is known for its night activity, but also for other 63 species belonging to 13 genera (*Agelaia*, *Angiopolybia*, *Asteloeca*, *Brachygastra*, *Clypearia*, *Leipomeles*, *Mischocyttarus*, *Parachartaegus*, *Polistes*, *Polybia*, *Protonectarina*, *Pseudopolybia* and *Synoeca*), which are all active during the day (Table 2).

A possible explanation for the capture of that many day species may be due to the Light Traps being controlled by photosensors, which make the traps trigger by the end of the afternoon, a time in which many foragers of wasp species active during the day are still returning to their nests. Social wasps, in the same way as bees, have positive phototropism, which makes them attracted to the luminosity in the trap and therefore captured by it.

Only six studies focused on the difference of the setting height for the sampling methods (Silveira, 2002; De Souza et al., 2011; Somavilla 2012; Somavilla et al., 2014b; Clemente, 2015; Barbosa, 2015), usually adopting two different heights,

the canopy (close to 5 meters high) and the understory (chest-height, approximately 1,5 meters high). Two of these studies (De Souza et al., 2011; Barbosa, 2015) recorded greater species richness for the traps set in canopy height and also exclusive species for each setting height. Therefore, these studies show the importance of sampling the different levels of the vegetal mosaic in the environment.

Regarding the use of diversity indexes, we observed that Mechi (2005) was the first study to apply a diversity index; on this particular case, the author used the Shannon-Wiener Index (H') while studying the social wasp fauna in Estação Ecológica Jataí, São Paulo state; the second study to use a diversity index was published by Souza and Prezoto (2006). Most publications (77.27%, n= 34) applied at least one diversity index, which shows the emergence of a trend to use this kind of test in order to discuss the results found since 2006.

Based on the studies that properly identified the social wasp species, 235 species were recorded, belonging to 19 different genera; of these, the most representative ones were the *Mischocyttarus* (n= 68), *Polybia* (n= 44) and *Polistes* (n= 25) genera (Table 2).

The calculated Constancy Index showed that among the 233 species identified in the publications, most (88.1%, n= 207) were Accidental, followed by Accessory (8.5%, n= 20) and Constant (3.4%, n= 8). The latter, present in most of the studies, were: *Polybia sericea* (n= 61), *Polybia ignobilis* (n= 58), *Polistes versicolor* (n= 56), *Polybia occidentalis* (n= 54), *Brachygastra lecheguana* (n= 49), *Polybia paulista* (n= 46), e *Protonectarina sylveirae* (n= 42), *Apoica pallens* (n= 39). The presence of few Constant and Accessory species may mean that they are more widespread throughout the Brazilian territory; however, we cannot ignore the polarization of social wasp studies on the Southeastern Region, which would make endemic species seem constant when this data is extrapolated to the whole country.

Regarding the occurrence of species per state (Table 2), we noted that five species were present in 14 or more sampled states: *Brachygastra lecheguana* (n= 15), *Polybia ignobilis* (n= 15), *Synoeca surinama* (Linnaeus, 1767) (n= 15), *Polybia sericea* (n= 15) e *Polybia occidentals* (n= 14). However, 36.17% (n= 85) of the identified species were recorded only for a single state. Amongst these, the Amazonas state stands out with the most species recorded (n =125), while the Goiás state has the least species recorded (n= 9) (Table 2).

This impressive number of species recorded for Amazonas surely does not yet represent the region's mega diversity, since there were only four studies carried out on this state; further investigations should lead to a significant increase of recorded species. On the other hand, the small amount of species recorded on the single study carried out in Goiás (Santos, 1996) shows the particular characteristics of its methodology, since the study which took place at an orchard and not at the state's typical biome environments.

While representatives of the Polistinae are found throughout the whole world, its greatest diversity is achieved in tropical regions (specially the Neotropical region); its worldwide fauna is made of 26 genera and more than 1000 species (Carpenter and Andena, 2013). Some authors (e.g. Fox, 1889; Richard, 1978; Carpenter, 1991; Carpenter and Marques, 2001; Carpenter and Andena, 2013) estimate that Brazil holds 22 genera and 346 species of social wasps. Therefore, based on the properly identified species in the 76 publications hereby listed (Table 1), we observe that the 233 species recorded correspond to 77.74% and 68.62% of the total estimated species.

By generating a Species Accumulation Curve based on the studies and recorded species (Fig 4), the estimators Jack 1 and Jack 2 estimated, respectively, 301.08 and 341.38 species for Brazil, a lower amount than the described in the literature; however, we believe this percentage to be a little higher when we add, to the diversity studies, publications on natural history, biology and ecology of social wasps.

Considering the potential of social wasps as role models for studies in biology, behavior and ecology due to their importance as ecological service providers in the ecosystem, we must highlight the value of studies that investigate the ecology of these species in detail, aiming to further understand this group of organisms. The small amount of studies on social wasp ecology may be a consequence of the sometimes exaggerated behavior of human societies when concerning wasps (by associating wasps to the risk of accidents provoked by their stings) or even of disregard (by believing that these species have no value). Therefore, the analysis presented here may guide and subside future research on social wasp diversity and its ecological relations on the different Brazilian biomes.

Finally, our study's contribution is to widen the possibilities on social wasp research scenario and to give directions for future researchers on their work through the material listed on this paper.

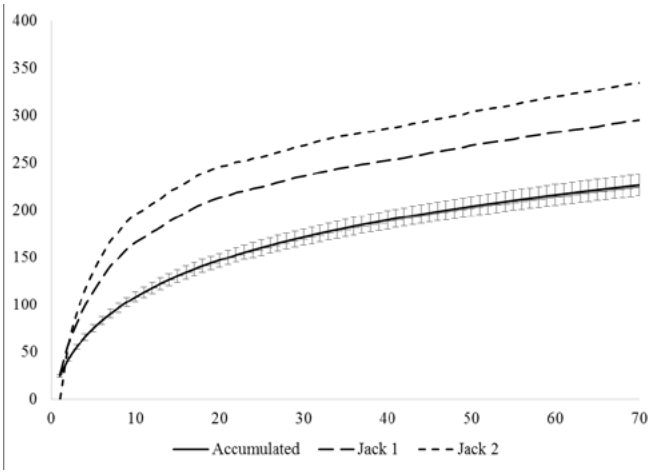

Fig 4. Rarefaction Curves for species richness estimators and Species Accumulation Curves generated through social wasp diversity studies in Brazil from 1982 to 2015, made from 5.000 randomizations on the sample order (see details in Data Analysis).

Table 2. Social wasp species, studied environment, sampling methods and publication references sampling species diversity in Brazil from 1982 to 2015: Studied Environment: AG – Agroecosystem; AM – Amazon rainforest; AT – Atlantic rainforest; CA – Caatinga; EU – Eucalyptus; MA – Mangrove; PA – Pantanal; RE – Restinga; RF – Riparian forest; RG – Rocky Grassland; SA – Savanna; UE – Urban Environment. Studied State: AC – Acre; AP – Amapá; AM – Amazonas; BA – Bahia; DF – Distrito Federal; GO – Goiás; MA – Maranhão; MT – Mato Grosso; MS – Mato Grosso do Sul; MG – Minas Gerais; PA – Pará; PR – Paraná; PI – Piauí; RS – Rio Grande do Sul; RO – Rondônia; RR – Roraima; SC – Santa Catarina; SP – São Paulo. Sampling Methods: AS – Active Search; BT – Bait Traps; F – Fogging technique; FS – Flower Search; LB - Liquid Bait; LT – Light Traps; MO – Möericke; MT – Malaise Trap; Q – Quadrant; ST –Shuey Trap; TT – Tray Traps. References: see Table 1.

Species	Studied Environment	Studied State	Sampling Methods	References	Constancy
Agelaia acreana Silveira & Carpenter, 1995	AM	AM	MT	43	1.28
Agelaia angulata (Fabricius, 1804)	AM, AT, UE	AM, MA, MG, PA, RO, RR, SP	BT, MT, ST, AS, LB	10, 12, 20, 27, 28, 43, 44,56, 57, 58, 63, 71, 74	16.67
Agelaia angulicollis (Spinosa, 1851)	AM	AM, PA	BT, MT, AS	10, 27, 42	3.85
*Agelaia brevistigma (*Richards, 1978)	AM	AM, AP	MT	22	1.28
Agelaia cajennensis (Fabricius, 1798)	AM, CA, SA	AM, AP, BA, PA, RO	BT, LT, MT, AS, LB	10, 12, 27, 42, 43, 51, 56, 71	10.26
Agelaia centralis (Cameron, 1907)	AG, AM, AT, CA	AM, AP, MA, MG, PA, RO	BT, LT, MT, AS, LB	10, 22, 27, 42, 43, 44, 51,56, 57, 58, 71	15.38
Agelaia constructor (de Saussure, 1854)	AM	AM	BT, AS	43, 56	2.56
Agelaia flavipennis (Ducke, 1905)	AM, SA	AM, MT	MT, AS	58, 70	2.56
Agelaia fulvofasciata (Degeer, 1773)	AM	AM, AP, MA, PA, RO, RR	BT, LT, MT, AS, LB	10, 12, 20, 22, 27, 42, 43, 56, 57, 58, 71, 74	15.38
Agelaia hamiltoni (Richards, 1978)	AM	RO	BT, LB	71	1.28
Agelaia lobipleura (Richards, 1978)	AM, SA	AM, MT, RO	MT, LB, Q	6, 20, 70, 71	5.13
Agelaia melanopyga Cooper, 2000	AM	RO	BT, LB	71	1.28
Agelaia multipicta (Haliday, 1836)	AG, AM, AT, EU, RF, RG, SA, UE	MG, MS, MT, RS, RR, SC, SP	BT, MT, ST, AS, TT, FS, LB, MO, Q	1, 2, 15, 19, 21, 23, 24, 28, 30, 32, 34, 39, 40, 41, 45, 49, 52, 53, 61, 63, 64, 65, 66, 67, 70, 72, 73, 74, 75, 76, 77, 78	41.03
Agelaia myrmecophila (Ducke, 1905)	AM, SA	AM, AP, MA, PA, RO	BT, LT, MT, AS, F, LB	10, 20, 22, 27, 42, 43, 56, 57, 70, 71	12.82
Agelaia ornata (Ducke, 1905)	AM	AM, RO	AS, LB	43, 56, 58, 71, 74	6.41
Agelaia pallidiventris (Richards, 1978)	AM	AM, RO	AS, LB	43, 71	2.56
Agelaia pallipes (Olivier, 1791)	AG, AM, AT, CA, EU, RF, AS, UE	AM, BA, CE, GO, MA, MG, MT, MS, PA, PI, RO, RS, SP	BT, LT, MT, AS, FS, LB	1, 7, 10, 12, 16, 19, 25, 27, 31,32, 34, 36, 37, 40, 42, 43, 47, 50,51, 54, 56, 57, 58, 60, 62, 65, 67, 70, 71, 72, 73, 77	41.03
Agelaia testacea (Fabricius, 1804)	AM	AM, AP, MA, PA, RO, RR,	BT, LT, MT, AS, LB	10, 27, 42, 43, 56, 57, 58, 71, 74	11.54
Agelaia timida Cooper, 2000	AM	RO	BT, LB	71	1.28
Agelaia vicina (Saussure, 1854)	AG, AT, CA, EU, RF, RG, SA,UE	AL, BA, CE, MG, SC, SP, RS	BT, LT, MT, AS, FS, LB, Q	2, 15, 21, 23, 24, 25, 26, 28, 30,31,32, 33, 34, 39, 40, 41, 46, 49, 51, 53, 59, 62, 64, 65, 66, 69, 72, 73, 75	37.18
Angiopolybia obidensis (Ducke, 1904)	AM	AM	BT, AS	43, 56	2.56
Angiopolybia pallens (Lepeletier, 1836)	AM, AT, CA, MG, RE, UE	AM, AP, BA, MA, PA, PE, RR, SP	BT, LT, MT, AS, FS	10, 12, 18, 20, 22, 27, 28, 42, 43, 51, 56, 57, 58, 74	17.95
Angiopolybia paraensis (Spinosa, 1851)	AM, CA	AM, MA, BA, PA, RO	BT, LT, MT, AS, LB	10, 12, 20, 27, 42, 43, 51, 56, 58, 71	12.82

Table 2. Social wasp species, studied environment, sampling methods and publication references sampling species diversity in Brazil from 1982 to 2015: Studied Environment: AG – Agroecosystem; AM – Amazon rainforest; AT – Atlantic rainforest; CA – Caatinga; EU – Eucalyptus; MA – Mangrove; PA – Pantanal; RE – Restinga; RF – Riparian forest; RG – Rocky Grassland; SA – Savanna; UE – Urban Environment. Studied State: AC – Acre; AP – Amapá; AM – Amazonas; BA – Bahia; DF – Distrito Federal; GO – Goiás; MA – Maranhão; MT – Mato Grosso; MS – Mato Grosso do Sul; MG – Minas Gerais; PA – Pará; PR – Paraná; PI – Piauí; RS – Rio Grande do Sul; RO – Rondônia; RR – Roraima; SC – Santa Catarina; SP – São Paulo. Sampling Methods: AS – Active Search; BT – Bait Traps; F – Fogging technique; FS – Flower Search; LB - Liquid Bait; LT – Light Traps; MO – Möericke; MT – Malaise Trap; Q – Quadrant; ST –Shuey Trap; TT – Tray Traps. References: see Table 1. (Continuation)

Species	Studied Environment	Studied State	Sampling Methods	References	Constancy
Angiopolybia zischkai Richards, 1978	AM	RO	BT, LB	71	1.28
Apoica albimacula (Fabricius, 1804)	AM	AM	LT, AS	43	1.28
Apoica arborea Saussure, 1854	AM	AM, MA, PA	BT, LT, MT, AS	10, 43, 56, 57, 58	6.41
Apoica flavissima Vecht, 1972	AM, AT, UE,CA, EU, AS	AM, AP, MS, PB, RR, SP	BT, LT, MT, AS, TT, LB, MO	1, 19, 22, 37, 47, 51, 55, 61, 74, 77	12.82
Apoica gelida Vecth, 1972	AG, AM, CA, RF, SA	AM, MG, PE, RO, SP	BT, LT, MT, LB	23, 35, 38, 43, 51, 52, 65, 71, 73	12.82
Apoica pallens (Fabricius 1804)	AG, AM, AT, CA, RG, EU, MG, PA, RE, RF, SA, UE	AM, AP, GO, BA, MA, MG, MT, MS, PA, SP	BT, LT, MT, ST, AS, FS, LB, Q	1, 3, 4, 5, 6, 7, 10, 11, 15 16, 18, 21,22, 23, 24, 26, 27, 28, 33, 36, 39, 40, 42, 43, 44, 45, 48, 50, 51, 56, 57, 58, 60, 63, 64, 65, 68, 72, 75, 77	51.28
Apoica pallida (Olivier, 1791)	AM, CA	AM, AP, BA, CE, MA, PA, RR	BT, LT, MT, AS	10, 22, 43, 51, 57, 58, 74	8.97
Apoica strigata Richards, 1978	AM	AM, MA, PA	BT, LT	27, 43, 57	3.85
Apoica thoracica Buysson, 1906	AM	AM, AP, RR	BT, LT, MT, AS	22, 43, 58, 74	5.13
Asteloeca traili (Cameron, 1906)	AM	MA, PA	BT, LT	10, 57	2.56
Brachygastra albula Richards, 1978	AM	AM, RO	MT, LB	20, 71	2.56
Brachygastra augusti (Saussure, 1854)	AM, AT, EU, PA, RF, SA, UE	AM, AP, DF, MA, MG, MS, MT, RO, SP	BT, MT,AS, FS, LB	1, 8, 15, 19, 22, 23, 32, 34, 36, 40, 44, 47, 48, 52, 57, 58, 59, 60, 62, 64, 70, 71, 72, 75	30.77
Brachygastra bilineolata (Spinosa, 1841)	AM, SA	AM, AP, MT, PA, RO	BT, MT, AS, LB, Q	6, 10, 22, 37, 58, 70, 71	8.97
Brachygastra cooperi (Richards, 1978)	AM	RO	BT, LB	71	1.28
Brachygastra lecheguana (Latreille, 1824)	AG, AM, AT, CA, EU, MG, PA, RE, RF, RG, SA, UE	AM, AP, BA, GO, MG, MS, MT, PA, PB, PE, PI, RO, RS, SC, SP	BT, LT, MT, AS, TT, FS, LB, MO	1, 2, 3, 4, 5, 7, 10, 11, 13, 14, 16, 17,18, 19, 20, 22, 24, 26, 32, 33, 34, 35, 38, 39, 40, 41, 44, 47, 48, 49, 51, 53, 54, 55, 58, 59, 61, 62, 64, 65, 66, 67, 68, 70, 71, 72, 75, 77, 78	62.82
Brachygastra moebiana (Saussure, 1867)	AM, AT, SA, UE	AM, MS, SP	MT, AS, LB	20, 34, 47, 72, 75	6.41
Brachygastra mouleae Richards, 1978	AT, SA	MS, SP	BT, MT, AS, TT, FS, LB, MO	34, 55, 61, 62, 72, 77	7.69
Brachygastra scutellaris (Fabricius, 1804)	AM, CA	AM, PE, PI, RO	MT, LB	43, 51, 58, 71	5.13
Brachygastra smithii de Saussure, 1853	AM	RR	AS	74	1.28
Chartergellus amazonicus Richards, 1978	AM	AM, RO	MT, AS, LB	43, 56, 71	3.85

Table 2. Social wasp species, studied environment, sampling methods and publication references sampling species diversity in Brazil from 1982 to 2015: Studied Environment: AG – Agroecosystem; AM – Amazon rainforest; AT – Atlantic rainforest; CA – Caatinga; EU – Eucalyptus; MA – Mangrove; PA – Pantanal; RE – Restinga; RF – Riparian forest; RG – Rocky Grassland; SA – Savanna; UE – Urban Environment. Studied State: AC – Acre; AP – Amapá; AM – Amazonas; BA – Bahia; DF – Distrito Federal; GO – Goiás; MA – Maranhão; MT – Mato Grosso; MS – Mato Grosso do Sul; MG – Minas Gerais; PA – Pará; PR – Paraná; PI – Piauí; RS – Rio Grande do Sul; RO – Rondônia; RR – Roraima; SC – Santa Catarina; SP – São Paulo. Sampling Methods: AS – Active Search; BT – Bait Traps; F – Fogging technique; FS – Flower Search; LB - Liquid Bait; LT – Light Traps; MO – Möericke; MT – Malaise Trap; Q – Quadrant; ST –Shuey Trap; TT – Tray Traps. References: see Table 1. (Continuation)

Species	Studied Environment	Studied State	Sampling Methods	References	Constancy
Chartergellus communis Richards, 1978	AM, CA, SA	BA, MG, MT, PA, RO	BT, MT, AS, LB, Q	6, 16, 26, 27, 37 51, 70, 71	10.26
Chartergellus nigerrimus Richards, 1978	AM	AM, AP	MT	22	1.28
Chartergellus punctatior Richards, 1978	AM	AM, AP	MT	22	1.28
Chartergellus zonatus (Spinola, 1851)	AM	RO	BT, LB	71	1.28
Charterginus fulvus Fox, 1904	AM	AM, PA, RO	BT, MT, AS, LB	10, 43, 56, 71	5.13
Chartergus chartarius (Olivier, 1971)	AM, SA	AM, AP, MT, RR	MT, AS, Q	6, 22, 58, 70, 74	6.41
Chartergus globiventris Saussure, 1854	AM, CA, PA, SA, UE	BA, MT, PA, RO	BT, MT, AS, LB	10, 26, 37, 48, 51, 71	7.69
Chartergus metanotalis Richards, 1978	AM	PA	BT, MT	10	1.28
Clypearia angustior Ducke, 1906	AT, CA, SA	BA, MG	BT, LT, MT, AS, FS	11, 23, 44, 51, 59, 68	7.69
Clypearia apicipennis (Spinosa, 1851)	AM	AM	AS	43, 56	2.56
Clypearia duckei Richards, 1978	AM	AM, AP	MT	22, 43	2.56
Clypearia sulcata (de Saussure, 1853)	AM	AM, AP, PA	BT, MT, AS	10, 22, 43, 56, 58	6.41
Clypearia weyrauchi Richards, 1978	AM	AM, AP	MT	22	1.28
Epipona tatua (Cuvier, 1797)	AM, SA	AM, DF, MA, MG, MT, PA	AS, BT, LT, MT, Q	6, 8, 10, 43, 56, 57, 70	10.26
Leipomeles dorsata (Fabricus, 1804)	AM, CA	AM, BA, CE, PA, RO	BT, LT, MT, AS, LB	10, 27, 42, 43, 51, 56, 58, 71	10.26
Leipomeles pussila (Ducke, 1904)	AM	AM	AS	43	1.28
Leipomeles spilogastra Cameron, 1912	AM	AM	MT, F	43	1.28
Metapolybia alfkenii (Ducke 1904)	AM	AM	MT	22	1.28
Metapolybia cingulata (Fabricius 1804)	AM, AT, CA, MG, RE, SA, UE	AM, AP, BA, MG, MT, PA, PE, SP	AS, BT, MT, LB, Q	6, 10, 18, 25, 26, 31, 37, 44, 51, 72	12.82
Metapolybia decorata (Gribodo, 1896)	AM	AM, AP	MT	22	1.28
Metapolybia docilis Richards, 1978	SA	SP	MT, AS, LB	34, 72	2.56
Metapolybia nigra Richards, 1978	AM	AM	AS	43, 58	2.56
Metapolybia rufata Richards, 1978	AM	AM, AP	MT	22, 43	2.56
Metapolybia suffusa (Fox, 1899)	SA	SP	AS	37	1.28
Metapolybia unilineata (Ihering, 1904)	AM, SA	AM, RR, SP	MT, AS	37, 43, 74	3.85
Mischocyttarus adolphi Zikán, 1949	AM	AM, PA	BT, MT, AS	10, 27, 42	3.85
Mischocyttarus alboniger Richards, 1978	AM	RR	AS	74	1.28
Mischocyttarus aracatubaensis Zikan, 1949	SA	SP	FS	62	1.28
Mischocyttarus araujoi Zikán 1949	AT, EU, RF	MG, SP	BT, AS	1, 15, 23, 44, 49, 64	7.69

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Species	Studied Environment	Studied State	Sampling Methods	References	Constancy
Mischocyttarus artifex (Ducke, 1914)	AM, RF, SA	AM, AP	BT, MT, AS	22, 23, 52	3.85
Mischocyttarus bahiae Richards, 1945	AG, CA, UE	BA, MG	LT, LT, MT, AS, FS	4, 5, 51, 78	5.13
Mischocyttarus bahiaensis Zikán, 1949	CA	BA, MG	AS, BT, LT, MT	44, 51	2.56
Mischocyttarus bertonii Ducke, 1918	UE	PA	AS	50	1.28
Mischocyttarus carbonarius (Saussure, 1854)	AM	AM, PA, RR	BT, MT, AS	10, 27, 42, 74	5.13
Mischocyttarus carinulatus Zikán, 1949	CA	BA	LT, MT	51	1.28
Mischocyttarus cassununga (Ihering, 1903)	AG, AT, CA, EU, RF, RG SA, UE	BA, DF, MG, PA, PE, SP	BT, LT, MT, AS, FS, LB, Q	1, 8, 15, 16, 19, 21, 23, 24, 26, 28, 30, 32, 35, 38, 39, 40, 41, 44, 45, 49, 50, 51, 52, 59, 62, 64, 68, 75, 78	37.18
Mischocyttarus cearensis Richards, 1945	CA	BA	LT, MT, FS	17, 51	2.56
Mischocyttarus cerberus Ducke, 1918	AG, AT, CA, EU, SA, UE	BA, DF, MT, MG, MS, SP	BT, LT, MT, AS, FS, LB, Q	1, 6, 8, 13, 16, 19, 25, 26, 31, 32, 34, 37, 47, 51, 62, 70, 72, 75	24.36
Mischocyttarus collarellus Richards, 1940	AM	AM, PA	BT, MT, AS	10, 27, 42	3.85
Mischocyttarus collaris (Ducke, 1904)	AM	AM	AS	43, 56	2.56
Mischocyttarus confusus Zikan, 1935	AT, RF, RG, SA	MG	BT, AS, FS	15, 23, 24, 33, 35, 38, 44, 45, 52	11.54
Mischocyttarus consimilis Zikán, 1949	AT, SA	SP	MT, AS, LB	34, 72	2.56
Mischocyttarus drewseni Saussure, 1954	AG, AM, AT, CA, EU, RF, RG, SA, UE	AM, BA, MG, MT, MS, RS, SP	BT, LT, MT, AS, FS, LB, Q	1, 4, 6, 11, 14, 15, 16, 19, 23, 24, 26, 30, 32, 33, 35, 36, 38, 39, 40, 41, 44, 45, 49, 51, 52, 53, 58, 59, 60, 62, 64, 65, 66, 68, 69, 70, 73, 78	48.72
Mischocyttarus duckei Buysson, 1908	AM	AM, PA	BT, MT, AS	10, 20, 27, 42	5.13
Mischocyttarus flavicans (Fabricius, 1804)	AM	AM, PA, RO	BT, AS, LB	24, 43, 56, 71	5.13
Mischocyttarus flavicornis Zikán, 1935	CA	BA	LT, MT	51	1.28
Mischocyttarus flavosculletatus Zikán, 1935	AT	MG	BT, AS	44, 64	2.56
Mischocyttarus fluminensis Zikán, 1949	AT	MG	BT, AS	44	1.28
Mischocyttarus foveatus Richards, 1940	AM	AM, AP, PA	BT, MT	10, 22	2.56
Mischocyttarus frontalis (Fox, 1898)	AS, UE	MG, MS	AS, BT, LB	44, 47	2.56
Mischocyttarus funerulus Zikán, 1949	AT	MG	BT, AS	15, 23, 44, 49	5.13
Mischocyttarus gomesi Silveira, 2013	AM	RO	BT, LB	71	1.28

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Species	Studied Environment	Studied State	Sampling Methods	References	Constancy
Mischocyttarus goyanus Zikán, 1949	SA	DF	AS	8	1.28
Mischocyttarus granadaensis Zikan, 1949	AM	RR	AS	74	1.28
Mischocyttarus ignotus Zikán, 1949	AG, AT, SA	MG, SP	MT, AS, LB	34, 72, 78	3.85
Mischocyttarus iheringi Zikán, 1935	UE	MG	AS	64	1.28
Mischocyttarus imitator Zikán, 1935	AM	AM, AP, PA	BT, MT	10, 22, 43	3.85
Mischocyttarus injucundus (Saussure, 1854)	AM, CA, SA	AM, AP, BA, PA, RR, SP	BT, LT, MT, AS	10, 22, 37, 51, 74	6.41
Mischocyttarus interruptus Richards, 1978	AM	RO	BT, LB	71	1.28
Mischocyttarus juranus Richards, 1978	AM	PA	BT	10	1.28
Mischocyttarus labiatus (Fabricius, 1804)	AM, AT, CA, EU, SA	AM, BA, MT, PA, RO, RR, SP	BT, MT, AS, LB, Q	1, 6, 10, 20, 43, 51, 56, 58, 71, 74	12.82
Mischocyttarus lanei Zikán, 1949	AG, CA, UE	BA	BT, LT, MT, AS, FS	4, 5, 13, 51	5.13
Mischocyttarus latior (Fox, 1898)	AG, AT, EU, RG, SA, UE	MG, MS, SP	BT, AS, FS, LB	1, 16, 19, 32, 35, 38, 45, 47, 77, 78	12.82
Mischocyttarus lecointei (Ducke, 1904)	AM	AM, AP, PA, RO	BT, MT, AS, LB	10, 22, 27, 42 ,43, 56, 71	8.97
Mischocyttarus malaris Richards, 1978	AM	AM	MT	42	1.28
Mischocyttarus maracaensis Raw, 1992	AM	RR	AS	74	1.28
Mischocyttarus marginatus (Fox, 1898)	AT CA, RG, SA	BA, MG, PA, SP	BT, LT, MT, FS, LB	19, 32, 35, 38, 45, 51	7.69
Mischocyttarus mattogrossoensis Zikán, 1935	AG, CA, RF, SA, UE	BA, MG, MT, MS, SP	AS, BT, FS, LB, Q	4, 5, 6, 40, 47, 65, 70, 78	10.26
Mischocyttarus melanops Cooper, 1996	AM	PA	BT	10	1.28
Mischocyttarus metathoracicus (Saussure, 1854)	AM, SA	AM, MT, PA	BT, MT, AS, Q	6, 10, 27, 43, 58	6.41
Mischocyttarus mirificus Zikán, 1935	RG	MG	BT, AS	45	1.28
Mischocyttarus montei Zikán, 1949	CA	BA	LT, MT	51	1.28
Mischocyttarus nomurae Richards, 1978	AG, CA	BA, MG	LT, MT, AS	51, 78	2.56
Mischocyttarus oecothrix Richards, 1940	AM	AM, PA	BT, MT, AS	10, 27, 42	3.85
Mischocyttarus paraguayensis Zikán, 1935	AG	MG	AS	78	1.28
Mischocyttarus parallellogrammus Zikán, 1935	AT, UE	MG, SP	BT, AS	28, 39	2.56
Mischocyttarus paulistanus Zikán, 1935	AT, SA	SP	MT, AS, LB	34, 72	2.56
Mischocyttarus prominulus Richards, 1941	AM	RR	AS	74	1.28
Mischocyttarus punctatus (Ducke, 1904)	AM	MG, PA	AS, BT	27, 44	2.56
Mischocyttarus riograndensis Richards, 1978	AT	RS	FS	53	1.28

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Species	Studied Environment	Studied State	Sampling Methods	References	Constancy
Mischocyttarus rotundicollis (Cameron, 1912)	AG, AM, AT, CA, EU, RG, RF, SA, UE	AM, BA, MG, MT, RS, SP	BT, MT, AS, FS, LB	1, 15, 19, 21, 23, 25, 28, 31, 32, 34, 35, 38, 40, 41, 43 44, 45, 49, 51, 53, 56, 59, 62, 64, 65, 67, 70, 72, 75, 78	38.46
Mischocyttarus saturatus Zikán, 1949	AM	AM, PA	BT, MT	10, 43	2.56
Mischocyttarus socialis (Saussure, 1854)	AM, AT, RF, RG, SA, UE	AM, SP, MG	BT, MT, AS, FS, LB	15, 16, 19, 23, 28, 32, 33, 35, 38, 39, 43, 45, 52, 56, 58, 64	20.51
Mischocyttarus surinamensis (Saussure, 1854)	AM, CA	AM, BA, CE, PA, RR	BT, MT, AS	10, 43, 51, 56, 58,, 74	7.69
Mischocyttarus sylvestris Richards, 1945	AM	AM, PA	BT, MT, AS	10, 27, 42	3.85
Mischocyttarus synoecus Richards, 1940	AM	AM, AP, PA	BT, MT, AS, F	10, 22, 27, 42, 43	6.41
Mischocyttarus tectus Cooper, 1996	AM	PA	BT, MT	10	1.28
Mischocyttarus timbira Silveira, 2006	SA	SP	AS	37	1.28
Mischocyttarus tomentosus Zikán, 1935	AM	PA, RO	BT, MT, LB	10, 71	2.56
Mischocyttarus tricolor Richards, 1945	AT, SA	MG	BT, AS	15, 23, 35, 38, 44, 49, 75	8.97
Mischocyttarus wagneri (Buysson, 1908)	AT, RF, RG	MG	BT, AS	15, 23, 44, 45, 49, 52, 64	8.97
Mischocyttarus ypiraguensis Fonseca, 1926	RG	MG	BT, AS	45	1.28
Parachartergus fasciipennis Ducke, 1905	AM	AM	MT	43	1.28
Parachartergus flavofasciatus (Cameron, 1906)	AM	RO	BT, LB	71	1.28
Parachartergus fraternus (Gribodo, 1891)	AM, AT, PA, RG, RF, SA, UE	AM, AP, DF, MA, MG, MT, PA, RO, SP	BT, MT, AS, FS, LB, Q	6, 8, 10, 19, 22, 23, 27, 32, 33, 37, 38, 39, 43, 44, 45, 48, 52, 57, 58, 64, 69, 70, 71	29.49
Parachartergus fulgidipennis (Saussure, 1854)	AM	AM, AP, PA	BT, MT	22, 27	2.56
Parachartergus griseus (Fox, 1898)	AM	AM	MT	43	1.28
Parachartergus lenkoi Richards, 1978	AM	RO	BT, LB	71	1.28
Parachartergus pseudoapicalis Willink, 1959	AG, AM, AT, CA, EU, MG, RE, AS, UE	BA, MG, PE, RO, SP	BT, LT, MT, AS, FS, LB	1, 4, 5, 16, 18, 26, 35, 51, 68, 71	12.82
Parachartergus richardsi Willink, 1959	AM	AM, PA	MT	10, 43	2.56
Parachartergus smithii (Saussure, 1854)	AM, AT, SA, UE	AM, AP, MS, MT, RO, SP	MT, AS, FS, LB	22, 34, 47, 62, 70, 71, 72	8.97
Polistes actaeon Haliday, 1836	AG, AT, EU, RF, AS, UE	MG, RS, SP	BT, AS, FS, LB	15, 21, 23, 35, 38, 39, 40, 44, 49, 52, 53, 59, 64, 66, 67, 78	20.51
Polistes biguttatus Haliday, 1836	AT	RS	FS	53	1.28

Table 2. Social wasp species, studied environment, sampling methods and publication references sampling species diversity in Brazil from 1982 to 2015: Studied Environment: AG – Agroecosystem; AM – Amazon rainforest; AT – Atlantic rainforest; CA – Caatinga; EU – Eucalyptus; MA – Mangrove; PA – Pantanal; RE – Restinga; RF – Riparian forest; RG – Rocky Grassland; SA – Savanna; UE – Urban Environment. Studied State: AC – Acre; AP – Amapá; AM – Amazonas; BA – Bahia; DF – Distrito Federal; GO – Goiás; MA – Maranhão; MT – Mato Grosso; MS – Mato Grosso do Sul; MG – Minas Gerais; PA – Pará; PR – Paraná; PI – Piauí; RS – Rio Grande do Sul; RO – Rondônia; RR – Roraima; SC – Santa Catarina; SP – São Paulo. Sampling Methods: AS – Active Search; BT – Bait Traps; F – Fogging technique; FS – Flower Search; LB - Liquid Bait; LT – Light Traps; MO – Möericke; MT – Malaise Trap; Q – Quadrant; ST –Shuey Trap; TT – Tray Traps. References: see Table 1. (Continuation)

Species	Studied Environment	Studied State	Sampling Methods	References	Constancy
Polistes billardieri Fabricius, 1804	AG, AT, CA, EU, MG, RE, RF, RG, SA, UE	BA, MG, MS, MT, PB, PE, RS, SP	BT, LT, MT, AS, FS, LB	1, 4, 13, 15, 16, 18, 24, 33, 35, 36, 38, 40, 41, 43, 44, 45, 46, 47, 49, 51, 52, 53, 60, 65, 68, 70	33.33
Polistes brevifissus Richards, 1978	AM, AT, CA, RF	BA, MS, PB, RR	BT, LT, MT, AS, LB, AS	36, 51, 60, 74	5.13
Polistes canadensis (Linnaeus, 1758)	AG, AM, AT, CA, EU, MG, RE, RG, SA, UE	AM, AP, BA, CE, MG, MT, MS, PB, PE, PI, RO, SP	AS, BT, LT, MT, TT, FS, LB, MO, Q	1, 3, 4, 5, 6, 11, 13, 14, 17, 18, 19, 22, 32, 37, 43, 44, 47, 51, 54, 55, 56, 58, 61, 68, 70, 71, 76, 77, 78	37.18
Polistes carnifex (Fabricius, 1775)	AM, AT, CA, MG, RE, UE	AM, BA, MG, PE, SP	AS, BT, LT, MT	18, 28, 44, 51, 58	6.41
Polistes cavapyta Saussure, 1853	AT	RS	FS	53	1.28
Polistes cavapytiformis Richards, 1978	AT	RS	FS	53	1.28
Polistes cinerascens Saussure, 1854	AG, AT, CA, MG, RE, RF, RG, SA	AL, BA, CE, MG, MS, RS, SP	BT, LT, MT, AS, FS, LB, Q	1, 11, 13, 15, 16, 18, 23, 24, 33, 35, 36, 38, 40, 41, 44, 45, 49, 51, 52, 53, 60, 62, 64, 65, 67, 73, 75	34.62
Polistes consobrinus Saussure, 1853	AG, AT, EU	RS, SC, SP	BT, AS, FS	1, 2, 53	3.85
Polistes davillae Richards, 1978	RG	MG	BT, AS	45	1.28
Polistes ferreri Saussure, 1853	AG, AT, CA, RG, RF, SA, UE	BA, MG, MS, PA, SC, SP	BT, LT, MT, AS, TT, MO, Q	2, 15, 16, 23, 24, 33, 35, 38, 40, 44, 45, 49, 50, 51, 55, 61, 77	21.79
Polistes geminatus Fox, 1898	AT, CA, SA, RF	BA, MG, MS, MT, SP	BT, LT, MT, AS, FS, LB	34, 35, 36, 38, 40, 51, 60, 62, 70, 72	12.82
Polistes goeldii Ducke, 1904	AM	AM, MG, PA	BT, MT, AS	10, 35, 43, 56	5.13
Polistes lanio (Fabricius, 1775)	AG, AT, CA, EU, AS, UE	BA, MG, SP, PA	BT, LT, MT, ST, AS, FS	21, 35, 38, 40, 50, 51, 62, 63, 65, 73, 75	14.10
Polistes occipitalis Ducke, 1904	AM	MG, PA, RO	AS, BT, MT, LB	10, 27, 44, 71	5.13
Polistes pacificus Fabricius, 1804	AM, AT, CA, RF, SA	AM, BA, MG, MT, PA, RS	BT, LT, MT, AS, FS, Q	6, 10, 15, 23, 43, 44, 49, 51, 52, 53, 56, 64, 75	16.67
Polistes rufiventris Ducke, 1904	AM	PA	BT, MT	27	1.28
Polistes satan Bequaert, 1940	AG, SA	DF, MG	BT, AS	8, 78	2.56
Polistes similimus Zikán, 1951	AG, AT, CA, EU, RG, RF, SA, UE	BA, MG, MS, RS, SP	BT, LT, MT, ST, AS, TT, FS, LB, MO	1, 14, 15, 17, 21, 23, 24, 31, 34, 36, 39, 40, 41, 44, 45, 49, 51, 52, 55, 60, 61, 62, 63, 64, 65, 66, 67, 72, 73, 75, 77, 78	41.03
Polistes subsericius Saussure, 1854	AG, AT, CA, RF, SA, UE	BA, MG, MT, MS, SP	BT, LT, MT, AS, FS, LB, Q	15, 16, 19, 23, 32, 35, 36, 38, 40, 41, 44, 45, 47, 49, 50, 61, 62, 65, 70	24.36
Polistes testaceicolor Bequaert, 1937	AM	AM, MA	MT, AS	43, 56, 57	3.85

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Species	Studied Environment	Studied State	Sampling Methods	References	Constancy
Polistes thoracicus Fox, 1898	SA	MT	AS	70	1.28
Polistes versicolor (Olivier, 1791)	AG, AM, AT, CA, EU, MG, PA, RE, RF, RG, SA, UE	AM, AP, BA, MA, MG, MS, MT, PA, RR, RS, SC, SP	BT, LT, MT, ST, AS, TT, FS, LB, MO	1, 2, 3, 4, 5, 10, 11, 13, 15, 16, 18, 19, 21, 22, 23, 25, 26, 28, 31, 32, 33, 34, 35, 36, 38, 39, 40, 41, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 55, 57, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 72, 73, 74, 75, 77, 78	73.08
Polybia affinis Buysson, 1908	AM	AM, PA	BT, MT	10, 27, 58	3.85
Polybia belemensis Richards, 1970	AM	AM, AP, PA	BT, MT, AS	22, 27, 43, 56, 58	6.41
Polybia bicyttarella Richards, 1951	AM, SA	SP, AM, AP, PA	BT, MT, AS	10, 22, 37, 43, 56, 58	7.69
Polybia bifasciata Saussure, 1854	AG, AM, AT, RF, SA,UE	AM, MG, RO, SP	BT, AS, FS, LB	15, 19, 23, 28, 32, 35, 38, 39, 40, 43, 44, 52, 59, 64, 70, 71, 78	21.79
Polybia bistriata (Fabricius, 1804)	AM	AM, BA, MA, PA, RO	BT, MT, LT, AS, LB	10, 27, 43, 51, 57, 56, 58, 71	10.26
Polybia brunnea (Curtis, 1844)	AM	PA	BT	27	1.28
Polybia cattillifex Moebius, 1856	AM, CA, UE	AM, SP, PA, RO	BT, LT, MT, AS, LB	20, 27, 28, 42, 51, 71	7.69
Polybia chrysothorax (Lichtenstein, 1796)	AG, AM, AT, CA, EU, PA, RF, RG, SA, UE	BA, CE, GO, MA, MG, MS, MT, SP	BT, LT, MT, AS, TT, FS, LB, MO	1, 3, 4, 5, 7, 11, 14, 15, 23, 31, 34,35,36, 37, 38, 40, 44, 45, 48, 49,51, 52, 55, 57, 59, 60, 61, 64, 65, 70, 72, 76, 78	42.31
Polybia depressa (Ducke, 1905)	AM, CA	AM, BA, MA, PI, RO	MT, AS, LB	43, 51, 56, 57, 58, 70, 71	8.97
Polybia diguetana Buysson, 1905	AM	RO	BT, LB	71	1.28
Polybia dimidiata (Olivier, 1791)	AG, AM, AT, CA, EU, RF, SA	AM, AP, BA, MG, MT, PA, RO, RR, SP	BT, MT, AS, LB	1, 10, 22, 27,34, 40, 42, 43, 44, 51, 56, 70, 71, 72, 74, 75	20.51
Polybia dimorpha Richards, 1978	AM, SA	AM, PA, RR	BT, MT, AS	10, 20, 27, 37, 43, 56, 58, 74	10.26
Polybia dubitata Ducke, 1910	AM	AM	AS	56	1.28
Polybia eberhardae Cooper, 1993	AM	RO	BT, LB	71	1.28
Polybia emaciata Lucas, 1879	AM	AM, PA, RO	BT, MT, AS, LB	20, 27, 42, 71	5.13
Polybia erythrothoraxla Richards, 1978	AG, SA	MG, MT	AS, Q	6, 70, 78	3.85
Polybia fastidiosuscula Saussure, 1854	AG, AM, AT, CA, EU, RG, RF, SA, UE	AM, BA, DF, MA, MG, PA, RS, SC, SP	BT, MT, ST, AS, FS, LB	1, 2, 8, 15, 19, 23, 24, 28, 31, 32,33,34, 35, 38, 39, 40, 43, 44, 45, 49, 50, 51, 53, 56, 57, 59, 62, 63, 64, 65, 72, 73, 75	42.31
Polybia flavifrons Smith, 1857	CA, SA, UE	BA, MT, SP	LT, AS, FS	26, 51, 62, 70, 75	6.41
Polybia flavitincta Fox, 1898	AT, MG, RE	BA	AS	18	1.28
Polybia gorytoides Fox, 1898	AM	AM, PA, RO	BT, MT, AS, LB	10, 27, 42, 71	5.13

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Species	Studied Environment	Studied State	Sampling Methods	References	Constancy
Polybia ignobilis (Haliday, 1836)	AG, AM, AT, CA, EU, MG, PA, RE, RF, RG, SA, UE	BA, CE, DF, GO, MA, MG, MS, MT, PA, PB, PI, RR, RS, SC, SP	BT, LT, MT, AS, TT, FS, LB, MO, Q	1, 2, 3, 4, 5, 7, 8, 11, 13, 14, 15, 16,17, 18, 19, 24, 25, 26, 28, 30, 31, 32, 33, 34, 35, 36, 38, 39, 40, 41, 44, 45, 46, 47, 48, 49, 50, 51, 53, 54, 55, 57, 59, 60, 61, 62, 64, 65, 66, 67, 68, 70, 72, 73, 74, 75, 76, 77, 78	75.64
Polybia jurinei Saussure, 1854	AG, AM, AT, CA, EU, RF, RG, PA, SA, UE	AM, BA, CE, MA, MG, MT, MS, PA, RO, SP	BT, MT, AS, FS, LB, Q	1, 6, 10, 15, 16, 19, 21, 25, 27, 28,32, 34, 36, 37, 38, 39, 40, 41, 43, 44, 45, 47, 48, 49, 51, 56, 57, 58, 59, 60,62, 64, 65, 70, 71, 72, 73, 75, 78	50.00
Polybia liliacea (Fabricius, 1804)	AM, SA, UE	AM, MA, MS, MT, PA, RO, RR	BT, MT, AS, LB	10, 27, 42, 43, 47, 57, 56, 58, 70,71, 74	14.10
Polybia lugubris Ducke, 1905	UE	MG	BT	64	1.28
Polybia micans Ducke, 1904	AM, CA	BA, MA, PA, RO	BT, LT, MT, LB	10, 27, 51, 57, 71	6.41
Polybia minarun Ducke, 1906	AG, AT, CA, RF, SA, UE	BA, MG, PA, RS, SP	BT, LT, MT, AS, FS, LB	4, 15, 19, 32, 35, 38, 44, 49, 50, 51, 53, 65, 73	16.67
Polybia occidentalis (Olivier, 1791)	AG, AM, AT, CA, EU, MG, PA, RE, RF, RG, SA, UE	AM, BA, DF, GO, MA, MG, MT, MS, PB, PE, PI, RR, SC, SP	BT, MT, LT, AS, TT, FS, LB, Q	1, 2, 3, 4, 5, 6, 7, 8, 11, 13, 14, 15,16, 17, 18, 19, 23, 25, 26, 28, 31, 32, 33, 34, 35, 36, 38, 41, 43, 44, 45, 47,48, 49, 51, 54, 56, 57, 58, 59, 60, 61, 62, 64, 65, 66, 68, 70, 72, 73, 74, 75, 77, 78	69.23
Polybia parvulina Richards, 1970	AM	AM, PA, RO	BT, MT, AS, LB	10, 27, 43, 56, 70, 71	7.69
Polybia paulista (Ihering, 1896)	AG, AT, CA, EU, MG, RF, RG, RE, SA, UE	BA, DF, MG, MT, MS, PI, SP	BT, LT, MT, AS, FS, LB, Q	1, 3, 4, 5, 6, 8, 11, 13, 14, 15, 16, 18, 19, 23, 24, 25, 26, 31, 32, 33, 34, 35, 36, 38, 39, 40, 41, 45, 47, 51, 52, 54, 60, 62, 64, 65, 68, 72, 73, 75, 78	58.97
Polybia platycephala Richards, 1951	AG, AM, AT, CA, EU, RG, RF, SA, UE	AM, BA, MG, PA, RO, RS, SP	BT, MT, ST, AS, FS, LB	1, 10, 15, 16, 23, 27, 37, 39, 41, 43,44, 45, 46, 49, 51, 52, 53, 56, 59, 63, 64, 66, 71	29.49
Polybia procellosa Zavattari, 1906	AM	AM, RO	AS, LB	43, 70, 71	3.85
Polybia punctata Buysson, 1908	AT, CA	BA, SP	LT, MT, ST	51, 63	2.56
Polybia quadricincta Saussure, 1854	AM, SA	AM, AP, MT, PA, RO	BT, MT, AS, LB, Q	6, 10, 22, 27, 43, 56, 58, 70, 71	11.54
Polybia rejecta (Fabricius, 1798)	AG, CA, SA, AM, AT, MG, RE	AM, AP, BA, GO, MA, MG, PA, PE, RO, RR	BT, LT, MT, AS, LB	7, 10, 18, 20, 22, 27, 37, 43, 44, 51, 56, 57, 58, 71, 74, 78	20.51
Polybia roraimae Raw, 1998	AM	RR	AS	74	1.28
Polybia ruficeps Schrottky, 1902	AT, CA, PA, RF, SA, UE	BA, CE, MG, MS, MT, PI, SP	BT, LT, MT, AS, FS, LB, Q	6, 16, 17, 19, 25, 32, 36, 47, 48, 51, 54, 60, 70, 72	17.95
Polybia rufitarsis Ducke, 1904	AM	AM, AP, PA, RO	BT, MT, AS, LB	10, 22, 27, 43, 56, 71	7.69
Polybia scrobalis Richards, 1970	AM	AM, MA, PA, RO	BT, MT, LT, AS, LB	10, 27, 43, 57, 58, 56, 71	8.97

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Species	Studied Environment	Studied State	Sampling Methods	References	Constancy
Polybia scutellaris (White, 1841)	AG, AT,CA, EU, RF, RG, SA,UE	BA, MG, PA, RS, SC	BT, LT, MT, AS, FS, LB	2, 15, 16, 23, 33, 44, 45, 46, 49, 50, 51, 52, 53, 66, 67	19.23
Polybia sericea (Olivier, 1792)	AG, AM, AT, CA, EU, MG, PA, RE, RF, RG, SA,UE	AM, BA, GO,MA, MG, MS, MT, PA, PB, PI, RO, RR, RS, SC, SP	BT, MT, ST,AS, FS, LB, Q	1, 2, 3, 4, 5, 6, 7, 11, 13, 14, 15, 16,18, 19, 21, 24, 23, 25, 26, 30, 31, 32, 33, 34, 35, 36, 38, 39, 37, 40, 41, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 56, 57, 59, 60, 62, 63, 64, 65, 66, 68, 69, 70, 71, 72, 73, 74, 75, 77, 78	79.49
Polybia singularis Ducke, 1909	AM, SA	AM, AP,MA, MT, PA, RO	BT, MT, AS, LB, Q	6, 10, 22, 27, 42, 43, 56, 57, 58, 71	12.82
Polybia striata (Fabricius, 1787)	AM, SA, UE	AM, AP, MG, MA, PA, RO	BT, MT, LT, AS, LB	10, 16, 22, 27, 30, 42,43, 57, 58,59, 64, 71	15.38
Polybia tinctipennis Fox, 1898	AM	AM, RO	MT, LB	20, 43, 71	3.85
Polybia velutina Ducke, 1907	AM	AM	AS	43, 56	2.56
Protonectarina sylveirae (Saussure, 1854)	AG, AT, CA, EU, MG, RE, RF, RG, SA, UE	BA, CE, MG, MS, PI, RS, SC, SP	BT, LT, MT, AS,TT, FS, LB, MO	1, 2, 3, 4, 5, 11, 13, 15, 17, 18, 19,23, 24, 25, 26, 31, 32, 33, 34, 35, 38, 39, 41, 44, 45, 46, 51, 52, 53, 54, 55, 59, 61, 62, 64, 65, 66, 67, 68, 72, 73, 75, 77	55.13
Protopolybia acutiscutis Cameron, 1907	AM	RO	BT, LB	71	1.28
Protopolybia bituberculata Silveira & Carpenter, 1995	AM	AM, MA,	MT, AS	43, 56, 57, 58	5.13
Protopolybia chartergoides (Gribodo, 1891)	AM, SA	AM, AP, MA, MT, PA, RO	BT, MT, AS, LB, Q	6, 10, 20, 22, 43, 56, 57, 58, 71	11.54
Protopolybia duckei (Buysson, 1905)	CA	BA	LT, MT	51	1.28
Protopolybia duckeiana Richards, 1978	AM	AM	?	43	1.28
Protopolybia emortualis (de Saussure, 1855)	AM	AM, PA	BT, MT	10, 43	2.56
Protopolybia exigua (Saussure, 1854)	AG, AM, AT, CA, EU, MG, RE, RG, SA,UE,	BA, CE, MA,MT, MG, MS, PA, PE, PI, RR, SP	BT, LT, MT,AS, FS, TT, LB, MO, Q	1, 3, 4, 5, 6, 11 13, 14, 18, 19,26, 27, 28, 32, 33, 34, 37, 39, 51, 54, 55, 57, 61, 62, 64, 66, 68, 70, 72, 74, 75, 77	41.03
Protopolybia holoxantha (Ducke, 1904)	AM	AM	AS	43	1.28
Protopolybia nitida (Ducke, 1904)	AM	AM	MT	58	1.28
Protopolybia rotundata Ducke, 1910	AM	RO	BT, LB	71	1.28
Protopolybia rugulosa Ducke, 1907	AM	AM	MT	43	1.28

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Species	Studied Environment	Studied State	Sampling Methods	References	Constancy
Protopolybia sedula (Saussure, 1854)	AG, AM, AT, CA, EU, RG, RF, SA	AM, BA, CE, MG, SP	BT, LT, AS, Q	1, 15, 33, 35, 37, 38, 45, 51,52, 58, 59, 64, 73, 78	17.95
Pseudopolybia compressa (Saussure, 1854)	AM, CA, SA	AM, AP, BA, MT, RO	AS, LB, Q	6, 22, 43, 51, 70, 71	7.69
Pseudopolybia difficilis (Ducke, 1905)	AM	PA	BT, MT	10, 27	2.56
Pseudopolybia langi Bequaert, 1944	AM	AM	?	43	1.28
Pseudopolybia vespiceps (Saussure, 1864)	AM, AT, CA, RF, SA	BA, DF, MA, MG, MT, PA, PE, RO, RR, SP	BT, LT, MT, AS, FS, LB, Q	6, 8, 15, 16, 19, 23, 27, 32, 35, 37, 38, 44, 51, 52, 57, 71, 74	21.79
Synoeca chalibea de Saussure, 1852	AM	RO	BT, LB	71	1.28
Synoeca cyanea (Fabricius, 1775)	AG, AM, AT, CA, EU, MG, RE, RG, SA, EU	BA, MG, PA, PE, RS, SP	BT, LT, MT, AS, FS, LB	1, 3, 4, 5, 10, 11, 14, 18, 19, 21, 24,25, 26, 28, 30, 31, 32, 33, 35, 38, 39, 40, 44, 45, 51, 52, 53, 64, 65, 67, 68, 69, 72, 73, 75, 78	46.15
Synoeca surinama (Linnaeus, 1767)	AG, AM, AT, CA, PA, SA, UE	AM, AP, BA, DF, GO, MA, MG, MT, MS, PA, PB, PE, RO, RR, SP	BT, LT, MT, AS, LB, Q	7, 6, 8, 10, 16, 22, 27, 31, 34, 37,43, 47, 48, 51, 56, 57, 58, 70, 71, 72, 74	26.92
Synoeca virginea (Fabricius, 1804)	AM, CA	AM, AP, MA, PA, PI, RO, RR	BT, LT, MT, AS, LB	20, 22, 27, 43, 51, 56, 57, 58, 71, 74	12.82

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