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**DRY FORESTS
ECOLOGY, SPECIES DIVERSITY AND
SUSTAINABLE MANAGEMENT**

**FRANCIS ELIOTT GREER
EDITOR**

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Chapter 2

**DIVERSITY AND DISTRIBUTION OF
HYMENOPTERA ACULEATA IN MIDWESTERN
BRAZILIAN DRY FORESTS**

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ABSTRACT

The highly diverse Hymenoptera fauna in Neotropical forests has been the focus of many studies investigating the structure of ecological communities, particularly in the last ten years. Studies on the biogeography and diversity of Hymenoptera, as well as the processes affecting their maintenance, can be of great interest for planning effective conservation of the biota on a regional scale. Such studies can also

contribute to producing new ecological and taxonomic data, particularly in areas where no previous records exist for the group, as in the case of dry forests located in the middle of South America.

In this context we present the first systematic inventory of Hymenoptera made in the pristine dry forests of midwestern Brazil. The study was conducted over eight years, in two regions; Bodoquena Mountain Range and Brazilian Chaco. These locations are set in a large open area in a diagonal formation of South America, the so-called "Pleistocenic Arc", extending from the Caatinga in northeastern Brazil to the Chaco in Argentina, where the contact areas occur between the Pantanal, Cerrado, Chaco, and Atlantic Forest. We investigated the distribution patterns from each Hymenoptera group and described the faunistic structure. An expressive number of rare and endemic species was detected, and high beta diversity was revealed for all Hymenoptera groups along the dry forest fragments. All groups studied showed a similar species abundance distribution profile, denoting a model that follows a truncated lognormal pattern. In order to identify species richness, the most diverse taxon in a regional spectrum of the dry forests analyzed was Formicidae with 294 species and morphospecies records, followed by Apidae (150), Pompilidae (103), Vespidae (79), Crabronidae (74), Mutillidae (21), Sphecidae (20), Tiphiidae (15), Scoliidae (6), and Rhopalossomatidae (1). In total, 763 species were identified and morphospecies in 236 genera in ten families. Despite the biogeographical relationships of the vegetation, evolutionary effects of environmental formations and anthropogenic current impacts may be reflected in the structure of the whole Hymenoptera community on dry forests from midwestern Brazil. This region is considered of very high biological importance, being extremely diverse, and it urgently needs to be reflected as a hotspot.

Keywords: Ants, Bees, Wasps, Beta diversity, Neotropical region, Pleistocenic arc

INTRODUCTION

Brazilian Dry Forests

On a large time-scale changes in climate and relief configuration would have caused expansions and retractions of wet and dry forests in South America. The Brazilian dry forests are represented by those which lose part of their leaves during a particular time of year (semideciduous) and those which

lose all of their leaves during a particular season (deciduous), located in Caatinga, Cerrado and Chaco (Prado 2000).

Fossil records indicate that in Tertiary and Quaternary periods, the Neotropical dry forests had a more continuous distribution in the recent geological past, especially in the late Pleistocene era, and more precisely at the end of the last glacial period, between 18,000 and 8,000 years ago (Werneck et al. 2012, Pennington et al. 2009). Prado and Gibbs (1993) pointed out that seasonal deciduous forests are remnants of a broader continuous distribution that was present in the past, ranging from northeastern Brazil to Argentina in the Pleistocene dry period. This currently fragmented structure is the result of the dry, cold climate that caused the retraction of wet forests to riversides and the spread of seasonal forests (Pennington et al. 2009). Deciduous forests comprise discontinuous patches along fertile valleys and basaltic and calcareous rocks in a matrix of Cerrado on the Brazilian Central Plateau. Some of these dry forests operate as islands or are mixed with other formations. This Cerrado matrix, intersected by riparian forests, acts as a connection among dry forests in northeastern Brazil, east of Minas Gerais and São Paulo states, and forest remnants in Pantanal.

The midwestern Brazilian Dry Forests, within the Chacoan sub-region, border the provinces of Chacoan, Cerrado, Pantanal and Parana Forest (Morrone 2014) and still remain poorly sampled with respect to the Hymenoptera fauna.

THE HYMENOPTERA GROUP

Hymenoptera are one of the largest orders of insects, comprising sawflies, wasps, ants and bees. Over 150,000 species are recognized, with many more remaining to be described. Hymenoptera have a great biodiversity and a great biological, ecological and economic importance, participating in more than 50% of terrestrial food chains. They are great deprecators of other life forms. The majority of wasp species (well over 100,000 species) are "parasitic" (technically known as parasitoids), and the ovipositor is used simply to lay eggs, often directly into the body of the host. Based on the feeding habits of the known world Hymenoptera, 85% species represent parasitic forms and 15% are predatory forms (Grissel 2010, Godfray 1994).

Taxonomists traditionally divide this group into Symphyta and Apocrita, the first being a relatively small and probably the most ancestral taxon, with representatives of the Triassic fossils from 200 million years ago. The

Symphyla (sawfly) have few living species; the main feature is a constriction between the thorax and the first segment of the abdomen (Goulet & Huber 1993). Apocrita is the group that contains most species of the Hymenoptera and is divided into two groups: Parasitic and Aculeata (Gauld & Bolton 1988). The Aculeata branch is characterized by special modifications of the ovipositor, a complex device found only in the adult female. The mechanism serves both as an egg depositing tube and a sting, allowing a female wasp to temporarily paralyze a host so that an egg can be laid upon or within its host (O'Neill 2001).

The most familiar wasps belong to Aculeata, whose ovipositors have adapted with a venomous sting, though many aculeate species do not sting. Traditionally, nine families of wasps are recognized inside Vespoidea (Fernández 2006, Brothers 1999), and traditionally the Apoidea comprises the lineage bees and spheciform wasps, and the number of families changes according to the adopted classification (Johnson et al. 2013, Debevec et al. 2012, Michener 2007, Melo & Gonçalves 2005, Brothers 1975). The parasitism can occur in species of the Chrysidoidea group (La Salle & Gauld 1993) that is classified inside Aculeata and have a group relationship with Vespoidea and Apoidea, representing an evolutionary link between wasps that have stinger apparatus and those which are parasitic.

Formicidae, with more than 14,954 names of valid species and subspecies worldwide, present estimates that can exceed 20,000 species (AntWeb 2014). 21 subfamilies are currently recognized, diagnosed from potential synapomorphies (Fernandez & Sendoya 2004, Agosti & Alonso 2000). The Neotropical region comprises 15 of these, with 136 genera and 4,164 species and subspecies, of which 1,906 species are endemic. In Brazil 1,456 species and 103 genera are recognized (AntWiki 2014).

Ants are one of the most important groups of insects in tropical forests. They strongly influence the ecosystem since it is important in the incorporation of nutrients to the soil and aeration, and they are predators of other organisms in the environment regulating diversity (Hölldobler & Wilson 1990). Although they occupy all strata of an environment, many groups have close relationships with plants, getting features like pollen and floral and extra floral nectar and mostly protecting the plant host from other herbivores (Delabie et al. 2007). The species composition of ants within assemblages is influenced by the distribution of resources to be exploited and the strategies used for obtaining, in this way, share the ecological niche with other organisms (Silva & Brandão 2010, Silvestre et al. 2003).

The ant fauna, in comparative terms, is especially suitable for use as a bio-indicator tool (ecological, environmental, and diversity) by presenting relatively high local abundance, high local species richness (alpha diversity) and high regional species richness (gamma diversity); it has many specialized taxa which present with higher sensitivity to changes in the environment and vegetation. Moreover, the taxon is sampled at a relatively low cost of collection methodology; one previously defined sampling protocol, and is usually easily separated into morphospecies, which make efficient processes for conducting rapid inventories of biodiversity (Silvestre et al. 2012, Hölldobler & Wilson 1990).

Inside the superfamily Vespoidea, Sapygidae, Bradynobaenidae, Sierolomorphidae, and Rhopalosomatidae are considered rare with restricted distribution and abundance, and Mutillidae, Pompilidae, Vespidae, Tiphidae and Scollidae are common in surveys in Brazil. These wasps are phylogenetically related to the following groups: Chrysididae, Bethyidae, Plumaridae and Apoidea Spheciformes (Peters et al. 2011).

Pompilidae contains 4,200 species distributed worldwide (Brothers & Finnamore 1993) and the Neotropics have about 750 species (Fernández 2000).

Vespidae has about 4,500 described species, distributed in 268 genera (Brothers & Finnamore 1993). Only three subfamilies are found in Brazil: Masarinae, Eumeninae and Polistinae (Carpenter & Marques 2001).

Mutillidae contains around 10,000 species in the world and two of the seven extant subfamilies are found in the Neotropics: Sphaerophthalminae and Mutillinae (Brothers 2006, Brothers & Carpenter 1993). Their common name velvet ant refers to their dense pile of hair. Their bright colors serve as aposematic signals. Mutillidae exhibit extreme sexual dimorphism; the males are winged and the females are wingless. Mutillidae are commonly associated with the parasitism of bees.

Tiphidae wasps are cosmopolitan, with predominance in tropical regions, containing about 1,500 species distributed into seven subfamilies. The most common species are parasitoids of Scarabaeoidea. Only some females and all males are winged (Kimsey & Brothers 2006).

Scoliidae has about 300 species and five genera in the world and in the Neotropics two genera of the subfamily Scoliinae are found: *Campsomeris* and *Scolia*. The females have a robust aspect and digger habits. The most common species are parasitoids of Scarabaeidae, Passalidae and Lucanidae (Fernández 2006).

Rhopalosomatidae consists of four genera and 40 species described worldwide, and three genera and 20 species are known in Neotropical region (Sarmiento 2006), and the genus *Rhopalossoma* is more commonly found in open areas and sandbanks in Brazil.

The wasps are essential organisms for the maintenance of the population of many arthropods, due to the fact that the diet of the larvae is based on animal protein. Pompilidae feed on spiders almost exclusively; Rhopalosomatidae feed on crickets; Vespidae eats mainly caterpillars, while Scoliidae and Tiphiidae prefer beetles which they use for the development of their larvae. The adults preferentially feed on nectar and so are potential pollinators, or even mandatory Anthophilous (Auko et al. 2013, Hunt 1991).

Traditionally, all species of Vespoidea are called predators, while in the development maturity the social wasps are progressively fed by adults, who use more than one individual, thus being characterized as predation feeding habits; the solitary species, which feed their larvae a different way, use only one individual (except Eumeninae) as a host for their larvae, thus characterizing a life cycle very similar to that found in the parasitic wasp, traditionally called parasitoids (Godfray 1994). The difficulty in defining groups Vespoidea inside the predatory and/or parasitoids behaviors should be the great diversity of species presented in this group, which allows a wide variety of habits and strategies, although belonging to the same taxon. Wasps are a key element in understanding the evolution of social behavior, as they comprise both species with solitary behavior and species that are truly social (eusocial) (Hermes 2013).

Spheciforms refers to an extremely diverse cosmopolitan group of wasps. There are currently 9,716 known living species in the world, distributed among the following families: Heterogynaidae (8), Ampulicidae (200), Sphecidae (735) e Crabronidae (8,773) (Pulawski 2014). Angarosphecidae is extinct, and Heterogynaidae is restricted to the Old World (Amarante 2006, Engel 2001). Amarante (2005, 2002) cataloged 1,928 species in the Neotropics with the following richness: Crabronidae (1,732 species), and Sphecidae (196) considering Ampulicinae as a subfamily of Sphecidae.

The females are usually solitary with hunters' habits; however, various levels of social behaviors are found, including at least one example of eusociality (Matthews 1991). Females can lay their nests by digging the sand, soil, wood, occupying pre-existing cavities or even using materials such as clay, waxes and plants for the construction of brood cells, which can be individualized or joint (Amarante 1999). Almost all orders of insects are used

as prey, and some groups of springtails and spiders (Buschini et al. 2008, Evans 2002, Bohart & Menke 1976).

In the world 16,000 species of bees are described with estimates of up to 20,000 species (Brady et al. 2009, Michener 2007, Pedro & Camargo 2000). According to Roubik (1989), considering the new species proportionately framed in groups under review; perhaps we would reach 40,000 species of bees in the world. In the Neotropical region 5,600 species of bees are recognized (Roubik 1995) and for the Brazil, Pedro & Camargo (2000) estimate there are 3,000 species. According with Melo & Gonçalves (2005) the faunal diversity of bees is restricted to a single family (Apidae), considering five subfamilies Andreninae, Apinae, Colletinae, Halictinae and Megachilinae, with 42 tribes and 219 species. The number of genera known in Brazil for each subfamily of Apidae is: Halictinae (34), Colletinae (30), Andreninae (30), Megachilinae (28) and Apinae 27 (+70), without the inclusion of Anthophoridae (Silveira et al. 2006).

Bees, both social and solitary, are responsible for the maintenance of plant diversity and ecological balance in most terrestrial ecosystems, and are considered a keystone mutualistic species (O'Toole, 1993). They are one of the most important pollinators in tropical forests in terms of number of species of plants pollinated (Momose et al. 1998). If the bees disappeared the forests' structure would alter, because the plant species fertilized by bees would have a diminished capacity to produce seeds. This essential "environmental service" determines the formation of fruit and fertile seeds, which maintains genetic diversity. The bees are not immune to "biodiversity crisis"; this is a big and serious problem, because about 30% of human food derived from plants is pollinated by bees (McGregor 1976 *apud* O'Toole, 1993).

In this study we described a species occurrence for Hymenoptera in two expressive continuous dry forests along midwestern Brazil, trying to estimate species richness for each taxon and check which model the distribution of these groups of aculeate Hymenoptera present in this type of forestry formation.

METHODS

Study Site

We had been surveying two particular dry forest regions located in Brazil. We surveyed seventeen localities along one continuous block of deciduous

forest from September 2005 to February 2013. Seventeen wild expeditions were performed in this period with seven days of collections in each, but not with all expert groups together. To compose the sample unit we combined the expeditions that have been made to the same location, and those performed in nearby sites within a radius of 10 km buffers were grouped. Nine sites emerged from this combination of collecting expeditions.

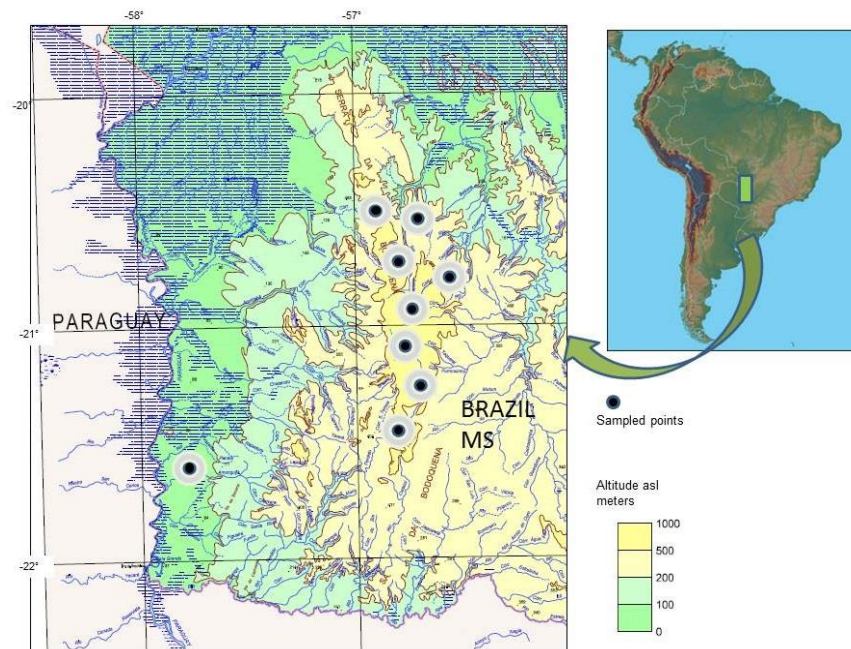


Plate 1. Nine buffers with 10 kilometers' radius sampled to Hymenoptera fauna in deciduous forests areas in Bodoquena plateau and in Brazilian Chaco.

Parque Nacional da Serra da Bodoquena

The Bodoquena's mountain range park (21°07'14,7"S 56°43'08,2"W-central location) possesses 77,232 ha frames on Cerrado-Pantanal Biodiversity Corridor; it is inserted on a core area of Atlantic Forest Biosphere Reserve. The area is an environmental planning unit, being a watershed which supplies the hydrological basin of western Brazil. The locality is sustained by calcareous rocks of the Corumbá group-Neoproterozoic III. The lithological characteristic of the tufas makes it possible to create a new unit, named Serra da Bodoquena formation (Sallun Filho et al. 2009). It is characterized by a high rocky massif, with altitudes varying between 200m and 770m asl.

Exposed limestone from the Tamengo formation predominates in this karstic region, where rivers are found within canyons. The annual average temperatures of the area fluctuate between 22°C and 26°C. The minimum temperature can be as low as 0°C. The relative humidity is low and rarely reaches 80%, and rainfall varies between 1300 mm and 1700 mm a year. The hot and rainy season occurs between October and April, and the cold and dry season from May to September.

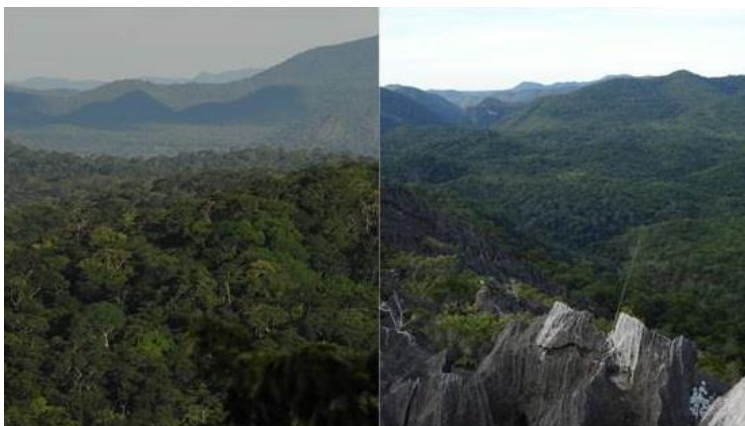


Plate 2. Bodoquena mountain range in midwestern Brazil, with predominance of deciduous and semi-deciduous plants species in carbonate rocks formation and iron formation.

Brazilian Chaco

Porto Murтинho municipality, Mato Grosso do Sul State (MS) (21°42'04"S 57°53'06"W). Located in Central South America, the Gran Chaco is the more extensive subtropical dry forest in the continent, and has approximately 3,400 plant species, including great diversity of plants with xeromorphic features such as microfilia (small leaves), abundant thorns, underground systems and stems adapted to drought (Pott et al. 2008, Prado 2000). With approximately 850,000 km² and classified as Stepic Savanna (Silva & Abdon 2006), it covers northern Argentina, western Paraguay, Bolivia and a small range in southeastern Brazil (only 7 %). The Chaco is one of the major wooded grassland areas in Central South America, and could therefore be of major economic importance, although this resource is being overutilized and suffers from intense degradation through unrestricted forest and bush clearing, overgrazing and continuous monoculture. It is important to stress that there is no desert zone within the Gran Chaco and that it extends into both tropical and

temperate zones. This vast region is an almost flat plain sloping gradually eastwards, varying from 100 - 500 m above sea level, except for the Sierras in Cordoba, Argentina, which reach 2,800 m; some hills in Paraguay are over 700 m (Riveros, 2002).

The name Chaco derives from the Quechua "Chaku" which means "hunting territory", an allusion to the annual hunting expeditions, undertaken by the Inca Empire in the region in pre-Columbian period (Pott et al. 2008). It presents great diversity of ecosystems, high species diversity and endemism of relatively high compared to other arid environments, semi-arid and sub-humid (Silva et al. 2000, Redford et al. 1990).



Plate 3. Brazilian Chaco in Porto Murtinho Municipality. Aspects of diversified dry forest vegetation.

A small fraction of the Chaco located in Brazil, bordering the extreme south of Pantanal lowland, named Nabileque sub-region, is a part of the portion known as Oriental or Humid Chaco, presents floristic contacts between Chaco/Cerrado, Chaco/Dry Forest, Chaco/Limestone Forest, and others as an extensive arboreal monodominant formation named *Carandazal-Copernicia alba* Morong (Fava et al. 2008, Delsinne et al. 2007, Abdon & Silva 2006).

Sampling Protocol

For sampling Hymenoptera we used the following techniques:

- *Entomological net*: The search for Hymenoptera specimens was performed on trails in the woods, flowers on the banks of rivers and streams, and directly into the nests. The sampling effort was five days per location for a total of six hours daily.
- *Moërick traps*: For each sampling event we utilized 50 yellow pans arranged in transects of 500 m with 10 m distance between traps, and collected after 24 hours. The specimens were transferred to alcohol 96%.
- *Malaise traps*: A Malaise trap is a large, tent-like structure used for trapping flying insects, particularly Hymenoptera and Diptera. Insects fly into the tent wall and are funneled into a collecting vessel attached to the highest point. Four Malaise traps were set at ground level in each area, arranged for a period of five days per locality.
- *Mini-Winkler apparatus*: The leaf-litter sampling was realized following *Ants of the Leaf Litter* protocol. For each sample unit one square meter of leaf-litter was extracted in Winkler's apparatuses covering one area with 10,000 m². The sampling site was chosen by selective form inside of each point, seeking the best micro-habitats for the leaf-litter extraction in the forest, in general, near to the biggest trees. In each sampling point material was extracted until we reached the superficial soil layer. The sifted volume with up to 2 kg was transferred to a collector bag. In the field laboratory this material was extracted with mini-Winkler apparatus for 24 hours, and after this period, the specimens were put in Eppendorfs pots.
- *Attractive baits*: The bait, containing 1 cm³ of sardine, was dispersed in a piece of paper for 1 h. A total of 100 baits were used in each of the sampled areas.
- *Aromatic essences*: Attractive with aromatic compounds for capturing Euglossine males contain cineol, methyl salicylate, methyl benzoate, eugenol, and vanillin. Fifty traps were performed (ten sets of five baits) dispersed at 200 meter intervals.

In the Hymenoptera Ecology Laboratory (HECOLAB-UFGD) all Hymenoptera species were kept in entomological pins. The voucher specimens were deposited in the Biodiversity Museum of Universidade Federal da Grande Dourados (UFGD), Mato Grosso do Sul State, Brazil.

Data Analyses

We adopt the concept of range, which is defined as the number of sites occupied by a species within a region and the concept of relative abundance of species, which is defined as the frequency distribution of absolute abundance of the sites, is used to refer to the common or rare species in a community (Magurran & McGill 2011).

The frequencies of species based in presence/absence were analyzed in the range of region and grouped into classes or octaves of abundance (Lobo & Favila 1999, Magurran 1988). The number of species in each octave varied as follows: 1 (0-2); 2 (2-4); 3 (4-8), 4 (8-16) and so on, allowing us to view the richness and quantitative distribution of species per sample unit. The data set was analyzed using R software with the Vegan package (R Development Core Team, 2010).

The sampling data of the nine samples localities were organized in different data matrix for each family of the aculeate Hymenoptera plotted in the software Microsoft Excel (2007). Only the presence/absence (occurrence) of species sampled, importing the data matrix into the EstimateS (Colwell, 2013), assess and compare the diversity and composition of species assemblages based on sampling data computed on this software. We built a table with the same values obtained of diversity analyses, as the Shannon diversity index, Chao 1 richness estimator and Second-order Jackknife richness estimator (Jack2). When comparing species similarity of nine localities, we calculate and use Morisita-Horn sample similarity index, using also distance in kilometers between localities obtained with the software Google Earth 7.1.2., which was compared with the similarity values obtained and distance using a Pearson correlation computed on the software Statistica 8.0 (Statsoft Inc. 2007).

RESULTS

In total 763 species were identified and morphospecies of Hymenoptera Aculeata (excluding Chrysidoidea) in 236 genera, classified in 10 families (Appendix), in midwestern Brazilian dry forest, with 1,551 registers in nine localities sampled. Some species illustrating the Hymenoptera fauna are in Plates 4-10.

Formicidae was represented by all live subfamilies in the Neotropical region. We sampled 294 species in 66 genera. The richest genera sampled was

Pheidole (27 species), *Hypoconera* (21), *Pachycondyla* (17), and *Cephalotes*, and *Camponotus* with 16 species each.

We sampled for the Apidae 992 individuals belonging to 150 species in 65 genera, but 59 species could not be named or properly classified; only morphospecies by a single expert, that was due to the absence of current revisions of some genera and species of bees. All Apidae subfamilies present in Brazil were sampled in the Bodoquena Plateau and Brazilian Chaco, Porto Murtinho region. Apinae was the richest subfamily with 87 species and 41 genera, of which 18 species correspond to stingless bees (Meliponina). The other subfamilies, in decreasing order, were Halictinae (28 species in nine genera), Megachilinae (27 species in 10 genera), Colletinae (six species in three genera), and Andreninae (two species in 2 genera). The richest genera sampled were *Megachile* (15 species), and *Ceratina* and *Augochlora* with nine species each.

We sampled 94 species of Spheciformes wasps (Apoidea) in 42 genera being Crabronidae (74 species in 34 genera), and Sphecidae (20 species in 8 genera). *Eremnophila binodis* (Fabricius) (Sphecidae) was the most abundant species recorded from the Spheciformes with 35 individuals collected. The Crabronidae species *Clitemnestra paraguayana* Bohart, 2000, *Trypoxylon marginatum* Cameron, 1912, and *Stenogorytes megalommiformis* (Strand, 1910) are recorded for the first time in Brazil.

A total of 225 species and 63 genera of the Vespoidea, in six families (excluding Formicidae), were sampled, being Pompilidae (103 species and 22 genera), Vespidae (79 species and 25 genera), Mutillidae (21 species and 8 genera), Tiphiidae (15 species and 6 genera), Scoliidae (six species and one genus), and Rophalosomatidae (one species and one genus). The more diverse genera were *Notochypus* (Pompilidae) and *Mischocyttarus* (Vespidae) with about 12 species sampled, and *Ageniella* and *Pepsis* with 10 species recorded, both Pompilidae. *Epipompilus aztecus* (Cresson, 1869) (Pompilidae) was registered for the first time in South America (Silvestre et al. 2010).



Plate 4. *Bombus* sp. (Apidae).



Plate 5. *Argogorytes umbratilis* (Crabronidae).



Plate 6. *Poecilopompilus* sp. (Pompilidae).



Plate 7. *Proctonectarina* sp. (Vespidae).



Plate 8. *Traumatomuilla* sp. (Mutillidae).



Plate 9. *Cephalotes clypeatus* (Formicidae).



Plate 10. *Cylindromyrmex brasiliensis* (Formicidae).

The estimated richness and Shannon diversity index for all taxa is presented in Table 1. The richness for Hymenoptera Aculeata is estimated to be up to 1,400 species, excluding Chrysidoidea wasps.

In the species abundance distribution (SAD) a truncated lognormal distribution profile was verified for all taxa analyzed (Figure 1). This kind of distribution denotes expressive rarity of species where the “hollow curve” is configured between the first and second abundance octaves.

The similarity between the sampled point’s buffers with 10 km radius indicates no correlation with distance. Less than 40% of faunistic similarity is explained by the proximity of the areas ($r = -0,397$). This pattern indicates high beta diversity in this region (Figure 2).

Table 1. Richness estimated for Hymenoptera Aculeata in midwestern Brazilian dry forest, and diversity index

Taxon	Species Observed	Jack-II Estimated	Chao 1 Estimated	Shannon Diversity Index
Ants	294	468.58	443.50	5.40
Bees	150	310.63	369.19	4.84
Spheciformes	94	182.05	186.42	4.34
Vespoidea	225	444.81	516.26	5.12
Total	763	1,406.09	1,476.77	6.36

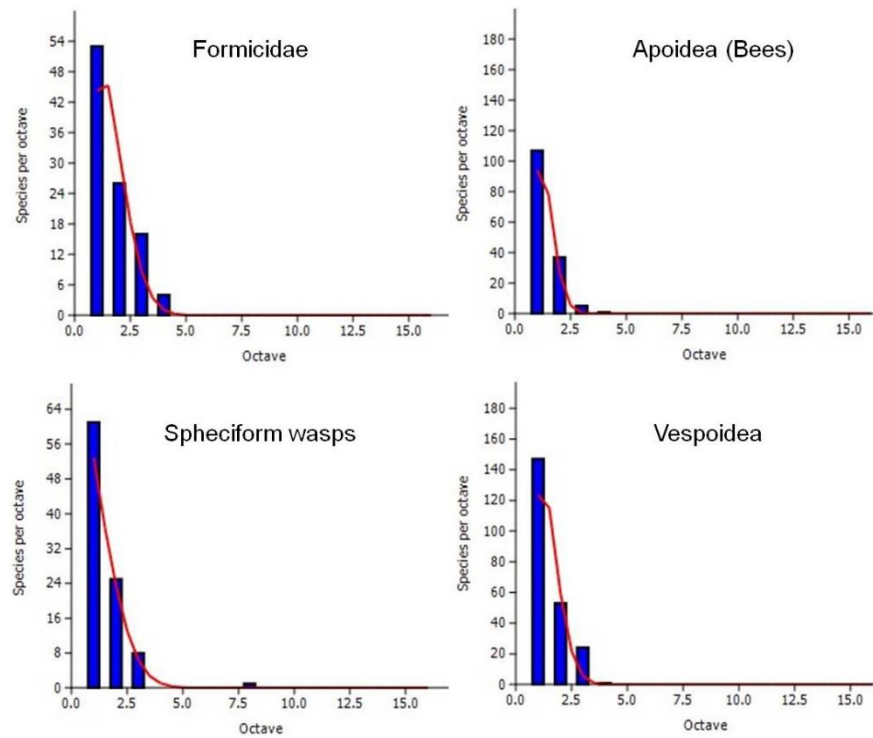


Figure 1. Distribution models for Hymenoptera, based on abundance of octaves, sampled in midwestern Brazilian dry forest, between the years 2005 and 2013, in 9 buffer localities from Bodoquena mountain range to Brazilian Chaco.

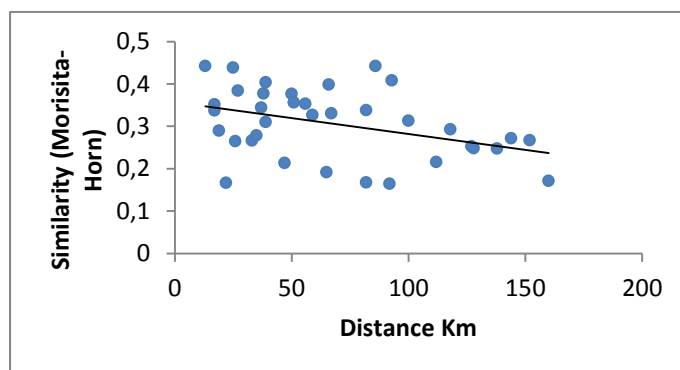


Figure 2. Correlation analysis between similarities, based on Morisita-Horn index, and distance in kilometers of the sampled points in midwestern Brazilian dry forest, between the years 2005 and 2013, in 9 buffer localities from Bodoquena mountain range to Brazilian Chaco ($r = -0,397$).

CONCLUSION

To detect and describe the fauna of a given region, and interpret the data obtained in the field, does not constitute an easy task, even for relatively undiversified groups. The preparation of a list of any vertebrate or invertebrate taxon is not a trivial task and involves, besides the use of specific and efficient techniques to sample a particular group, a reasonable knowledge of their systematics, taxonomy, ecology and natural history in general (Lewinsohn & Prado 2005). Faunal inventories currently are the most direct way to access and experience the diversity of the components of the biome or locality in a given space and time; however, the biological diversity cannot be reduced to knowledge of the taxa that occur in a given area. This limitation of the approach renounces the background history of the evolution of the area. The species abundance distribution (SAD) is one of the most studied patterns in ecology due to its potential insights into commonness and rarity, community assembly, and patterns of biodiversity. However, the distribution pattern of species abundance found in this study revealed that the Hymenoptera fauna on dry forests is strongly influenced by the rarity of the species, or else there are a great number of species with low frequency of occurrence and a smaller number of species with high frequency of occurrence in all Hymenoptera

groups presented in this study. It is well established that the Hymenoptera community is composed of a few common and many rare species.

The low similarity between the sampled points suggests that the aculeate species are randomly distributed over the region. There is a trend of the similarity between the samples to decrease with increasing distance ($r=-0.39$). Consecutive sampled sites suggest a strong formation effect and the influence of adjacent areas, considering the Cerrado matrix where the dry formations are encountered, which are evidenced by high beta diversity, with different arrangements of this Hymenoptera fauna and a high turnover in species across sample points.

Hanson and Gauld (1995) registered the Hymenoptera fauna in Costa Rica with the following richness in the families: Apidae (700), Formicidae (620), Spheciformes (400), Vespidae (180), Pompilidae (250), Mutillidae (300), Tiphidae (30), Scoliidae (15), and Rhopalosomatidae (8). The richness sampled in the Brazilian dry forest was approximately 40% of the fauna richness of the Tiphidae, Scoliidae, Pompilidae and Formicidae found in Costa Rica that can be considered interchangeable between the fauna of South and North America.

Rasmussen and Asenjo (2009) reported species-group taxa of aculeate wasps of Peru and presented the first checklist of the 225 genera and 1,169 species, including Chrysidoidea wasps, not considered here; in this work they sampled 301 species of Spheciformes (Crabronidae 262, Sphecidae 38, and Ampulicidae 1), and 691 species of Vespoidea (Vespidae 403, Pompilidae 158, Mutillidae 88, Tiphidae 32, Scoliidae 8, and Rhopalosomatidae 2), totaling 992 species/morphospecies sampled of these aculeate wasp families in Peru. In our work we obtained 319 species/morphospecies of these wasps' families in a small region of dry forest localities in midwestern Brazil.

All Vespoidea families occurring in Brazil were sampled here; about 50 % of the genera of Vespoidea recognized from Brazil were sampled in this dry forest region. The diversity of species of Vespoidea recorded here is higher than in other biomes in Brazil, although the methods used in those studies are not standardized (Santos et al. 2014, Morato et al. 2008). When comparing only species of social wasps (Polistinae), the diversity of the dry forest was similar to the work carried out in the Atlantic Forest (Tanaka Jr. & Noll 2011, Santos et al. 2007), but was much lower than that observed in the Amazon region by Silveira et al. (2008).

The diversity of Mutillidae (20 species registered) is underestimated due to the difficulty of determining species and association between males and females. These wasps are more common in savannahs or semi-desert areas

(Hanson & Gauld 2006). Previous studies have reported that *Ageniella* (Pompilidae) and *Ephuta* (Mutillidae) are the richest tropical forests in the Vespoidea genera (Santos et al. 2014, Morato et al. 2008). In our work *Pepsis*, *Ageniella*, and *Notocyphus* were the richest genera in number of species between Vespoidea groups. *Pepsis* is the most diverse genus in open environments (Vardy 2000), and *Notocyphus* is associated with the presence of other genera, as its species are cleptoparasitic of other Pompilidae.

Due to the shortage of Spheciformes specialists in Brazil, knowledge of the group is incipient. Large gaps are still found in the geographical distribution of the species and information about their biology are still presented in a fragmented way, whereby a small number of species, which are generally more tolerant of anthropogenic presence, are better known than most rare and sensitive organisms.

Ruiz et al. (2002) catalogued 615 Spheciformes species in Mexico, and Rasmussen and Asenjo (2009) registered 301 species of these wasps in Peru. Amarante (2002) recorded 633 species in Brazil, and in the Mato Grosso do Sul he indicates 57 species. In this work we obtain 94 Spheciformes species.

In this work we observed a nearby association of certain species to the physical structure of environments, such as in areas with exposed soil and riverbanks, where we observed that species make their nests by digging the soil; for example, *Argogorytes umbratilis* (R. Bohart 2000), and *Penepodium* sp. were observed nesting in exposed soil areas. At these sites we also observed the activity of collecting mud by *Sceliphron asiaticum* (Linnaeus, 1758) which uses clay to build grouped cells in protected sites, as in the bark of trees, rocky outcrops, or in cave walls and often more tolerant species use human buildings. Other species use pre-existing cavities in which to supply food for their offspring, as observed with the genera *Podium* and *Trypoxylon*. We also observed the nesting activity of digger sand wasps (Bembicini) in open areas of exposed sandy soils, common in dry forests in this region.

The number of bee species presented in this study differs from sampling in areas of dry forest made by other researchers in other Neotropical localities. Osorio-Beristain et al. (1997) recorded the bee fauna of the Biological Station of Chamela, Mexico, composed of 87 genera and 228 species. Vinson et al. (1993) in Costa Rica (Tempisque dry forest) reported 250 species. The lowest species richness found in this study is probably due to the smaller size of the sampled area. However, our inventory compared to that performed by Gonçalves & Brandão (2008) in 17 selected localities, using Malaise traps, representing a gradient of almost 20° of latitude in evergreen pristine Atlantic

Forest, was superior in number of species and genera sampled (107 species and 50 genera for Atlantic Forest).

Vergara (2002) in the Central Plateau of Mexico detected the same pattern of distribution of abundance found in this work for bees. In contrast to modified landscapes, such as agroecosystems, with intensive management it is possible to create homogenous habitats which often indicate a loss of rare taxa and keystone species and dominance of a few aggressive/opportunistic species of aculeate Hymenoptera (Vinson et al. 1993; Gess & Gess, 1993). Batista-Matos et al. (2013) consider the solitary bees, and conclude that the least disturbed and oldest areas shelter a greater richness and rare species; while the types of land use more intensively managed house the greatest abundance and lower species diversity.

New records of ant distributions were obtained in this work for Brazilian dry forest. *Probolomyrmex brujitae* Agosti, 1995 and *Atta saltensis* Forel, 1913 were previously reported only in Argentina and Uruguay, and *Gracilidris pombeiro* Wild & Cuezco, 2006 only in Paraguay. This ant inventory is comparable to that made by Groc et al. (2013) in a Pristine Amazon Forest in French Guiana in the number of genera sampled.

We verify for leaf litter ants a specificity of micro-environmental niche in the samples, and that many species' population have geographical restrictions, where many unpredictable filters may be operating. Many specialized species with reduced amplitudes inserted into specific guilds were observed. There is a strong selective pressure induced by the action of fragmentation both locally and within the limits of the biome/region, which may cause effects of chaotic vicariates.

The result of the model abundance distribution of Hymenoptera species in dry forest areas presented here follows the expected pattern of most large assemblies studied by ecologists who follow a log normal pattern of abundance of species. The log normal model shows that diversity is influenced by the rarity of the species; this indicates that there is also a better structure and higher occupation of niches in ecosystems with more conserved landscapes, consequently having a greater number of micro-habitats (Magurran, 2004). One aspect is extremely important for the conservation of aculeate Hymenoptera observed in the dry forest in this study, which is the maintenance of the integrity of the environments in many localities near rivers and hills are actually more preserved than plane areas where agriculture and livestock alter the integrity of the landscape (Silva, 2009).

The study area has a high diversity and high anthropogenic pressure; it harbors endemic species and has among the phytophysiognomic components

one of the largest continuous examples of this type of vegetation in South America. The seasonal deciduous forests play a role key in the distribution of various elements of the fauna and flora (Morrone 2006, Morrone et al. 2004, Spichiger et al., 2004, Prado & Gibbs 1993). The studied sites are located diagonally from open areas and have a great variety of species, including endemic species (Souza 2005, Colli et al. 2002, Duellman 1999).

The assessment and identification of priority areas and actions for biodiversity conservation in Brazilian Biomes (MMA, 2002) has been identified through studies of invertebrate fauna, mammals, birds, reptiles, amphibians, and fishes in Bodoquena Plateau and Brazilian Chaco, which are considered to be sites of very high biological importance, being extremely diverse; this needs to be urgently reflected as a hotspot.

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APPENDIX

Checklist of Hymenoptera sampled in midwestern Brazilian dry forest

Species/Morphospecies**Formicidae**

- Acanthostichus brevicornis* Emery, 1894
Acanthostichus sp.
Acromyrmex crassispinus (Forel, 1909)
Acromyrmex rugosus
Acromyrmex subterraneus (Forel, 1893)
Acromyrmex sp. 1
Acromyrmex sp. 2
Anochetus diegensis Forel, 1912
Apterostigma auriculatum Wheeler, 1925
Apterostigma manni Weber, 1938
Apterostigma pilosum Mayr, 1865
Apterostigma wasmanni Forel, 1892
Asphinctanilloides sp. n
Atta sexdens Linnaeus, 1758
Atta sp. 1
Atta saltensis Forel, 1913
Azteca alfari Emery, 1893
Azteca chartifex Emery, 1896
Azteca constructor Emery, 1896
Azteca sp. 1
Azteca sp. 2
Basiceros disciger (Mayr, 1887)
Blepharidatta conops Kempf, 1967
Brachymyrmex patagonicus Mayr, 1868
Brachymyrmex sp. 1
Brachymyrmex sp. 2
Brachymyrmex sp. 3
Brachymyrmex sp. 4
Camponotus crassus Mayr 1862
Camponotus melanoticus Emery, 1894
Camponotus (Myrmaphaenus) blandus blandus (Smith, F. 1858)
Camponotus (Myrmobrachys) mus Roger, 1863
Camponotus (Myrmothrix) renggeri Emery, 1894
Camponotus (Myrmothrix) rufipes (Fabricius, 1775)

Camponotus (*Myrmobrachys*) *senex* (Smith, F., 1858)
Camponotus (*Myrmepomis*) *sericeiventris* Guérin-Méneville, 1838
Camponotus (*Myrmocladoecus*) *sexguttatus* (Fabricius, 1793)
Camponotus (*Tanaemyrmex*) *termitarius* Emery, 1902
Camponotus sp. 1
Camponotus sp. 2
Camponotus sp. 3
Camponotus sp. 4
Camponotus sp. 5
Camponotus sp. 6
Carebara sp. 1
Carebara sp. 2
Cephalotes *atratus* (Linnaeus, 1758)
Cephalotes *borgmeieri* (Kempf, 1951)
Cephalotes *clypeatus* (Fabricius, 1804)
Cephalotes *depressus* (Klug, 1824)
Cephalotes *eduarduli* (Forel, 1921)
Cephalotes *guayaki* De Andrade & Baroni Urbani, 1999
Cephalotes *incertus* (Emery, 1906)
Cephalotes *jheringi* (Emery, 1894)
Cephalotes *maculatus* (Smith F., 1876)
Cephalotes *minutus* (Fabricius, 1804)
Cephalotes *pallens* (Klug, 1824)
Cephalotes *pellans* De Andrade & Baroni Urbani, 1999
Cephalotes *persimilis* De Andrade & Baroni Urbani, 1999
Cephalotes *pusillus* (Klug, 1824)
Cephalotes sp. 1
Cephalotes sp. 2
Cerapachys *splendens* Borgmeier, 1957
Crematogaster *acuta* (Fabricius, 1804)
Crematogaster *bruchii* Forel, 1912
Crematogaster *crinosa* Mayr, 1862
Crematogaster *curvispinosa* Mayr, 1862
Crematogaster *quadriformis* Roger, 1863
Crematogaster *stollii* Forel, 1885
Crematogaster sp. 1
Crematogaster sp. 2
Crematogaster sp. 3
Crematogaster sp. 4
Cryptomyrmex *boltoni* (Fernández, 2003)
Cylindromyrmex *brasiliensis* Emery, 1901
Cyphomyrmex (*gr. rimosus*) sp. 1
Cyphomyrmex (*gr. rimosus*) sp. 2

Cyphomyrmex (gr. *rimosus*) sp. 3
Cyphomyrmex (gr. *rimosus*) sp. 4
Cyphomyrmex (gr. *rimosus*) sp. 5
Cyphomyrmex (gr. *rimosus*) sp. 6
Cyphomyrmex (gr. *rimosus*) sp. 7
Cyphomyrmex (gr. *rimosus*) sp. 8
Cyphomyrmex (gr. *strigatus*) sp. 1
Cyphomyrmex (gr. *strigatus*) sp. 2
Cyphomyrmex lectus (Forel, 1911)
Cyphomyrmex olitor Forel, 1893
Cyphomyrmex sp. 1
Dinoponera australis Emery, 1901
Dolichoderus bispinosus (Olivier, 1792)
Dolichoderus lutosus (F. Smith, 1858)
Dolichoderus lujae Santschi, 1923
Dolichoderus sp.
Dorymyrmex bicolor Wheeler, 1906
Dorymyrmex brunneus Forel, 1908
Dorymyrmex thoracicus Gallardo, 1916
Dorymyrmex sp.
Eciton burchellii (Westwood, 1842)
Ectatomma brunneum Smith, 1858
Ectatomma edentatum Roger, 1863
Ectatomma opaciventre (Roger, 1861)
Ectatomma permagnum Forel, 1908
Ectatomma suzanae Almeida, 1986
Ectatomma tuberculatum Olivier, 1792
Forelius sp. 1
Gnamptogenys (gr. *striatula*) sp.1
Gnamptogenys striatula Mayr, 1884
Gnamptogenys sulcata (Smith, F. 1858)
Gracilidris pombeiro Wild & Cuzzo, 2006
Heteroponera microps Borgmeier, 1957
Hylomyrma balzani (Emery, 1894)
Hylomyrma sp. 1
Hypoponera sp. 1
Hypoponera sp. 2
Hypoponera sp. 3
Hypoponera sp. 4
Hypoponera sp. 5
Hypoponera sp. 6
Hypoponera sp. 7
Hypoponera sp. 8

Hypoponera sp. 9
Hypoponera sp. 10
Hypoponera sp. 11
Hypoponera sp. 12
Hypoponera sp. 13
Hypoponera sp. 14
Hypoponera sp. 15
Hypoponera sp. 16
Hypoponera sp. 17
Hypoponera sp. 18
Hypoponera sp. 19
Hypoponera sp. 20
Hypoponera sp. 21
Kalathomyrmex emeryi (Forel, 1907)
Labidus coecus (Latreille, 1802)
Labidus mars (Forel, 1912)
Labidus praedator (Fr. Smith, 1858)
Leptogenys sp.
Linepithema humile (Mayr, 1868)
Linepithema micans (Forel, 1908)
Linepithema sp. 1
Linepithema sp. 2
Megalomyrmex silvestrii Wheeler, 1909
Megalomyrmex wallacei Mann, 1916
Monomorium floricola Jerdon, 1851
Monomorium sp.
Mycetarotes sp.
Myocepurus goeldii (Forel, 1893)
Myocepurus smithi (Forel, 1893)
Myocepurus sp.
Myrmelachista sp.
Myrmicocrypta sp. 1
Myrmicocrypta sp. 2
Neivamyrmex carettei (Forel, 1913)
Neivamyrmex sp. 1
Neivamyrmex sp. 2
Nomamyrmex esembecki (Westwood, 1842)
Nesomyrmex spininodis (Mayr, 1887)
Nylanderia fulva (Mayr, 1862)
Nylanderia sp. 1
Nylanderia sp. 2
Nylanderia sp. 5
Octostruma balzani (Emery, 1894)

Octostruma iheringi (Emery, 1888)
Octostruma rugifera (Mayr, 1887)
Octostruma stenognatha Brown & Kempf, 1960
Octostruma sp. 1
Octostruma sp. 2
Octostruma sp. 3
Octostruma sp. 4
Odontomachus bauri Emery, 1892
Odontomachus meinerti Forel, 1905
Odontomachus sp. 1
Oligomyrmex sp.
Oxiepoecus sp.
Pachycondyla apicalis (Latreille, 1802)
Pachycondyla bucki (Borgmeier, 1927)
Pachycondyla constricta (Mayr, 1884)
Pachycondyla crassinoda (Latreille, 1802)
Pachycondyla ferruginea (Smith, F. 1858)
Pachycondyla harpax (Fabricius, 1804)
Pachycondyla inversa (Smith, F. 1858)
Pachycondyla lunaris (Emery, 1896)
Pachycondyla luteola (Roger, 1861)
Pachycondyla marginata (Roger, 1861)
Pachycondyla mesonotalis (Santschi, 1923)
Pachycondyla obscuricornis Emery, 1890
Pachycondyla striata (Smith F., 1858)
Pachycondyla verenae (Forel, 1922)
Pachycondyla villosa (Fabricius, 1804)
Pachycondyla sp. 1
Pachycondyla sp. 2
Paraponera clavata (Fabricius, 1775)
Paratrechina longicornis (Latreille, 1802)
Paratrechina sp. 1
Paratrechina sp. 2
Paratrechina sp. 3
Paratrechina sp. 4
Paratrechina sp. 5
Pheidole (gr. flavens) sp.
Pheidole cornicula Wilson, 2003
Pheidole dinophila Wilson, 2003
Pheidole gertrudae Forel, 1886
Pheidole gigaflavens Wilson, 2003
Pheidole jelskii Mayr, 1884
Pheidole oxyops Forel, 1908

Pheidole radoskowskii Mayr, 1884
Pheidole scapulata Santschi, 1923
Pheidole spininodis Mayr, 1887
Pheidole transversostriata Mayr, 1887
Pheidole vafra Santschi, 1923
Pheidole sp. 1
Pheidole sp. 2
Pheidole sp. 3
Pheidole sp. 4
Pheidole sp. 5
Pheidole sp. 6
Pheidole sp. 7
Pheidole sp. 8
Pheidole sp. 9
Pheidole sp. 10
Pheidole sp. 11
Pheidole sp. 12
Pheidole sp. 13
Pheidole sp. 14
Pheidole sp. 15
Pogonomyrmex abdominalis Santschi, 1929
Pogonomyrmex micans Forel, 1914
Pogonomyrmex uruguayensis Mayr, 1887
Pogonomyrmex naegelli Emery, 1878
Prionopelta marthae Forel, 1909
Probolomyrmex boliviensis Mann, 1923
Probolomyrmex petiolatus Weber, 1940
Probolomyrmex brujitae Agosti, 1995
Procryptocerus attenuatus Smith, 1876
Procryptocerus montanus (Kempf, 1957)
Procryptocerus sp.
Pseudomyrmex (gr. *ferrugineus*) sp. 1
Pseudomyrmex (gr. *oculatus*) sp. 1
Pseudomyrmex acanthobius (Emery, 1896)
Pseudomyrmex denticolis (Emery, 1890)
Pseudomyrmex gracilis (Fabricius, 1804)
Pseudomyrmex pallidus (Smith, 1855)
Pseudomyrmex termitarius (Smith F., 1855)
Pseudomyrmex sp. 1
Pseudomyrmex sp. 2
Rogeria alzatei Kugler, 1994
Rogeria lirata Kugler, 1994
Rogeria sp. 1

Rogeria sp. 2
Serycomymex (gr. *amabilis*) sp. 1
Serycomymex (gr. *amabilis*) sp. 2
Serycomymex sp.
Solenopsis (gr. *germinata*) sp.
Solenopsis (gr. *invicta*) sp. 1
Solenopsis (gr. *invicta*) sp. 2
Solenopsis (gr. *rimulus*) sp. 1
Solenopsis invicta Burren, 1972
Solenopsis pusillignis Trager, 1991
Solenopsis sp. 1
Solenopsis sp. 2
Solenopsis sp. 3
Solenopsis sp. 4
Solenopsis sp. 5
Solenopsis sp. 6
Solenopsis sp. 7
Solenopsis sp. 8
Stigmatomma armigerum (Mayr, 1887)
Stigmatomma sp. 1
Stigmatomma sp. 2
Stigmatomma sp. 3
Strumigenys elongata Roger, 1863
Strumigenys eggersi Emery, 1809
Strumigenys xenochelyna (Bolton, 2000)
Strumigenys sp. 1
Strumigenys sp. 2
Strumigenys sp. 3
Strumigenys sp. 4
Strumigenys sp. 5
Strumigenys sp. 6
Tapinoma melanocephalum (Fabricius, 1793)
Thaumatomyrmex contumax Kempf, 1975
Thaumatomyrmex mutilatus Mayr, 1887
Trachymyrmex urich (Forel, 1893)
Trachymyrmex sp. 1
Trachymyrmex sp. 2
Trachymyrmex sp. 3
Typhlomyrmex rogenhoferi Mayr, 1862
Typhlomyrmex sp.
Wasmannia auropunctata (Roger, 1863)
Wasmannia lutzi Forel, 1908
Wasmannia sp. 1

Wasmannia sp. 2

Wasmannia sp. 3

Total= 294

Apidae sensu lato

Agapostemon sp. 1

Alepidosceles hamata Moure, 1947

Ancyloscelis cfr. *apiformis* (Fabricius, 1793)

Anthodioctes cfr. *camargoi* Urban, 1999

Anthodioctes sp. 1

Apis mellifera Linnaeus, 1756

Arhysosage flava Moure, 1958

Augochlora sp. 1

Augochlora sp. 2

Augochlora sp. 3

Augochlora sp. 4

Augochlora sp. 5

Augochlora sp. 6

Augochlora sp. 7

Augochlora thusnelda (Schrottky, 1909)

Augochlorella neocorinora

Augochlorella sp. 1

Augochlorella sp. 2

Augochlorella sp. 3

Augochloropsis cfr. *tupacamaru* (Holmberg, 1884)

Augochloropsis sp. 1

Augochloropsis sp. 2

Augochloropsis sp. 3

Augochloropsis sp. 4

Augochloropsis sp. 5

Augochloropsis sp. 6

Austrostelis zebrata (Schrottky, 1905)

Bombus (*Fervidobombus*) *morio* (Swederus, 1787)

Bombus (*Fervidobombus*) *pauloensis* Friese, 1913

Bothranthidium lauroi Moure, 1947

Centris (*Aphemisia*) *mocsaryi* Friese, 1899

Centris (*Hemisiella*) *tarsata* Smith, 1874

Centris (*Hemisiella*) *vittata* Lepeletier, 1841

Centris (*Heterocentris*) *analis* (Fabricius, 1804)

Ceratina (Ceratinula) sp. 1
Ceratina (Ceratinula) sp. 2
Ceratina (Crewella) sp. 1
Ceratina (Crewella) sp. 2
Ceratina (Crewella) sp. 3
Ceratina (Crewella) sp. 4
Ceratina sp. 1
Ceratina sp. 2
Ceratina sp. 3
Coelioxys (Acrocoelioxys) tolteca Cresson, 1878
Coelioxys (Acrocoelioxys) sp. 1
Diadasia cfr. *willineri* (Moure, 1947)
Diadasina riparia (Ducke, 1907)
Dialictus sp. 1
Dichanthidium exile Moure, 1947
Epanthidium bolivianum Urban, 1995
Epanthidium tigrinum (Schrottky, 1905)
Epicharis (Epicharana) flava Friese, 1900
Epicharis (Epicharis) bicolor Smith, 1854
Epicharis (Hoplepicharis) fasciata Lepeletier & Serville, 1828
Eufriesea auriceps (Friese, 1899)
Eufriesea violacea (Blanchard, 1840)
Euglossa (Euglossa) fimbriata Moure, 1968
Euglossa (Euglossa) townsendi Cockerell, 1904
Euglossa (Glossura) annectans Dressler, 1982
Eulaema (Apeulaema) cingulata (Fabricius, 1804)
Eulaema (Apeulaema) nigrata Lepeletier, 1841
Eulonchopria psauenyithioides Brèthes, 1909
Exaerete smaragdina (Guérin, 1844)
Exomalopsis (Exomalopsis) auropilosa Spinola, 1853
Exomalopsis (Phanomalopsis) sp. 1
Exomalopsis sp. 1
Exomalopsis sp. 2
Exomalopsis sp. 3
Habralictus sp. 1
Habralictus sp. 2
Habralictus sp. 3
Habralictus sp. 4
Hylaeus sp. 1

Hylaeus sp. 2
Hylaeus sp. 3
Hylaeus sp. 4
Hypanthidium obscurius Schrottky, 1908
Leiopodus trochantericus Ducke, 1907
Lestrimelitta chacoana Roig Alsina, 2010
Lophopedia pygmaea (Schrottky, 1902)
Megachile (*Acentron*) *verrucosa* Brèthes, 1909
Megachile (*Austromegachile*) *fiebrigi* Schrottky, 1908
Megachile (*Chrysosarus*) *bella* Mitchell, 1930
Megachile (*Chrysosarus*) *diversa* Mitchell, 1930
Megachile (*Chrysosarus*) *guaranitica* Schrottky, 1908
Megachile (*Leptorachis*) *rubricrus* Moure, 1948
Megachile (*Melanosarus*) *brasiliensis* Dalla Torre, 1896
Megachile (*Melanosarus*) *nigripennis* Spinola, 1841
Megachile (*Moureapis*) *apicipennis* Schrottky, 1902
Megachile (*Neochelynia*) *brethesi* Schrottky, 1909
Megachile (*Pseudocentron*) *curvipes* Smith, 1853
Megachile (*Pseudocentron*) *inscita* Mitchell, 1930
Megachile (*Sayapis*) *planula* Vachal, 1909
Megachile (*Tylomegachile*) *orba* Schrottky, 1913
Megachile (*Zonomegachile*) *gigas* Schrottky, 1908
Melipona orbignyi (Guérin, 1844)
Melipona quinquefasciata Lepeletier, 1836
Melissodes nigroaenea (Smith, 1854)
Melissodes sexcincta (Lepeletier, 1841)
Melissodes tintinnans (Holmberg, 1884)
Melissoptila paraguayensis (Brèthes, 1909)
Melitoma nudipes (Burmeister, 1876)
Melitoma sp. 1
Mesocheira bicolor (Fabricius, 1804)
Mesoplia rufipes (Perty, 1833)
Moureanthidium paranaense Urban, 1995
Nananthidium willineri Moure, 1947
Neocorynura sp. 1
Osiris sp. 1
Oxytrigona tataira (Smith, 1863)
Paratetrapedia connexa (Vachal, 1909)
Paratetrapedia flaveola Aguiar & Melo, 2011

Paratetrapedia fervida (Smith, 1879)
Paratetrapedia leucostoma (Cockrell, 1923)
Paratetrapedia lineata (Spinola, 1853)
Paratetrapedia lugubris (Cresson, 1878)
Partamona cupira (Smith, 1863)
Pereirapis sp. 1
Plebeia droryana (Friese, 1900)
Plebeia sp. 1
Plebeia sp. 2
Plebeia sp. 3
Protosiris sp. 1
Ptiloglossa sp. 1
Ptilotrix cfr. *relata* (Holmberg, 1903)
Ptilotrix cfr. *scalaris* (Holmberg, 1903)
Ptilotrix sp. 1
Rhathymus bicolor Lepeletier & Serville, 1828
Rhophitulus sp. 1
Scaptotrigona depilis Moure, 1942
Schwarziana mourei Melo, 2003
Schwarzula timida (Silvestri, 1902)
Temnosoma sp. 1
Tetragona clavipes (Fabricius, 1804)
Tetragonisca fiebrigi (Schwarz, 1938)
Tetrapedia garofaloi Moure, 1999
Tetrapedia sp. 1
Tetrapedia sp. 2
Tetrapedia sp. 3
Tetrapedia sp. 4
Triepeolus sp. 1
Trigona aff. *fuscipennis* Friese, 1900
Trigona hypogea Silvestri, 1902
Trigona spinipes (Fabricius, 1793)
Trigona truculenta Almeida, 1984
Trophocleptria sp. 1
Xylocopa (*Neoxylocopa*) *suspecta* Moure & Camargo, 1988
Xylocopa (*Schonnherria*) *muscaria* (Fabricius, 1775)
Xylocopa (*Stenoxylocopa*) *nogueirai* Hurd & Moure, 1960
Xylocopa sp. 1
Total= 150

Pompilidae

- Ageniella* sp. 1
- Ageniella* sp. 2
- Ageniella* sp. 3
- Ageniella* sp. 4
- Ageniella* sp. 5
- Ageniella* sp. 6
- Ageniella* sp. 7
- Ageniella* sp. 8
- Ageniella* sp. 9
- Ageniella* sp. 10
- Agenioideus* sp. 1
- Agenioideus* sp. 2
- Aimatocare* sp. 1
- Aimatocare* sp. 2
- Anoplius* (*Arachnophroctonus*) *taschenbergi* (Brèthes)
- Anoplius* sp. 1
- Anoplius* sp. 2
- Anoplius* sp. 3
- Anoplius* sp. 4
- Aplochares* sp.
- Aporus* sp. 1
- Aporus* sp. 2
- Auplopus* sp. 1
- Auplopus* sp. 2
- Auplopus* sp. 3
- Auplopus* sp. 4
- Auplopus* sp. 5
- Auplopus* sp. 6
- Auplopus* sp. 7
- Auplopus* sp. 8
- Caliadurgus* sp. 1
- Caliadurgus* sp. 2
- Caliadurgus* sp. 3
- Caliadurgus* sp. 4
- Caliadurgus* sp. 5
- Caliadurgus* sp. 6
- Caliadurgus* sp. 7

Ceropales sp. 1
Ceropales sp. 2
Dicranopilus sp. 1
Dicranopilus sp. 2
Entypus sp. 1
Entypus sp. 2
Entypus sp. 3
Entypus sp. 6
Epipompilus aztecus (Cresson, 1869)
Epipompilus sp. 1
Epipompilus sp. 2
Epipompilus sp. 3
Epipompilus sp. 4
Episyron conterminus conterminus (Smith, 1855)
Episyron sp. n
Euplaniceps sp. 1
Euplaniceps sp. 2
Euplaniceps sp. 3
Euplaniceps sp. 4
Notocyphus sp. 1
Notocyphus sp. 2
Notocyphus sp. 3
Notocyphus sp. 4
Notocyphus sp. 5
Notocyphus sp. 6
Notocyphus sp. 7
Notocyphus sp. 8
Notocyphus sp. 9
Notocyphus sp. 10
Notocyphus sp. 11
Notoplaniceps sp.
Paracyphononyx sp. 1
Paracyphononyx sp. 2
Paracyphononyx sp. 3
Pepsis crassicornis Móczary, 1885
Pepsis sp. 1
Pepsis sp. 2
Pepsis sp. 3
Pepsis sp. 4

Pepsis sp. 5
Pepsis sp. 6
Pepsis sp. 7
Pepsis sp. 8
Pepsis sp. 9
Poecilopompilus sp. 1
Poecilopompilus sp. 2
Poecilopompilus sp. 3
Poecilopompilus sp. 4
Poecilopompilus sp. 5
Poecilopompilus sp. 6
Poecilopompilus sp. 7
Priochilus (Foximia) opacifrons Banks, 1944
Priochilus captivum Fabricius, 1804
Priochilus gloriosum Cresson, 1869
Priochilus cf. *gracile* Evans, 1966
Priochilus gracillimus Smith, 1855
Priochilus nobilis (Fabricius, 1787)
Priochilus nubilus Banks, 1946
Priochilus rhomboideus Banks, 1944
Priochilus scrupulum (Fox, 1897)
Priochilus sericeifrons (Fox, 1897)
Priocnemella sp. n
Priocnemella sp. 1
Priocnemella sp. 2
Priocnemella sp. 3
Tachypompilus sp. 1
Total= 103

Vespidae

Agelaia multipicta (Haliday, 1836)
Agelaia pallipes (Oliver)
Ancistroceroides alasteroides (Saussure, 1852)
Ancistroceroides atripes (Fox, 1902)
Ancistroceroides conjunctus (Fox, 1902)
Ancistroceroides rufimaculatus (Fox, 1902)
Ancistroceroides venuustus (Brèthes, 1905)
Apoica flavissima van der Vecht, 1972

Apoica pallens (Fabricius)
Brachygastra lecheguana (Latreille, 1824)
Brachygastra moulae Richards, 1978
Brachymenes discherus (Sausurre, 1852)
Ceramiopsis paraguaensis Bertoni, 1921
Eumenes rufomaculatus Fox, 1899
Hypalastoroides brasiliensis (Saussure, 1856)
Hypalastoroides elongatus (Brèthes, 1906)
Hypalastoroides nitidus (Brèthes, 1906)
Hypalastoroides paraguayensis (Zavattari, 1911)
Hypancistrocerus advena (Saussure, 1856)
Minixi brasilianum (Saussure, 1875)
Minixi suffusum (Fox, 1899)
Monobia angulosa Saussure, 1852
Monobia apicalipennis (Saussure, 1852)
Monobia schrottkyi Bertoni, 1918
Montezumia azurescens (Spinosa, 1851)
Montezumia ferruginea brasiliensis Saussure, 1856
Montezumia infernalis (Spinosa, 1851)
Montezumia pelagica sepulchralis Saussure, 1856
Montezumia petiolata Saussure, 1856
Montezumia sp.
Myschocyttarus latior Fox
Myschocyttarus sp. 1
Myschocyttarus sp. 2
Myschocyttarus sp. 3
Myschocyttarus sp. 4
Myschocyttarus sp. 5
Myschocyttarus sp. 6
Myschocyttarus sp. 7
Myschocyttarus sp. 8
Myschocyttarus sp. 9
Myschocyttarus sp. 10
Myschocyttarus sp. 11
Omicron sp. 1
Omicron sp. 2
Omicron sp. 3
Omicron sp. 4
Omicron spegazzinii (Brèthes, 1905)

Omicron tuberculatum (Fox, 1899)
Pachodynerus brevithorax (Saussure, 1852)
Pachodynerus corumbae (Fox, 1902)
Pachodynerus grandis (Willink & Roig0Alsina, 1998)
Pachodynerus guadulpensis (Saussure, 1853)
Pachodynerus nasidens (Latreille, 1812)
Pachodynerus serrulatus (Brèthes)
Pachymenes ghilianii (Spinosa, 1851)
Pachymenes picturatus Fox, 1899
Parancistrocerus longicornutus (Dalla Torre, 1904)
Plagiolabra andina Brèthes, 1906
Plagiolabra nigra Schulthess, 1903
Polistes canadensis (Linnaeus, 1758)
Polistes ferreri Saussure, 1853
Polistes simillimus Zikan, 1951
Polistes versicolor (Olivier, 1791)
Polistes sp. 1
Polistes sp. 2
Polistes sp. 3
Polybia ignobilis (Haliday, 1836)
Polybia occidentalis (Oliver, 1791)
Polybia sericea (Oliver, 1791)
Polybia sp.
Protonectarina sylveirae (Saussure, 1854)
Protopolybia exigua exigua (Saussure, 1906)
Santamenes novarae (Saussure, 1867)
Stenodynerus suffusus (Fox, 1902)
Zeta argillaceum (Linnaeus, 1758)
Zethus cylindricus (Fox, 1899)
Zethus diminutus (Fox, 1899)
Zethus romandinus (Saussure, 1852)
Zethus sessilis Fox, 1899
Total= 79

Crabronidae

Alinia sp.
Argogorytes umbratilis Bohart, 2000
Astata lugens Tashenber, 1870
Bembecinus sp.

Bicyrtes angulata (F. Smith, 1856)
Bicyrtes discisa (Taschember, 1870)
Bicyrtes lilloi (Willink, 1947)
Bicyrtes variegata (Olivier, 1789)
Bothynostethus sp.
Cerceris sp. 1
Cerceris sp. 2
Cerceris sp. 3
Cerceris sp. 5
Cliteminestra brasílica Bohart, 2000
Cliteminestra paraguayana Bohart, 2000
Ectemnius carinatus (Smith, 1873)
Ectemnius semipunctatus (Lepelletier & Brullé, 1835)
Ectemnius sp. 1
Ectemnius sp. 2
Hoplisoides vespoides (F. Smith, 1873)
Incastigmus iphis (Finnamore, 2002)
Incastigmus neotropicus (Kohl, 1890)
Incastigmus sp.
Larra bicolor predatrix (Strand, 1910)
Liris sp. 1
Liris sp. 2
Liris sp. 3
Liris sp. 4
Liris spp.
Lyroda sp.
Megistommum procerus (Handlirsch, 1888)
Metanysson sp.
Microbembex uruguayensis (Holbery, 1884)
Nitela (Tenila) sp.
Nitela sp.
Oxybelus peruvicus R. Bohart, 1993
Pison (gr. cressoni) sp.
Pison delicatum Menke, 1988
Pison longicorne Menke, 1988
Pison sp.
Pluto axillaris van Lith, 1979
Pluto nitens van Lith, 1979
Podagritus sp.

Rhopalum sp.
Rubrica nasuta (Christ, 1791)
Sagenista brasiliensis (Shukard)
Sagenista cayennensis (Spinola)
Scapheutes laetus (Smith, 1860)
Solierella sp. 1
Solierella sp.2
Stenogorytes megalommiformis (Strand, 1910)
Stenogorytes specialis (F. Smith, 1873)
Stictia punctata (Fabricius, 1775)
Stigma sp. ♂
Tachysphex inconspicuus (W. F. Kirby, 1890)
Tachysphex ruficaudis (Taschenberg, 1870)
Tachysphex sp.
Tachytes chrysopyga (Spinola, 1841)
Tachytes coloratus R. Bohart, 1979
Tachytes fraternus (Taschenberg, 1870)
Tachytes hades Schrottky, 1903
Trypoxylon duckei Richards, 1934
Trypoxylon marginatum Cameron, 1912
Trypoxylon nitidissimum Richards, 1934
Trypoxylon oculare Menke, 1968
Trypoxylon spp.
Trypoxylon Trypargilum (gr. *albitarse*) sp.
Trypoxylon Trypargilum sp. 1
Trypoxylon Trypargilum sp. 2
Trypoxylon Trypargilum sp. 3
Trypoxylon Trypargilum sp. 4
Trypoxylon Trypargilum spp.
Trypoxylon Trypoxylon sp.
Zannyson sp.
Total= 74

Mutillidae

Atillum sp.
Hoplocrates monacha (Gerstaecker, 1874)
Hoplocrates sp.
Mickelia sp.
Ptilomutilla pennata André, 1905

Sphinctopsis sp. 1
Sphinctopsis sp. 2
Sphinctopsis turnalia (Cresson, 1902)
Suareztilia sp.
Timulla sp. 1
Timulla sp. 2
Timulla sp. 3
Timulla spp. ♂
Traumatomutilla graphica (Gerstaecker, 1874)
Traumatomutilla manca (Cresson, 1902)
Traumatomutilla sp. 1
Traumatomutilla sp. 2
Traumatomutilla sp. 3
Traumatomutilla sp. 4
Traumatomutilla sp. 5
Traumatomutilla sp. 6
Total= 21

Sphecidae

Ammophila sp. 1
Ammophila sp. 2
Eremnophila binodis (Fabricius, 1798)
Eremnophila melanaria (Dahlbom, 1843)
Eremnophila opulenta (Guérin-Méneville, 1838)
Isodontia costipennis (Spinola, 1851)
Isodontia sp.
Penepodium haematogastrum (Spinola, 1851)
Penepodium sp. 1
Penepodium sp. 2
Penepodium sp. 3
Penepodium sp. 4
Podium sp. 1
Podium sp. 2
Prionyx thomae (Fabricius, 1775)
Sceliphron asiaticum Linnaeus, 1758
Sceliphron fistularium Dahlbom, 1843
Sphex dorsalis Lepeletier, 1845
Sphex ingens F. Smith, 1856
Sphex servillei Lepeletier, 1845

Total= 20

Tiphiidae

Aelurus sp. 1
Aelurus sp. 2
Epomidiopteron sp.
Myzinum sp. 1
Myzinum sp. 2
Myzinum sp. 3
Myzinum sp. 4
Myzinum sp. 5
Myzinum sp. 6
Myzinum sp. 7
Pterombrus sp. 1
Pterombrus sp. 2
Thiphiodes sp.
Tiphia sp. 1
Tiphia sp. 2
Total= 15

Scoliidae

Campsomeris (Pygodases) terrestris (Saussure, 1858)
Campsomeris sp. 1
Campsomeris sp. 2
Campsomeris sp. 3
Campsomeris sp. 4
Campsomeris sp. 5
Total= 6

Rhopalosomatidae

Rhopalosoma sp.
Total= 1

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