

Bees (Hymenoptera: Apoidea) and flowers in natural forest patches of southern Pantanal

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Abstract: This is the first systematic survey of bees in the Pantanal wetland, Brazil. We recorded bee species and their floral resources within grassland and natural forest edge habitats in the Pantanal. Surveys were conducted during two to four-days per month, for a total of 12 months. Overall, we recorded 56 bee species visiting a total of 63 flowering plants. Asteraceae and Fabaceae presented the highest number of visited species, however *Hyptis suaveolens* (Lamiaceae) was the plant most visited by different bee species (18). The most generalist native bee was *Trigona fuscipennis* visiting a total of 17 flowering plant species. *Apis mellifera*, an exotic bee, visited 27 species. We also report the overlap (37.5%) in the use of floral resources between the exotic bee *Apis mellifera* and native bee species. Our updated bee checklist here presented includes 10 new records for the State of Mato Grosso do Sul. These data will support management strategies targeting the conservation of plant-pollinator interactions in the Pantanal ecosystem.

Keywords: bees, floral visitors, forest fragments, surveys.

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Resumo: Esta é a primeira amostragem sistemática de abelhas realizada no Pantanal, Brasil. Nós coletamos espécies de abelhas bem como as plantas que utilizaram como recurso floral em áreas de pastagens naturais e bordas de áreas florestadas. As coletas foram conduzidas durante dois a quatro dias a cada mês, durante 12 meses. Foram registradas 56 espécies de abelhas visitando um total de 63 espécies de plantas. As famílias Asteraceae e Fabaceae apresentaram o maior número de espécies visitadas, entretanto *Hyptis suaveolens* (Lamiaceae) foi a espécie visitada pelo maior número de espécies diferentes de abelhas (18). A abelha nativa mais generalista encontrada foi *Trigona fuscipennis*, que visitou 17 espécies de plantas. *Apis mellifera*, uma espécie exótica, visitou 27 espécies. Reportamos também a sobreposição (37,5%) no uso de recursos florais entre *A. mellifera* e espécies de abelhas nativas. A listagem de abelhas aqui apresentada inclui 10 espécies ainda não mencionadas para o estado de Mato Grosso do Sul. Esses dados apoiarão estratégias de manejo focadas na conservação das interações entre plantas e polinizadores no ecossistema Pantanal.

Palavras-chave: abelhas, visitantes florais, fragmentos florestais, inventários.

Introduction

The Brazilian Pantanal, which primarily lies in the state of Mato Grosso do Sul in south-western Brazil, is the largest floodplain on Earth, covering ca. 140000 Km² (Silva & Abdon 1998) and encompassing a high diversity of habitats (Nunes da Cunha & Junk 2001). Of the ca. 2000 plant species recorded in this region, few are endemic and the other are typically species with wide geographic distributions (Pott & Pott 1994, Pott et al. 2011) common to the surrounding ecosystems: Amazonia, Cerrado and Chaco (Prance & Schaller 1982, Ratter et al. 1988, Pott & Pott 1994, Nunes da Cunha & Junk 2001). Furthermore, community dynamics within the Pantanal are dominated by annual hydro-climatic fluctuations (Agência... 2004).

In Brazil, studies on bee fauna have been conducted across a diversity of habitats: the Atlantic Forest (Wilms et al. 1996, Alves-dos-Santos 1999, Ramalho, 2004), the Cerrado (Pedro & Camargo 1991, Silveira & Campos 1995, Viana et al. 1997, Andena et al. 2005), the Caatinga (Carvalho & Marchini 1999, Zanella 2000, Zanella & Martins 2003, Lorenzon et al. 2003, Aguiar & Zanella 2005), in sand dunes (Alves-dos-Santos 1999, Viana & Kleinert 2005), in the southern grasslands (Schlindwein 1998, Alves-dos-Santos 1999, Gonçalves & Melo 2005, Gonçalves et al. 2009) and in transitional areas of the Cerrado-Amazonia (Santos et al. 2004). Most of these records are concentrated in the eastern part of the country. Therefore, systematics surveys of the bee community including some areas in the Amazon rainforest and the Pantanal wetland are almost unknown (Freitas et al. 2009).

Surveys of species, mainly in areas of little taxonomic knowledge, are essential as baseline data on local biodiversity and species distribution for conservation management (Pinheiro-Machado et al. 2002). Furthermore, bee faunal data or native floral resources for bees are lacking for the State of Mato Grosso do Sul. An exception is a single study (Aoki & Sigrist 2006), carried out through rapid assessment, which highlights the scarcity of knowledge on the bee fauna in the Mato Grosso do Sul.

In relation to interactions among bees and plants in the Pantanal region, we found only one study, a report on the interactions of the exotic bee *Apis mellifera* Linnaeus 1758, with plants whose flowers make up its pollen diet (Boff et al. 2011). Despite floristic surveys recording a high richness of melittophilous plants in the Pantanal (Pott & Pott 1986, Araujo & Sazima 2003), and preliminary reports of bee visitation for some plant species (Pott & Pott 1994), no systematic surveys of bee pollinators and their forage plants have been conducted in this region.

Bees play an integral role in maintaining the sexual reproduction and genetic diversity of native and agricultural plant species through pollination services (Kevan & Imperatriz-Fonseca 2002). The accelerating losses of natural habitats in the State of Mato Grosso do Sul, including the Pantanal, are primarily driven by this region's harboring one of the largest herds of beef cattle in Brazil and thousands kilometers are used mainly for soybean crop (Harris et al. 2005). Given the key role bee pollinators play in wild and agricultural ecosystems (Kevan & Phillips 2001, Kevan & Imperatriz-Fonseca 2002, Murray et al. 2009), we present a list of plant species visited by bees and species of bees occurring in natural forest patches in the Brazilian Pantanal wetland. This is the first reported survey of bees from Southern Pantanal, representing new records of some species for the state of Mato Grosso do Sul.

Material and Methods

The study was carried out over 12 months (September 2006 to August 2007), in the Miranda and Abobral sub-regions, Corumbá,

Mato Grosso do Sul, Brazil. This area presents tropical sub-humid climate type Aw (Köppen 1948). Annual rainfall in 2006 was 1162 mm, and in 2007 it was 927 mm (data from Meteorological station from São Bento ranch). There are two well defined seasons: the rainy season (October to March) and the dry season (April to September), with a mean annual temperature of 26 °C.

Data were gathered in ten natural forest patches at São Bento ranch (19° 34' 36" S, 57° 01' 08" W). The forest islets are natural patches of forest vegetation presenting circular or elliptic shapes, lying 1 to 3 m above the surrounding floodable grasslands (Figure 1). These areas remain dry during the high water periods of the Pantanal, and can be viewed as refuges, where plant species intolerant to inundation can grow (Oliveira-Filho & Martins 1991). Vegetation is primarily composed of riparian forest and Chaco species at the edges, and species typical of semi-deciduous and deciduous forests in the center (Prance & Schaller 1982). The São Bento ranch is a private propriety where the main activity is cattle ranching. Forest habitats are restricted to these islets and to the riparian forest of the Abobral River, which crosses the ranch.

The studied forest islets are inserted in a matrix of herbaceous/shrubby species (mainly *Sebastiania hispidula* (Mart.) Pax ex Engl.) that grow in the seasonally flooded grasslands (Figure 2). For most of the year this matrix, which is typically non-managed grassland, serves as a natural pasture for cattle on ranches in the Pantanal. As natural pasture areas extend up to the edges of forest islets, many plants consumed by cattle are less abundant, so favoring occurrence of non-grazed pioneer and ruderal plant species. Nevertheless, some forage species, such as *Bidens gardneri* Baker (Asteraceae), regrow and flower afterwards, or like *Licania parvifolia* Huber (Chrysobalanaceae) and *Helicteres guazumaefolia* (Malvaceae), stay partially out of reach of cows around the forest islets, thus not being consumed by them.

We collected bees and flowers at the edges of the forest islets through two to four - day expeditions per month. Due to access difficulties during the flooding period, when the road access and some areas around of the studied islets remained flooded, some of the chosen forest islets could not be sampled every month. As a result, two forest islets were sampled for 12 months (September/2006-August/2007), another two islets for four months (September to December/2006), other two only during three months (September



Figure 1. Studied natural patch of forest vegetation (forest islet). Vegetation of fragments is primarily composed of riparian forest and Chaco species at the edges, and species typical of deciduous and semi-deciduous forests in its central portion, São Bento ranch, Pantanal, Brazil.

to November/2006) and four forest islets for eight months (January to August/2007) (Figure 3).

We established four permanent plots along the edge of each forest islet. All plots were 20 m long and 5 m wide (100 m²). The plots were oriented according to the compass points, i.e., one in the North position of the forest islets, one on the East, one on the West and another in the South, adding to 400 m² sampling area on each forest islet. In each plot, all flowering species whose flowers stayed up to 3m high were monthly recorded and assorted by habit.

Focal observations were made between 08:00 h and 17:00 h. The method used to survey bees in our study differs from the survey sampling described by Sakagami et al. (1967). Here, the bees were qualitatively recorded by one sampler, inside the same plot where plants were monthly monitored regarding to their flowering phenology. Bees were surveyed by focal observation of 10 minutes per flowering individual for each flowering species, inside a given plot or, in case of species occurring in patches, the same amount of time was spent observing flowers in the patch. The collection effort (CE) was calculated based on the formula,

$CE = \sum nfs \times 10 \div 60$, where the sum of the total number of flowering species (nfs) per plot of a given forest islet, was multiplied by the duration of focal observation (10 min) and divided by 60 to transform the collection effort into hours. We recorded the identity of the visitor and, when possible the collected resources, plus its role as a possible pollinator. A bee was considered a potential pollinator (PP) if it was observed contacting the flower's reproductive structures during the visit. We used a conservative method to designate a species as PP considering data just when the visitor was collected. After data recording, bees (except *Apis mellifera*, given its easy identification in the field) were collected with an insect net and put in a killing jar with ethyl acetate.

The collected botanical material was placed in the Herbarium CGMS at the Universidade Federal de Mato Grosso do Sul. The bee specimens were placed in the Laboratory of Zoology, in the same institution and in the personal collection of Dr. Sebastião Laroca who, in collaboration with Dr. Danuncia Urban (both from Universidade Federal do Paraná), identified the bee species. Data referring to the geographic distribution of the bee species in the studied region were compiled from Aoki & Sigrist (2006) and Moure's Bee Catalogue, online version (Moure et al. 2008).

Results

We recorded 187 flowering species, of which 63 species, belonging to 26 plant families, were recorded as being visited by native and exotic bees *Apis mellifera*. Asteraceae and Fabaceae presented the highest number of visited species, with eight and seven species, respectively, followed by Malvaceae and Rubiaceae (five species each) and Lamiaceae and Verbenaceae (four and three species, respectively). Concerning plant habit, most species visited by bees were herbs (52%), followed by trees (19%), shrubs (13%), liana (9%) and sub-shrubs (6%). A mean of 22 (± 5.65) visited plant species was recorded per month. The lowest number of blooming plants was recorded in March (10), compared to the highest number recorded in November and December (28 each month). The plants visited by the highest number of bee species were ruderal, such as *Hyptis suaveolens* (L.) Poit. (18 species), *Centrosema brasilianum* (L.) Benth. (seven species), *Sphagneticola brachycarpa* Pruski (six



Figure 2. The studied forest islets are inserted in a matrix mainly composed by herbaceous and shrubby species that grow in the seasonally flooded grasslands in the Pantanal, Brazil.

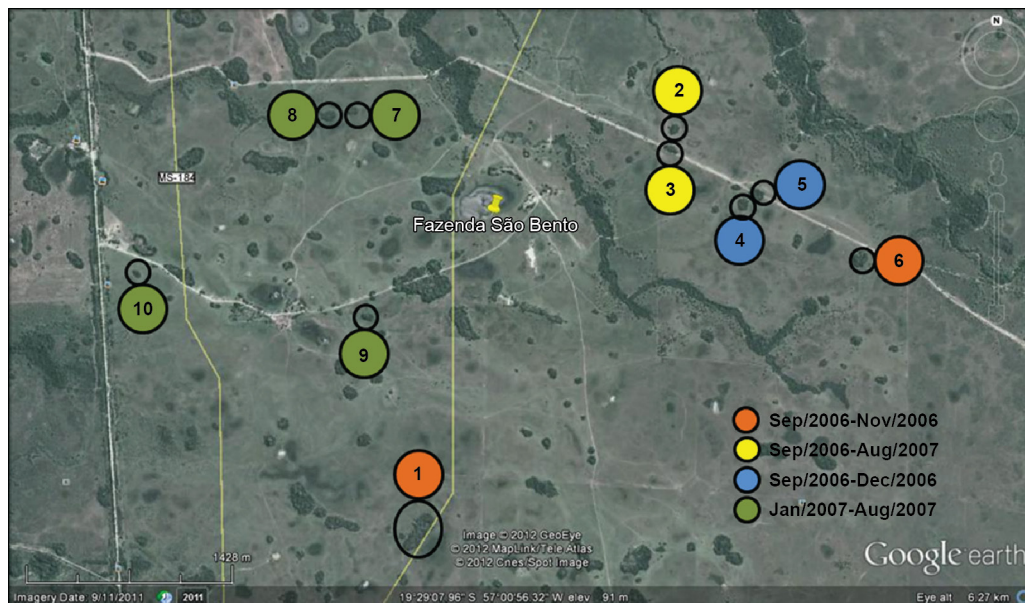


Figure 3. Location of the studied areas at São Bento ranch, southern Pantanal, Brazil. Data collection was conducted between September 2006 and August 2007. The highlighted areas show sampling periods for each islet. Image: modified from Google Earth 2011.

Bees and flowers of southern Pantanal

Table 1. Visited plant species, flowering period observed (F.P.O.), families and species of bees visitor during study in the Pantanal, Brazil. Plants are also classified according to the type of floral resource (r) searched as: nectar (N), pollen (P), oil (O) and mixed (P+N or P+O). Floral visitors are sorted into potential pollinator (po) or plunderer (pl), and when it was not possible to identify its potential role in pollination, no comments were added. NC=Number of bee specimens collected. (*first record of the bee species for Mato Grosso do Sul).

Plant family	Species	F.P.O.	Habit	Bee family	Species	r	po	pl	NC
Amaranthaceae	<i>Pfaffia glomerata</i> (Spreng.) Pedersen	Jan-July	Herb	Apidae	<i>Bombus pauloensis</i> Friese 1913		X		1
Apocynaceae	<i>Thevetia bicornuta</i> Muell. Arg.	Nov-Feb	Shrub	Apidae	<i>Ceratina morrensis</i> Strand, 1910	N			1
				Apidae	<i>Bombus pauloensis</i>	N	X		1
Arecaceae	<i>Attalea phalerata</i> Mart. ex Spreng.	Sept	Tree	Apidae	<i>Trigona fuscipennis</i> Friese, 1900	P	X		1
Asteraceae	<i>Bidens gardneri</i> Baker	Feb/May-Aug	Herb	Apidae	<i>Bombus pauloensis</i>	N			1
	<i>Centratherum punctatum</i> Cass.	Dec/Apr	Herb		<i>Apis mellifera</i>				
	<i>Chromolaena odorata</i> (L.) R.M. King & H. Rob.	Nov-Feb/May-June	Shrub	Apidae	<i>Bombus pauloensis</i>	N		X	2
	<i>Conyza bonariensis</i> (L.) Cronq.	Dec-Feb	Herb	Apidae	<i>Apis mellifera</i>				
				Apidae	<i>Trigona fuscipennis</i>	P			6
				Apidae	<i>Tetragonisca angustula</i> Latreille, 1811	P+N			3
				Halictidae	<i>Dialictus</i> sp.				1
				Halictidae	* <i>Dialictus ypirangensis</i> (Schrottky, 1910)				1
				Megachilidae	<i>Coelioxys vidua</i> Smith. F (1854)	P	X		1
	<i>Lepidaploa remotiflora</i> (Rich.) H. Rob.	Feb/Apr	Herb	Apidae	<i>Apis mellifera</i>				
	<i>Porophyllum lanceolatum</i> DC.	May-June	Herb	Apidae	<i>Trigona fuscipennis</i>				1
	<i>Praxelis clematidea</i> R.M. King & H. Rob.	Sept-Feb/May-Aug	Herb	Halictidae	<i>Augochloropsis</i> sp.1				1
				Megachilidae	<i>Megachile</i> sp.1	N			1
				Apidae	<i>Apis mellifera</i>				
				Apidae	<i>Bombus pauloensis</i>	N			1
				Apidae	<i>Trigona fuscipennis</i>	P			1
			Herb	Apidae	<i>Apis mellifera</i>				
	<i>Sphagneticola brachycarpa</i> (Baker) Pruski	Sept-Jan							
				Apidae	<i>Ceratina</i> sp.1				2
				Apidae	<i>Nannotrigona testaceicornis</i> (Lepeletier, 1836)	N			1
				Apidae	<i>Ceratina morrensis</i>	N	X		1
				Halictidae	<i>Augochlora</i> sp.1	N			1
				Megachilidae	* <i>Coelioxys pampeana</i> Holmberg, 1887	N			1
	<i>Stilpnopappus pantanalensis</i> H. Rob	Dec/Apr	Herb	Apidae	<i>Apis mellifera</i>				
	<i>Vernonanthura brasiliiana</i> (L.) H. Rob.	Jul-Sept	Herb	Apidae	<i>Apis mellifera</i>				
				Apidae	<i>Bombus pauloensis</i>				1
				Megachilidae	* <i>Larocanthidium nigrifulum</i> Urban, 1997				1
Bignoniaceae	<i>Fridericea florida</i> (DC.) L.G. Lohmann	Oct/ May-Jun	Tree	Apidae	<i>Ceratina morrensis</i>			X	1
				Apidae	<i>Xylocopa</i> sp.	N	X		4
Chrysobalanaceae	<i>Couepia uiti</i> (Mart. Et Zucc.) Bth.	Sept/Nov-Jan	Tree	Apidae	<i>Paratrigona lineata</i> Lepeletier, 1836	P		X	1

Table 1. Continued...

Plant family	Species	F.P.O.	Habit	Bee family	Species	r	po	pl	NC
	<i>Licania parviflora</i> (Sag.) Fritsch	Nov-Jan	Tree	Apidae	<i>Apis mellifera</i>	N	X		
				Apidae	<i>Bombus pauloensis</i>	P			1
				Apidae	<i>Tetragonisca angustula</i>	P			1
				Apidae	<i>Trigona fuscipennis</i>				1
Combretaceae	<i>Combretum laxum</i> Jacq.	Jun-Aug	Liana	Apidae	<i>Tetragonisca angustula</i>	P			1
Commelinaceae	<i>Commelina erecta</i> L.	Oct-Feb/Apr-Aug	Herb	Apidae	<i>Apis mellifera</i>				
				Apidae	<i>Dasyhalonia</i> sp.	P	X		1
				Apidae	<i>Trigona fuscipennis</i>	P			1
Convolvulaceae	<i>Aniseia cernua</i> Moric.	Mar	Liana	Megachilidae	<i>Pseudocentron</i> sp.2	N			1
	<i>Ipomoea cordatoiriloba</i> Dennst.	Sept/Nov	Herb	Apidae	<i>Ceratina morrensis</i>	N			1
	<i>Ipomoea rubens</i> Choisy	Oct-Feb/Jul-Aug	Liana	Apidae	<i>Ceratina morrensis</i>	P+N			1
	Indetermined			Megachilidae	<i>Megachile</i> sp.1	N			
Erythroxylaceae	<i>Erythroxylum anguifugum</i> Mart.	Oct/Apr/Aug	Tree	Apidae	<i>Ceratina</i> sp. 1				1
				Apidae	<i>Apis mellifera</i>				
Euphorbiaceae	<i>Croton glandulosus</i> (L.) M. Arg.	Oct-Dec/May-Aug	Herb	Apidae	<i>Apis mellifera</i>	P			
				Apidae	<i>Nannotrigona testaceicornis</i>	P			1
				Apidae	<i>Trigona spinipes</i> Fabricius, 1793	P			1
				Apidae	<i>Trigona fuscipennis</i>	P			1
	<i>Sebastiana hispida</i> (Mart.) Pax ex Engl.	Sept-Aug	Herb	Apidae	<i>Trigona fuscipennis</i>	P			2
			Sub-shrub		<i>Bombus pauloensis</i>	P			1
				Apidae	<i>Bombus pauloensis</i>	P			
Fabaceae				Megachilidae	<i>Megachile</i> sp.	N	X		1
	<i>Aeschynomene histrix</i> Poir.	Sept-Feb		Apidae	<i>Exomalopsis analis</i> Spinola, 1853	N	X		1
	<i>Canavalia mattogrossensis</i> (Barb. Rodr.) Malme	May-Jun	Liana	Apidae	<i>Trigona fuscipennis</i>				1
	<i>Centrosema brasilianum</i> (L.) Benth.	Sept-Feb/May-Aug	Liana	Apidae	<i>Ceratina morrensis</i>				2
				Apidae	* <i>Centris lutea</i> Friese, 1899	N			1
				Apidae	* <i>Centris xanthocnemis</i> Perty, 1833	N			1
				Apidae	<i>Centris</i> sp. 2	N			1
				Apidae	<i>Bombus pauloensis</i>	N			3
				Apidae	* <i>Centris aenea</i> Lepeletier, 1841	N			1
				Halictidae	<i>Augochloropsis aff.</i> <i>cleopatra</i>				1
	<i>Crotalaria micans</i> Link.	Sept/Dec-Jan/July	Herb	Megachilidae	<i>Megachile</i> sp. 1	N			1
				Megachilidae	<i>Megachile orba</i> Schrottky, 1913	N			1
				Apidae	<i>Trigona fuscipennis</i>	N			1
				Apidae	<i>Xylocopa</i> sp. 1	N			1
				Apidae	* <i>Xylocopa frontalis</i> (Olivier, 1789)	N			1
	<i>Indigofera lespedezioides</i> Kunth	Sept-Feb/Apr-June/Aug	Herb	Apidae	<i>Centris aenea</i>	N			1
	<i>Inga vera</i> Kunth	Sept-Oct/ Apr-June	Tree	Apidae	<i>Trigona fuscipennis</i>	N+P			6
				Apidae	<i>Bombus</i> sp.	N			
				Apidae	<i>Xylocopa</i> sp.	N			

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Table 1. Continued...

Plant family	Species	F.P.O.	Habit	Bee family	Species	r	po	pl	NC
Lamiaceae	<i>Senna occidentalis</i> (L.) Link	Apr-May	Sub-shrub	Apidae	<i>Trigona fuscipennis</i>	P		X	1
				Apidae	<i>Xylocopa ordinaria</i> Smith, 1874	P	X		1
	<i>Senna splendida</i> (Vogel) H.S. Irwin & Barneby	Apr-May	Herb	Apidae	<i>Xylocopa frontalis</i>	P	X		2
				Apidae	<i>Trigona fuscipennis</i>	P		X	2
				Apidae	<i>Xylocopa ordinaria</i>	P	X		1
					<i>*Centris fuscata</i>	P			2
	<i>Hyptis brevipes</i> Baker	Oct-Nov/Jan-Feb/June	Herb	Apidae	<i>Apis mellifera</i>				
				Apidae	<i>Centris fuscata</i>	P			?
	<i>Hyptis suaveolens</i> (L.) Poit.	Sept-Aug	Sub-shrub	Halictidae	<i>Augochloropsis aff. deianira</i>				1
				Apidae	<i>Apis mellifera</i>	N			
				Megachilidae	<i>Coelioxys pampeana</i>				1
				Megachilidae	<i>Coelioxys</i> sp.				1
				Apidae	<i>Ceratina morrensis</i>				4
				Apidae	<i>Bombus pauloensis</i>	N			12
				Megachilidae	<i>Larocanthidium nigritulum</i>	N			1
				Megachilidae	<i>Megachile paulistana</i> Schrottky, 1902	N			1
				Halictidae	<i>Augochloropsis</i> sp. 3				1
				Apidae	<i>Nannotrigona testaceicornis</i>	N+P			1
				Megachilidae	<i>Megachile</i> sp.	N			1
				Megachilidae	<i>Coelioxys pirata</i> Holmberg, E. L. (1884)	N			2
			Halictidae	<i>Agapostemon</i> sp. 1				1	
			Megachilidae	<i>Coelioxys vidua</i>	N			1	
			Apidae	<i>Ceratinula</i> sp.				1	
			Megachilidae	<i>Coelioxys</i> sp. 2	N			1	
			Halictidae	<i>Augochlora</i> sp. 1				1	
			Megachilidae	<i>Coelioxys</i> sp. 1	N			1	
			Apidae	<i>Centris</i> sp. 1	N			1	
			Apidae	<i>Tetragonisca angustula</i>	N+P			1	
	<i>Marsypianthes chamaedrys</i> (Vahl) Kuntze	Feb/Apr	Herb	Megachilidae	<i>Coelioxys vidua</i>				
Lythraceae	<i>Vitex cymosa</i> Bertero ex Spreng.	Sept-Oct	Tree	Apidae	<i>Apis mellifera</i>	N			
				Apidae	<i>*Centris spilopoda</i>	N	X		1
				Apidae	<i>Trigona fuscipennis</i>	P			1
	<i>Adenaria floribunda</i> Kunth	Oct-Apr	Shrub	Apidae	<i>Apis mellifera</i>				
Malpighiaceae	<i>Byrsonima orbignyana</i> A. Juss.	Sept-Dec	Tree	Halictidae	<i>Augochloropsis aff. deianira</i>	P+N			1
				Colletidae	<i>Hylaeus</i> sp. 1				1
				Apidae	<i>Trigona fuscipennis</i>			X	2
				Apidae	<i>Tetragonisca angustula</i>	P		X	3
				Apidae	<i>Nannotrigona testaceicornis</i>				1
			Halictidae	<i>Augochloropsis</i> sp. 2	P	X		1	
			Apidae	<i>Alepidosceles aff. imitatrix</i>	O+P	X		1	
			Apidae	<i>Tetragonisca angustula</i>	P			5	
			Apidae	<i>Trigona fuscipennis</i>	P			1	
			Apidae	<i>Plebeia</i> sp. 1	P				

Table 1. Continued...

Plant family	Species	F.P.O.	Habit	Bee family	Species	r	po	pl	NC
Malvaceae	<i>Helicteres guazumaefolia</i> H.B.K.	Sept-Nov/Jan-Apr/ June/Aug	Shrub	Apidae	<i>Trigona fuscipennis</i>	N			1
	<i>Melochia graminifolia</i> A.St. Hil.	Feb/Apr	Herb	Apidae	<i>Apis mellifera</i>				
	<i>Melochia parvifolia</i> Kunth	Oct-Nov/Feb-Aug	Shrub	Apidae	<i>Apis mellifera</i>	N			
				Apidae	<i>Bombus pauloensis</i>				3
	<i>Melochia simplex</i> A. St. Hil	Annual	Herb	Apidae	<i>Apis mellifera</i>				
				Apidae	<i>Bombus pauloensis</i>	N	X		1
	<i>Melochia villosa</i> (Mill.) Fawc. & Rendle	Sept/Nov/Feb-Aug	Sub-shrub	Apidae	<i>Apis mellifera</i>				
				Apidae	<i>Ceratina</i> sp. 1	N			1
				Apidae	* <i>Ceratina chloris</i> (Fabricius, 1804)				1
				Apidae	<i>Ceratina morrensis</i>	N			1
				Apidae	<i>Xylocopa ordinaria</i>	N			1
	<i>Sida santaremensis</i> Monteiro	Annual	Herb	Apidae	<i>Apis mellifera</i>	N			
				Andrenidae	<i>Anthrenoides</i> sp. 1				1
<i>Sida viarum</i> A. St.-Hil.	Oct	Herb	Apidae	<i>Apis mellifera</i>					
			Apidae	<i>Centris spilopoda</i> Moure, 1969	N			1	
Onagraceae	<i>Ludwigia tomentosa</i> (Cambess.) H. Hara	Dec-Jan/Apr-May	Herb	Apidae	<i>Ceratina morrensis</i>	N			1
				Halictidae	<i>Dialictus</i> sp. 1	P+N			1
Plantaginaceae	<i>Bacopa australis</i> V.C. Souza	Apr	Herb	Apidae	<i>Apis mellifera</i>	P			
				Halictidae	<i>Dialictus</i> sp. 1				1
Portulacaceae	<i>Portulaca pilosa</i> D. Legrand	Oct/Jan-Feb/May-June	Herb	Apidae	<i>Ceratina morrensis</i>	P			1
				Apidae	<i>Alepidosceles imitatrix</i> (Schrottky, 1909)				1
Rubiaceae	<i>Borreria eryngioides</i> Cham. & Schltldl	Out-Dec	Herb	Apidae	<i>Apis mellifera</i>				
				Apidae	<i>Tetragonisca angustula</i>	P		X	1
	<i>Chomelia pohliana</i> Müll. Arg.	Nov-Dec	Shrub	Apidae	<i>Tetragonisca angustula</i>	P		X	1
	<i>Psychotria carthagenensis</i> Jacq.	Out-Feb	Shrub	Megachilidae	<i>Megachile paulistana</i>			X	1
	<i>Richardia grandiflora</i> (Cham. & Schltldl.) Steud.	Nov-Feb/May-Aug	Herb	Apidae	<i>Apis mellifera</i>	P+N			
				Apidae	<i>Ceratina morrensis</i>	P	X		1
				Apidae	<i>Bombus pauloensis</i>	N			1
	<i>Staëlia thymoides</i> Cham. et Schltldl.	Sept-Nov/May-Aug	Herb	Apidae	<i>Ceratina</i> sp. 1	N+P			1
Apidae				<i>Apis mellifera</i>					
Megachilidae				<i>Megachile aetheria</i> Mitchell, 1930	N			1	
Apidae				<i>Ceratina</i> sp. 1	N			1	
<i>Tocoyena formosa</i> (Cham. & Schltldl.) K. Schum.	Dec-Jan/Apr	Shrub	Megachilidae	<i>Coelioxys aff. otomita</i>	N			1	
			Apidae	<i>Trigona fuscipennis</i>	N		X	2	

Table 1. Continued...

Plant family	Species	F.P.O.	Habit	Bee family	Species	r	po	pl	NC
Rutaceae	<i>Zanthoxylum rigidum</i> Humb. & Bonpl. ex Willd.	Apr/June	Tree	Apidae	<i>Trigona fuscipennis</i>				1
Salicaceae	<i>Casearia aculeata</i> Jacq.	Dec/Feb/Apr-May	Tree	Halictidae	<i>Augochloropsis</i> sp. 1	P+N			2
				Halictidae	<i>Augochloropsis</i> sp. 2	P+N			2
				Halictidae	<i>Augochloropsis</i> sp. 3	P+N			1
Sapindaceae	<i>Paullinia pinnata</i> D.R. Simpson	Sept-Oct/Jan/Mar	Liana	Apidae	<i>Ceratina morrensis</i>	N			1
Solanaceae	<i>Solanum viarum</i> Dunal	Sept-Apr	Herb	Halictidae	<i>Augochloropsis</i> sp. 1	P	X		1
				Apidae	<i>Centris flavifrons</i> (Fabricius, 1775)	P	X		1
					<i>Xylocopa frontalis</i>	P	X		1
					<i>Bombus pauloensis</i>	P	X		4
				Megachilidae	<i>Megachile paulistana</i>	P	X		1
Verbenaceae	<i>Lantana canescens</i> Kunth	Dec/Feb	Herb	Apidae	<i>Ceratina</i> sp.1	N			1
					<i>Trigona fuscipennis</i>	P			1
	<i>Lippia alba</i> (Mill.) N.E.Br. ex Britton & P. Wilson	Annual	Herb		<i>Apis mellifera</i>				
	<i>Stachytarpheta</i> <i>cayennensis</i> (Rich.) Vahl	Sept-Feb/July	Herb	Apidae	<i>Apis mellifera</i>				
				Apidae	<i>Bombus pauloensis</i>	N			5
Vochysiaceae	<i>Vochysia divergens</i> Pohl	Aug-Oct	Tree	Apidae	<i>Apis mellifera</i>				

species), *Crotalaria micans* Link and *Solanum viarum* Dunal (five species each), and pioneer species, such as *Adenaria floribunda* Kunth and *Byrsonima cydoniifolia* A. Juss (five species each). The other flowering species were visited by one to four species of bees (Table 1).

We recorded 188 native bees from 55 species representing 27 genera and five families, plus the exotic feral honeybee (*Apis mellifera*) visiting flowers at the edge of the surveyed forest islets (Table 1) in a total of 306.72 hours of collection effort (Table 2). Native bee species belonged mainly to Apidae (54, 54%), followed by Megachilidae (ca. 25, 45%), Halictidae (ca. 16, 36%), Colletidae and Andrenidae with only 1,81% each. We recorded the presence of 10 species not yet cited for Mato Grosso do Sul. These species are mainly solitary bees and the most are specialized oil foragers from the tribe Centridini: *Centris aenea* Lepeletier, 1841, *C. flavifrons* (Fabricius, 1775), *C. fuscata* Lepeletier, 1841, *C. lutea* Friese, 1899, *C. spilopoda* Moure 1969, *C. xanthocnemis* Perty 1833, *C. sp. 1* and *C. sp. 2* (Table 1).

The native bees that visited the greatest diversity of plant species were *Trigona fuscipennis* Friese 1900 (19 species), *Bombus pauloensis* Friese 1913 (14 species), *Ceratina morrensis* Strand 1910 (12 species) and *Tetragonisca angustula* Latreille, 1811 (seven species). The other bee species visited between one and four flowering species (Table 1).

Amongst the species of plants visited by the native bees, 21 were also visited by *Apis mellifera* (37.5 % overlapping). The feral honeybee was also an exclusive visitor of seven other species, summing to 27 species, approximately 51% of the plants that were visited by native bees. Asteraceae and Malvaceae were the families with the highest number of species visited by *A. mellifera* (seven and five, respectively). Despite the fact that bees were only qualitatively recorded, we noted that *A. mellifera* was in general more common than the other bee species inside the plots, and was recorded throughout the sampling period.

In 25% (33/132) of the recorded interactions, we observed the behavior of the bees on the flowers. In 23 interactions the bees acted as

Table 2. The number of species, specimens and collection effort in the studied areas. MS=Number of months sampled, SS=number of specimens sampled, HCE= Hours of collection effort. A=Jan, B=Feb, C=Mar, D=Apr, E=May, F=June, G=July, H=Aug, I=Sept, J=Oct, K=Nov and L=Dec.

Islet forest	MS	Species	SS	HCE
1	3(I-K)	7	16	14
2	12(I-H)	17	37	46.34
3	12(I-H)	16	36	50
4	4(I-L)	12	28	21.5
5	4(I-L)	7	13	23.84
6	3(I-K)	5	6	13.6
7	8(A-H)	14	17	38.34
8	8(A-H)	11	17	38.34
9	8(A-H)	9	10	31.66
10	8(A-H)	5	6	29.10
Total			188	306.72

potential pollinators, considering that they contacted the reproductive structures of the flower at the moment of the visit. However, in the 10 remaining interactions the bees just plundered the resource (Inouye 1980). The amounts of each interaction varied among plant/visitor species (Table 1).

Discussion

In the studied plots, Asteraceae and Fabaceae were the dominant families containing most of the species utilized as a resource by bees; similar to data recorded in Cerrado vegetation (Pedro & Camargo 1991, Andena et al. 2005). These findings confirm the status of these plant families as important sources of forage for wild bees in these forest islets, as already suggested by the analysis of the pollen diet of *Apis mellifera* in the same region (Boff et al. 2011). The predominance of herbaceous species in the edge of the forest islets was already

reported in previous studies (Pott & Pott 1986, Araujo & Sazima 2003), but may have been a consequence of only sampling flora up to 3m in height. Despite the high number of flowering species in the studied islets ($n = 187$) and the predominance of melittophilous species (Araujo & Sazima 2003), the number of plant species visited by bees species, around 35% ($n = 64$) was lower than reported by previous studies in other Brazilian habitats, such as a transition areas such as the Cerrado-Amazonia in the North (Santos et al. 2004), and in the Southern grasslands (Gonçalves et al. 2009, Pedro & Camargo 1991, Silveira & Campos 1995).

Native bees visited less than 30% of the total of blooming species recorded. However, bee surveying was restricted to the selected plots in this study. Other studies that employed more traditional surveying methodologies, with sampling not restricted to plots, reported a higher number of specimens and species (e.g. Pedro & Camargo 1991, Alves-dos-Santos 1999, Gonçalves et al. 2009). In a rapid assessment at different habitats in the Cerrado, in Mato Grosso do Sul, Aoki & Sigrist (2006) reported 113 bee species in 170 hours of collection effort. Although the collection effort (in hours) was less than used in this study, Aoki & Sigrist (2006) reported twice the number of species recorded here, primarily due to the number of people collecting (eight) in the rapid assessment study. Beyond that in that report surveys were focused solely on the rainy period.

Additionally, the number of open flowers, or floral display, could also affect the abundance and diversity of species observed in this study (Ohashi & Yahara 2001). Within the studied areas, and excluding some trees species (e.g. *Vochysia divergens* Pohl, *Vitex cymosa* Bertero ex Spreng., *Licania parviflora*) and the herbaceous *Hyptis suaveolens* and *Richardia grandiflora* (Cham. & Schltdl.) Steud., there was a lack of conspicuous floral display, which may have decreased the attractiveness of the forest islets to bees in this area. During surveys in an area with a large floral display of *Byrsonima cydonifolia* and *Couepia uiti* Benth, we observed a lot of individuals from 15 species of Centridini outside the focal plots. Meanwhile, when observing flora of the same species in conditions of lower floral display inside the studied plots, the bees from this tribe were completely absent.

We recorded many ruderal plant species surrounding the forest islets, potentially as a consequence of the annual flooding in the surrounding fields, which eliminates flood-intolerant species. In addition, farmers usually manage the pastures for cattle use and these animals selectively graze the plants at the edges of the forest islets. We observed a high diversity of bee species visiting flowers of ruderal species, e.g. *H. suaveolens*, in support of previous studies conducted in different habitats (Lorenzon et al. 2003, Fernando César Vieira Zanella, unpublished data). *Hyptis suaveolens* may potentially be an important floral resource for the studied bee fauna, because it represents a persistent source of pollen and nectar throughout the year for a wide spectrum of bee species (18 in this study). Other abundant ruderal plants recorded were: *Borreria eryngioides* Cham. & Schltdl., *Conyza bonariensis* (L.) Cronquist, *Sphagneticola brachycarpa*, and mainly *Richardia grandiflora*; but these species were primarily visited by honeybees.

Bees of the families Apidae, Megachilidae and Halictidae composed, in this order, the highest species richness of bees in this study, similar to reported in other neotropical biogeographical regions such as Cerrado, Caatinga and Amazonia (Silveira & Campos 1995, Carvalho & Bego 1996, Viana 1999, Santos et al. 2004.) Studies carried out in Southern Brazil report that species richness of Halictidae is higher than the reported for other areas in Brazil (Barbola & Laroca 1993, Alves-dos-Santos 1999, Gonçalves et al. 2009), although one study carried out in Rio Grande do Sul reported the Apidae as being the most diverse family (Truylio & Harter-Marques 2007).

According to the number of visited plant species, the most generalist bees in this study were the species from Apidae, *Apis mellifera* and *Trigona fuscipennis*. This result is similar to the observations in areas of Cerrado in São Paulo, where *T. spinipes* (Fabricius, 1793) and *A. mellifera* were reported as the most generalist bees (Pedro & Camargo 1991, Andena et al. 2005). In general, many individuals of these social bees concentrate their forage on several floral resources (Roubik 1989, Kerr et al. 2001). In contrast, non-social bees are usually restricted to a lower diversity of plant species (Michener 2007), as recorded in the present study for solitary Apidae like: *Centris* species, *Exomalopsis analis* Spinola 1853 and other non-social species from the Halictidae and Megachilidae.

In this study we documented 10 new records of bee species for Mato Grosso do Sul, compared to both Aoki & Sigrist (2006) and the currently available species list for this region (Moure et al. 2008). This highlights the lack of knowledge about plant-visitors interactions in this state (Pinheiro-Machado et al. 2002, Freitas et al. 2009), and why species with wide distribution in Brazil such as *Centris aenea*, *C. fuscata* and *C. lutea* were not previously recorded in Mato Grosso do Sul. As this is the first systematic survey of the native bee fauna in the Pantanal region, future studies in other habitats, as well as extending surveys to larger areas of forest islets, will certainly add more species to the Pantanal checklist.

The Africanized *Apis mellifera* was the only floral visitor recorded in seven flowering species and utilized more than 38% of species visited by native bees. This overlap in flower visitation has been reported in areas of Cerrado in the State São Paulo (Pedro & Camargo 1991), and to a lesser extent in arid areas in northeastern Brazil (Zanella & Martins 2003). Plenty of studies show evidences that *Apis mellifera* affects the reproductive success of different plant species (Gross & Mackay 1998, Hansen et al. 2002, Carmo et al. 2004) as well as the diversity and abundance of communities of native bees through resource competition (Roubik 1980, 2009, Roubik & Villanueva-Gutiérrez 2009).

Although this study provides baseline data for bees and their floral resources in the Pantanal wetland, and bee biogeography within Brazil, new studies are still needed for the region. Therefore, given the high conservation value of the Pantanal, in terms of its habitat diversity and of pollinator richness, quantitative surveys of new areas and habitats should be conducted to extend our knowledge on bee species and the pollination services they provide in this region.

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