



First report on dung beetles in intra-Amazonian savannahs in Roraima, Brazil

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Abstract: This is the first study to address the dung beetle (Coleoptera: Scarabaeidae: Scarabaeinae) diversity in intra-Amazonian savannahs in the state of Roraima, Brazil. Our aim was to survey the dung beetle fauna associated with these savannahs (regionally called 'lavrado'), since little is known about the dung beetles from this environment. We conducted three field samples using pitfall traps baited with human dung in savannah areas near the city of Boa Vista during the rainy seasons of 1996, 1997, and 2008. We collected 383 individuals from ten species, wherein six have no previous record in intra-Amazonian savannahs. The most abundant species were *Ontherus appendiculatus* (Mannerheim, 1829), *Canthidium* aff. *humerales* (Germar, 1813), *Dichotomius nisus* (Olivier, 1789), and *Pseudocanthion* aff. *xanthurus* (Blanchard, 1846). We believe that knowing the dung beetles diversity associated with the intra-Amazonian savannahs is ideal for understanding the occurrence and distribution of these organisms in a highly threatened environment, it thus being the first step towards conservation strategy development.

Keywords: *Tropical environments, new species occurrence, 'lavrado', Scarabaeinae.*

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Resumo: Este é o primeiro estudo da diversidade de besouros rola-bosta (Coleoptera: Scarabaeidae: Scarabaeinae) nas savanas intra-amazônicas de Roraima, Brasil. Nosso objetivo foi inventariar a fauna de besouros associada com savanas (conhecidas regionalmente como 'lavrado'), uma vez que pouco se sabe sobre esses besouros nesse ambiente. Nós amostramos em savanas próximas a cidade de Boa Vista durante a estação chuvosa nos anos 1996, 1997 e 2008, utilizando armadilhas pitfall iscadas com fezes humanas. Coletamos 383 indivíduos de dez espécies, das quais seis não haviam ocorrência prévia para savanas intra-amazônicas. As espécies mais abundantes foram *Ontherus appendiculatus* (Mannerheim, 1829), *Canthidium* aff. *humerales* (Germar, 1813), *Dichotomius nisus* (Olivier, 1789) e *Pseudocanthion* aff. *xanthurus* (Blanchard, 1846). Nós acreditamos que conhecendo a diversidade de besouros associada às savanas intra-Amazônicas se torna ideal para o entendimento da ocorrência e distribuição desses organismos em um ambiente altamente ameaçado, sendo o primeiro passo para a tomada de estratégias de conservação.

Palavras-chave: *Ambientes tropicais, nova ocorrência de espécies, lavrado, Scarabaeinae.*

Introduction

The Amazon environment comprises a mosaic of ecosystems, including deciduous forests, 'campinaramas' (meadows), semi-deciduous seasonal forests, rain and montane forests, dry land forests, floodplain forests, woodlands and intra-Amazonian savannahs (Junk 1983, Ribeiro et al. 1999). The Brazilian intra-Amazonian savannah landscape encompasses a predominantly grassy-woody vegetation (e.g. grasses, sedges, and small herbs), with low arboreal-shrub density (Barbosa et al. 2007, Sarmiento

1984) and specific edaphic characteristics (Cavalcante et al. 2014, Sanaiotti et al. 2002). These savannahs are located in the extreme north of the Brazilian Amazon forest, mainly in the triple border between Venezuela, Brazil and Guyana (Barbosa et al. 2007, Barbosa & Fearnside 2005, Prance 1996). This eco-region known as Guyana's shield (Hubber 2006) comprises the largest contiguous area of intra-Amazonian savannah (around 54.000 km²), of which approximately 72% are located in the northeastern region of the Roraima State in Brazil (Barbosa & Fearnside 2005, Barbosa & Campos 2011, Copobianco et al. 2001, Ferreira 2001).

Furthermore, those savannahs are regionally known as 'lavrado' (Barbosa et al. 2007, Sanaïotti 1997), which means 'place where the trees are absent' (Vanzolini & Carvalho 1991) and reflects its typical non-forest vegetation.

Despite a review about the Phanaeini tribe (Pacheco & Vaz-de-Mello 2015), no work to our knowledge has reported the dung beetle fauna from the intra-Amazonian savannahs in Roraima. The dung beetles are a responsive taxonomic group (Bicknell et al. 2014), with more than 600 species recorded in Brazil (Vaz-de-Mello 2000) and distributed throughout all Brazilian terrestrial ecosystems. Regarding their diversity within Brazilian opened areas, studies have recorded between 13 and 66 species from the Brazilian southeastern savannahs (known as 'cerrado') and pasturelands (Abot et al. 2012, Almeida et al. 2011, Durães et al. 2005, Gries et al. 2012, Milhomem et al. 2003, Silva & Audino 2011, Silva et al. 2010, Vieira & Silva 2012). Furthermore, 15 dung beetle species were reported from the intra-Amazonian savannahs near to *Alter do Chão* village, state of Pará, Brazil (Louzada et al. 2010, Matavelli & Louzada 2008). Hence, considering the dung beetles' ecological importance in many ecosystem processes (Nichols et al. 2008) and the poor knowledge about their fauna from the largest intra-Amazonian savannah area in Brazil, here we aimed to present the dung beetle species that were sampled within three *lavrado* savannahs of Roraima state, Brazil.

Materials and Methods

The city of Boa Vista in the state of Roraima has a humid tropical climate, characterized as a rainy summer, which extends from April to September, and a dry season from October to March. The average annual rainfall and temperature are respectively 1612 ± 400 mm and 27.4 °C (Barbosa & Fearnside 2005, Meneses et al. 2007). We used dung-baited pitfall traps to sample dung beetles during September 1996, July 1997, and November 2008 in three savannah areas near Boa Vista, Roraima, Brazil.

The first sampling period (1996) was carried out in a small savannah area in the municipality of Cantá ($2^{\circ}46'$ N $60^{\circ} 38'$ W) located on the margin of the 'Rio Branco' river. The region is a large *lavrado* area continuous with small anthropogenic areas and subjected to floods during the rainy season. We installed five pitfall traps in this area, separated at least 50 m apart from each other, baited with human dung and exposed for 48 h to the dung beetle community. In the second sampling period (1997), a large area of *lavrado* in the 'Serra da Moça' region (north of Boa Vista, approx.

$6^{\circ}12'$ N $60^{\circ}41'$ W) was sampled. We placed seven pitfall traps, located at least 50 m apart, baited with human dung and collected daily during five days with two exchanges of bait during the sampling period. In the third sampling period (2008), we sampled a large area of *lavrado* located on the opposite side of the *Rio Branco* river ($02^{\circ}62'$ N $60^{\circ}72'$ W). We used seven pitfall traps, separated at least 50 m apart from each other, baited with human dung and left in the field for 48 h.

Pitfall traps were plastic containers (14 cm in diameter; 9 cm deep) buried in the ground with the opening at ground level, and with approximately 30 g of bait. We covered each pitfall with a lid to protect it from the rain and filled each one with 250 ml of a saline solution and detergent. After the exposition in the field, we collected, sorted, mounted and identified all dung beetles to the lowest possible taxonomic level. All voucher specimens were deposited in the Reference Collection of Neotropical Scarabaeinae in the Insect Ecology and Conservation Laboratory, Universidade Federal de Lavras and in the Entomology section of the Zoological Collection at Universidade Federal de Mato Grosso, Brazil. To further discussions about the geographical distribution and feeding habits of each genera and species here collected, we reviewed published and unpublished bibliographical references about the species ecology and distribution. Furthermore, we present an illustrated guide from each identified species we have found.

Results and Discussion

We collected 383 dung beetles belonging to ten species and eight genera (Table 1). From the collected species, only *Canthidium* sp. could not be identified and it is a possible new species. *Ontherus appendiculatus*, *Canthidium* aff. *humerales*, *Dichotomius nisus*, and *Pseudocanthon* aff. *xanthurus* were the most abundant species. As such, we have sampled six species without any previous occurrence from intra-Amazonian savannahs, as only the dung beetle species *O. appendiculatus*, *D. nisus*, *P.* aff. *xanthurus* and *C. mutabilis* have been previously recorded in these environments (Génier 1996, Louzada et al. 2010, Matavelli & Louzada 2008).

Most species we found belong to species-clusters that have been collected within dry, open and highly disturbed environments on the American continent, some of them with records from Argentina (Damborsky et al. 2015), Mexico (Novelo et al. 2007), Ecuador (Carpio et al. 2009), Venezuela (Lozano 2010), Colombia (Noriega et al. 2007) and Costa Rica (Padilla-Gil &

Table 1. Dung beetle species collected in three intra-Amazonian savannahs close to Boa Vista, Roraima, Brazil. In each sampling period, we sampled a different area.

Species	Sampling period			Total individuals
	1996	1997	2008	
<i>Canthidium</i> aff. <i>humerales</i> (Germar, 1813)	1	10	50	61
<i>Canthidium</i> sp.	5	0	0	5
<i>Canthon</i> (<i>Canthon</i>) aff. <i>scrutator</i> Balthasar, 1939	0	2	0	2
<i>Canthon</i> (<i>Canthon</i>) aff. <i>mutabilis</i> Lucas, 1959	0	5	0	5
<i>Malagioniella astyanax</i> (Oliver, 1789)	0	0	1	1
<i>Pseudocanthon</i> aff. <i>xanthurus</i> (Blanchard, 1846)	4	21	22	47
<i>Dichotomius nisus</i> (Olivier, 1789)	13	22	14	49
<i>Ontherus appendiculatus</i> (Mannerheim, 1829)	161	0	3	164
<i>Onthophagus</i> aff. <i>hirculus</i> Mannerheim, 1829	10	0	0	10
<i>Coprophanæus gamezi</i> Arnaud, 2002	0	39	0	39

Halffter 2007). In Brazil, those have been registered within the semi-arid scrub forest (known as ‘*caatinga*’) (Hernández 2007, Lopes et al. 2006, Silva et al. 2007), coastal sandy vegetation (‘*restinga*’) (Costa et al. 2014), coastal low land forests (‘*Tabuleiro*’ forests) (Endres et al. 2007) and native and exotic pasturelands (Almeida et al. 2011, Costa et al. 2009, 2013, Silva et al. 2010, Silva et al. 2011, 2014). In addition, the species reported here were also found within highly impacted Brazilian forests, such as northeastern fragments of Atlantic forest (Salomão & Iannuzzi 2015, Viegas et al. 2014), planted *Eucalyptus* sp. forests (Audino et al. 2011) and Amazonian secondary forests, savannahs and agricultural areas (Korasaki et al. 2012, Louzada et al. 2010, Matavelli & Louzada 2008).

The number of dung beetle species and individuals reported here was lower than in other intra-Amazonian savannahs (Louzada et al. 2010, Matavelli & Louzada 2008), southern *cerrado* (Abot et al. 2012, Almeida et al. 2011, Durães et al. 2005, Gries et al. 2012, Silva et al. 2010, Vieira & Silva 2012) and native grasslands of the ‘*Pampa*’ region (Silva et al. 2011). We believe this lower species-rich sample can be due the historical isolation of the intra-Amazonian from the *cerrado* savannahs in central Brazil during the Pleistocene period (Sanaiotti et al. 2002), besides some natural specific habitat characteristics, such as edaphic factors, vegetation structure and fire occurrence (Barbosa & Fearnside 2005, Louzada et al. 2010). Henceforward, we will discuss the knowledge concerning the distribution and ecology of each identified species.

***Canthidium* Erichson (1847):** Considered as one of the most diverse dung beetle groups (Halffter & Martínez 1966), this genus needs urgent revision, which may result in the creation of new genera. It currently includes about 170 described species, mainly recorded with dung-baited pitfalls in Neotropical forests and savannahs (Gill 1991, Silva et al. 2014, Vaz-de-Mello & Louzada 1997, Vaz-de-Mello et al. 1998). There are also some records of species sampled with carrion-baited pitfalls or consuming rooting fruit, fungi and dead insects (Medri & Lopes 2001, Silva & Audino 2011, Silva et al. 2014). Hence, species have been suggested as myrmecophilous associated with nests of *Atta* ants Fabricius, 1804, probably exploiting rotting fungi (Falqueto et al. 2005). *Canthidium* aff. *humerales* (Figure 1A) belongs to a species-cluster that contains species considered as coprophagous (Silva et al. 2007) and distributed within many opened environments. Species in this cluster have been recorded in northeastern Brazilian grassland areas (Almeida et al. 2011, Costa et al. 2009, Silva et al. 2007), *Tabuleiro* forests (Endres et al. 2007), secondary regeneration zones between *caatinga* and *cerrado* (Lopes et al. 2006) and transitional regions between the Amazon forest and *cerrado* (Andrade et al. 2011). The other *Canthidium* species we found could not be identified accurately, thus no further comments are possible about its ecology and distribution.

***Canthon* Hoffmannsegg (1817):** Featuring approximately 200 species, this genus has been studied at a supraspecific level, except for some species that are not yet grouped into any subgenera. It is an American group, with species mainly found from Argentina to Canada (Vaz-de-Mello 2000). Although most species are considered as copro-necrophagous, other feeding habits, including fungi and debris feeders (Vaz-de-Mello 1999b) and ant predation (Hertel & Colli 1998, Vaz-de-Mello et al. 1998,

Villalobos et al. 1998) were also recorded. The subgenus *Canthon* (*Canthon*) Hoffmannsegg, 1817 includes mainly coprophagous or necrophagous dung beetles, despite species preying on ants (Cantil et al. 2014, Forti et al. 2012, Villalobos et al. 1998) and feeding on dead insects and millipedes (Villalobos et al. 1998). *Canthon* (*Canthon*) aff. *scrutator* Balthasar, 1939 (Figure 1B) belongs to the *Canthon virens* species-group (Halffter & Martínez 1977), which is distributed throughout the northern Amazon Basin, Guyana and Atlantic Forest region. This species-group comprises copro-necrophagous dung beetles, also recorded consuming insect carcasses (Forti et al. 2012) or sampled with carrion-baited pitfall traps (Salomão & Iannuzzi 2015). We believe the species *Canthon* (*Canthon*) aff. *mutabilis* Lucas, 1859 (Figure 1C) needs urgent revision, given that individuals identified as *C. mutabilis* may comprise a complex group of different species. This species-group have been recorded within open environments in America, such as Colombia (Noriega et al. 2007), Costa Rica (Padilla-Gil & Halffter 2007), Argentina (Boito et al. 2009) and primary forests from Suriname (Larsen 2011). In Brazil, there are samples from flight intercept traps (Audino et al. 2011, Costa et al. 2009) and pitfalls baited with dung and carrion (Costa et al. 2013, 2014, Silva et al. 2007, 2014, Silva & Audino 2011).

***Malagoniella* Martínez, 1961:** Halffter & Martínez (1966) reviewed this genus, which includes nine colorful metallic dung beetle species distributed across the Neotropical region, from USA (Texas) to Argentina (Padilla-Gil & Halffter 2007). *Malagoniella astyanax* (Oliver 1789) (Figure 1D) belongs to a species complex that is currently being revised. It has been found in the Brazilian *caatinga* (Hernández, 2007, Silva et al. 2007, Vieira & Silva 2012), Ecuadorian Amazon (Carpio et al. 2009), Colombia (Escobar 1997), Costa Rica (Padilla-Gil & Halffter 2007), Mexico (Novelo et al. 2007), Venezuela (Ferrer-Paris et al. 2013), Bolivia (Vidaurre et al. 2008) and Guyana (F.Z. Vaz-de-Mello, unpublished data). Species in this group have been considered as nocturnal (Hernández 2007), sampled by pitfall traps baited with dung and carrion (Carpio et al. 2009, Hernández 2007, Novelo et al. 2007, Silva et al. 2007).

***Pseudocanthon* Bates, 1887:** This genus is small, including nine species distributed from the USA to Argentina and Antilles (Halffter & Matthews 1966, Padilla-Gil & Halffter 2007). Although small, it urgently needs taxonomic revision, at least for the continental species. The species *Pseudocanthon* aff. *xanthurus* (Figure 1E) is a complex of species, which is difficult to identify (Korasaki et al. 2012) and, as the genus, it needs taxonomic revision. Although extensively sampled with dung baited pitfalls, the species have been considered as generalist (Andrade et al. 2011), with records from open habitats in Colombia and Venezuela (Ferrer-Paris et al. 2013). In Brazil they have been reported within pastures and grasslands (Costa et al. 2009, Schiffler et al. 2015, Silva et al. 2014), *caatinga* (Lopes et al. 2006), degraded *restinga* (Costa et al. 2014), northeastern Atlantic forest (Costa et al. 2013, Salomão & Iannuzzi 2015), intra-Amazonian savannahs (Matavelli & Louzada 2008) and Amazonian agricultural areas (Korasaki et al. 2012).

***Dichotomius* Hope (1838):** According to the last taxonomic revision, this genus features approximately 165 valid species widely distributed from the USA to Argentina (Luederwaldt 1929),

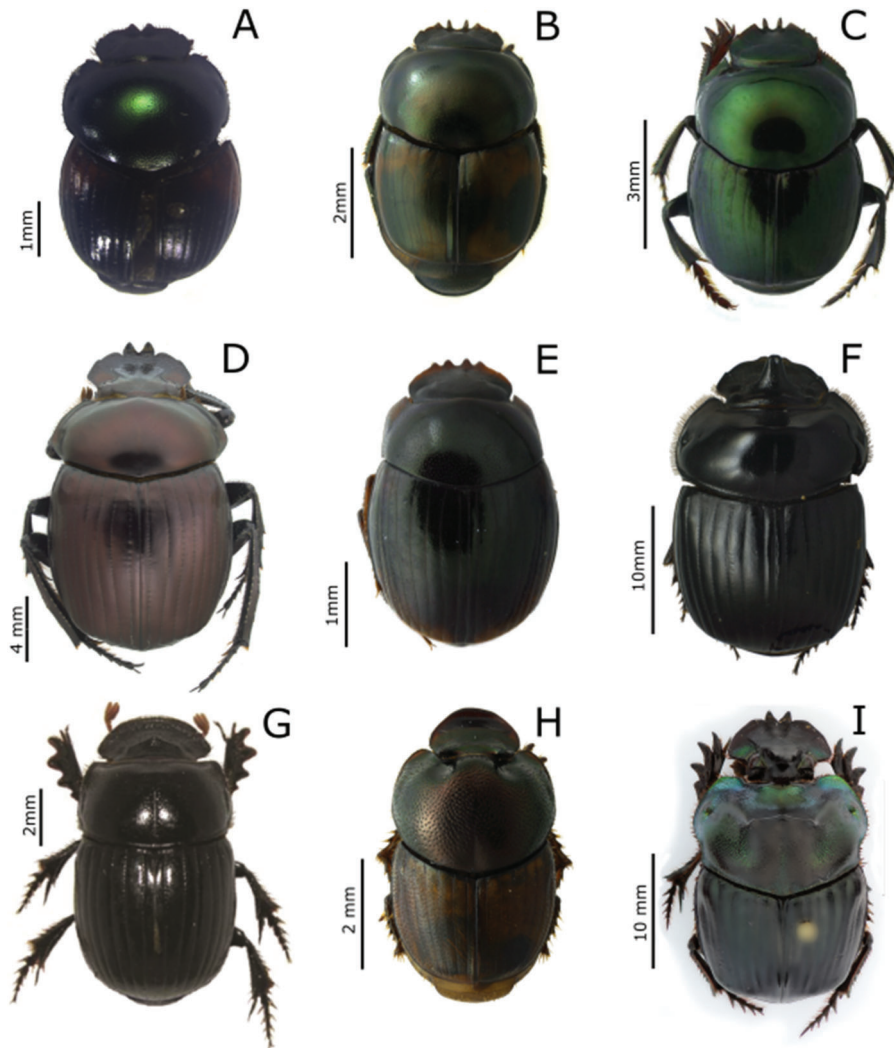


Figure 1. Dung beetle species sampled from intra-Amazonian savannahs in the state of Roraima: (A) *Canthidium* aff. *humerale*; (B) *Canthon* aff. *scrutator*; (C) *Canthon* aff. *mutabilis*; (D) *Malagoniella astyanax* (extracted from Vieira & Silva, 2012); (E) *Pseudocanthon* aff. *xanthurus*; (F) *Dichotomius nisus*; (G) *Ontherus appendiculatus* (extracted from Vidaurre et al., 2008); (H) *Onthophagus* aff. *hirculus*; (I) *Coprophanaeus gamezi* (extracted from Pacheco & Vaz-de-Mello, 2015).

especially in Neotropical forest and savannah areas (Vaz-de-Mello 1999b, 2000). Although most species are coprophagous, we believe there are some exceptions. *Dichotomius nisus* (Olivier 1789) (Figure 1F) is considered a nocturnal coprophagous-generalist species (Hernández 2007, Silva et al. 2007, Vieira et al. 2008), commonly occurring within opened and/or disturbed environments (Filgueiras et al. 2015, Nunes et al. 2012). It is widely distributed, with records from Guyana (Boilly & Vaz-de-Mello 2014), Argentinian *Chaco* (Damborsky et al. 2015), transitional forests in Bolivia (Vidaurre et al. 2008), Colombia Andes (*Putumayo region*) (Escobar et al. 2005) and Venezuelan dry forests and pastures (Ferrer-Paris et al. 2013, Lozano 2010). In Brazil, it has been sampled with both dung and carrion-baited pitfall traps within more than 17 states (Louzada et al. 2007). Accordingly, it has been extensively collected from the northern intra-Amazonian savannahs (Koller et al. 1999, Matavelli & Louzada 2008) to southern *Campanha* region (Silva et al. 2008), within non-native forests of *Eucalyptus* sp. (Audino et al. 2011). Furthermore, there are records from *restinga* (Costa et al. 2014, Schiffler et al. 2015, Vieira et al. 2008), *Tabuleiro* forest (Endres et al. 2007), *caatinga* (Hernández 2007,

Medina & Lopes 2014, Santos et al. 2014, Vieira & Silva 2012), Atlantic forest fragments (Costa et al. 2013, Flechtmann et al. 2009, Salomão & Iannuzzi 2015, Silva et al. 2015, Viegas et al. 2014), *cerrado* (Almeida et al. 2011, Rodrigues et al. 2010) and many pasturelands and altered grasslands (Costa et al. 2009, Filgueiras et al. 2015, Louzada & Silva 2009, Louzada et al. 2007, Puker et al. 2013, Scheffler 2005, Silva et al. 2011).

***Ontherus* Erichson, 1847:** This genus is distributed from Mexico to Argentina and was recently reviewed by Génier (1996), which resulted in 56 species divided into three subgenera. We believe that most of the species are coprophagous; however, there are some species associated with sediment deposits within ant colonies of *Atta* Fabricius, 1804 and *Acromyrmex* Mayr, 1865 (Halfiter & Halfiter 2009). *Ontherus appendiculatus* (Mannerheim, 1829) (Figure 1G), although considered as typically coprophagous, has been collected also with carrion (Flechtmann et al. 2009, Rosa et al. 2011, Silva et al. 2007). Widely distributed in South America (Génier 1996), *O. appendiculatus* has been reported in Argentina, Bolivia, Brazil, Colombia, Ecuador, French Guyana,

Guyana, Paraguay, Uruguay and Venezuela (Génier 1996, Louzada et al. 2007, Vidaurre et al. 2008, Ferrer-Paris et al. 2013). In Brazil, it has a broad distribution, with records from intra-Amazonian savannahs (Matavelli & Louzada 2008), *Tabuleiro* forest (Lima et al. 2013) and Atlantic forest fragments (Silva et al. 2015). Furthermore, it has been recorded in transitional forests between *cerrado* and Amazon forest (Andrade et al. 2011), and *cerrado* within *Pantanal* regions (Louzada et al. 2007, Puker et al. 2013, Rodrigues et al. 2010).

Onthophagus Latreille, 1802: It is a very diverse and cosmopolitan genus with more than 2000 species (Tarasov & Kabakov 2010). Although considered as coprophagous, there are species attracted by the defense secretions from millipedes (Brühl & Krell 2003, Schmitt et al. 2004) or associated with caves (Slay et al. 2012), bird nests (Kristofik et al. 2003) and rodents (Sánchez-Huerta et al. 2015). *Onthophagus* aff. *hirculus* Mannerheim, 1829 (Figure 1H) belongs to a complex of species that is taxonomically close to *O. hirculus* and needs urgent taxonomic revision. Those species have been considered as coprophagous and generalist (Hernández 2007, Silva et al. 2011), collected by pitfall traps baited with different types of dung, rotting fruits and carcass (Audino et al. 2011, Flechtmann et al. 2009, Puker et al. 2013, Rosa et al. 2011, Silva & Audino 2011, Silva et al. 2008). This species-complex have been recorded in South American open areas at altitudes < 1000 m, such as Argentinian *Chaco* (Damborsky et al. 2015), Colombian secondary dry forests (Noriega et al. 2007) and Bolivian transitional forests (Vidaurre et al. 2008). In Brazil, they have been collected within pasturelands (Puker et al. 2013, Silva et al. 2010, Silva et al. 2014), *caatinga* (Hernández 2007, Santos et al. 2014, Silva et al. 2007, Vieira & Silva 2012) and *restinga* areas (Costa et al. 2014, Vieira et al. 2008). In addition, they have been recorded in Atlantic forest fragments (Silva et al. 2015) and transitional areas between the Amazon forest and *cerrado* (Andrade et al. 2011).

Coprophanaeus d'Olsoufieff, 1924: Reviewed by Edmonds & Zidek (2010), this genus includes 38 species distributed among three subgenera and eight species recorded from Texas to Argentina. *Coprophanaeus gamezi* Arnaud, 2002 (Figure 1I) has been found in tropical dry forests in Colombia (Solís et al. 2011), the coast and provinces in Venezuela (Ferrer-Paris et al. 2013, Lozano 2010) and adjacent Amazon regions of Brazil, Colombia and Guyana (Edmonds & Zidek 2010). Accordingly, it has been suggested as preferring open habitats and readily invading pasturelands (Edmonds & Zidek 2010), and has already been reported in introduced pastures and banana plantations (Gámez & Acconcia 2009, Gámez 2010).

Here we reinforce the unique botanical and faunal characteristics that Amazonian savannahs exhibit, which are considered an important area of endemism within South America (Barbosa et al. 2007). Hence, the studies concerning the fauna of this region should aim to establish conservation strategies associated with this important environment. Our study was the first to document the dung beetle fauna from Roraima savannahs and we believe that knowing the biodiversity is the first step in developing conservation strategies. Thus, since human disturbances threaten these environments (Barbosa et al. 2007, 2011), what leads to biodiversity loss, we reinforce that efforts should be undertaken towards the conservation of intra-Amazonian savannahs. Furthermore, we

suggest further studies aiming to understand the effects of human disturbances on the dung beetle diversity in the Brazilian intra-Amazonian savannahs.

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