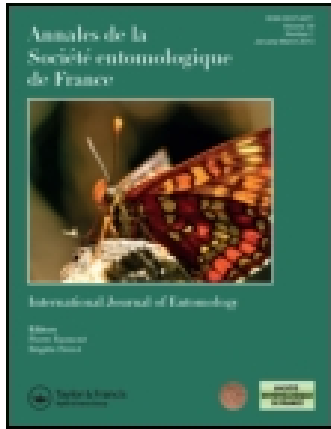


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Taxonomic composition of Scarabaeinae dung beetles (Coleoptera: Scarabaeidae) inhabiting fluvial islands in the southern Brazilian Amazon

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Summary. We evaluated the taxonomic composition of Scarabaeinae dung beetles inhabiting fluvial islands in Juruena River, southern Brazilian Amazon. We sampled seven islands and two localities on each side of the mainland. We collected 41 species, all of which are widely distributed in the Amazon rainforest. Nine of these were exclusive to the islands, 24 were exclusively found on the mainland while eight species were found in both the islands and the mainland. The insular dung beetle fauna is mainly composed of typical species of *várzea* forest or edge forest/gap with the absence of *Eurysternus* and elements of primary forest in the Amazon. This result suggests that three main processes are shaping these communities: flooding and associated disturbance events, resource competition (presence of primates) and differential dispersal power among species. Depending on the context and age of island formation all these processes could have different levels of importance. Specific questions regarding these processes requires a previous knowledge of the taxonomic composition of these communities.

Résumé. Composition taxonomique des Scarabaeinae bousiers (Coleoptera : Scarabaeidae) d'îles fluviales en Amazonie brésilienne méridionale. Nous avons étudié la composition de la faune des Scarabaeinae coprophages d'îles fluviales sur la rivière Juruena, en Amazonie brésilienne méridionale, d'un point de vue d'une analyse taxinomique. Nous avons effectué des prélèvements sur sept îles et deux localités témoins situées sur les berges continentales du fleuves. Nous avons récoltées 41 espèces. Toutes ces espèces sont largement distribués dans la forêt amazonienne. Neuf d'entre elles n'ont été rencontrées que sur les îles, 24 ne l'ont été que sur le continent et seulement huit sont communes aux deux entités. La faune des Scarabaeinae coprophages insulaires est composée principalement d'éléments de forêt *várzea* ou de lisière, sans représentant du genre *Eurysternus*, et d'éléments de forêt primaire amazonienne. Ces résultats suggèrent que trois paramètres modèlent la composition de la faune des bousiers en milieu insulaire fluvial: inondations et perturbations associées, compétition pour les ressources (liée à la présence de primates) et potentiel de dispersion des différentes espèces. En fonction du contexte et de l'âge de la formation des îles, ces trois paramètres revêtent une importance relative différente selon les espèces. L'analyse plus en profondeur de ces paramètres nécessite la description précise de la communauté étudiée d'un point de vue taxinomique.

Keywords: Juruena; Tapajós; taxonomic composition; taxonomic hypothesis; *várzea* forest

Despite fluvial islands being commonly found in large rivers of the Amazon Basin, aspects of the fauna and flora of these interesting systems remain unknown for many taxonomic groups (Ward et al. 2002). It has been demonstrated that fluvial islands can contribute directly to increasing regional diversity and the genetic flow of populations (Remsen & Parker 1983; Rosenberg 1990; Ward et al. 2002; Borges 2006). From the evolutionary point of view, insular species are potentially subject to geographic isolation followed by speciation (Heffer 1997; Thompson 1998; Cox & Moore 2011). Understanding variations in

diversity on fluvial islands can be a valuable tool in conservation, to understand the consequences of habitat fragmentation (Larsen et al. 2008).

In the Brazilian Amazon, the Juruena River is about 400 km long and joins with the Teles-Pires River to form the Tapajós River, a major component of an important biogeographical zone with several cases of plant and animal endemism (Dinerstein et al. 1995; Morrone 2000, 2001, 2010). In addition, the Juruena River is positioned in a highly productive agricultural region called the "Arc of Deforestation". Over the last 20 years, continuous

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forest in this region has been replaced by a fragmented landscape (Lees & Peres 2006; Barona et al. 2010).

Fluvial islands are commonly found in Amazon rivers, including Juruena. They constitute a dynamic system in which considerable portions of land may be washed out in high flows or be formed in a relative short period (Wyrick & Klingeman 2011). There is also the possibility of long-term island formation by silt deposition (Osterkamp 1998). There are very few studies of the composition of fauna and flora on these islands (Ward et al. 2002; Campos et al. 2013). Consequently, studies of the ecology and evolution of fluvial biodiversity are also limited.

Our work is delimited by a single question: which species of Scarabaeinae dung beetles inhabit the fluvial islands in Juruena River at the Brazilian Meridional Amazon? We used the species composition and the data associated to each taxonomic name (Wheeler & Valdecasas 2007) to discuss and draw some observations on these practically unknown biological communities.

Material and methods

Site characterization

This study was undertaken in the north of the state of Mato Grosso in the municipalities of Cotriguaçu and Nova Bandeirantes, which are delimited by the Juruena River (Figure 1). We sampled seven accessible fluvial islands of variable size (Table 1, Figure 1). The islands are used for tourism, fishing and mammal hunting activities. We classify two habitats in the islands: *várzea* forest (Veloso et al. 1991; or river edge forest *sensu* Remsen & Parker 1983), and open sand beach habitat, which was not sampled since it was present only in one island. The Amazonian *várzea* forests are subject to periodic flooding due to the changes in river levels. Depending on the topography, this system is more or less susceptible to flooding, and thus may hold different successional stages (Remsen & Parker 1983). In our samples, both the mainland and the islands had some strong evidence of recent flooding (e.g. low density of plants in the understory, exposed soil, litter with large amounts of dust, indications of water level on the trees and reports of local users). The islands were dominated by plants of the genera *Cecropia*, *Ochroma* and *Erythrina*, while *Heliconia* is dominant in some parts of the understory. The soil in the islands is characterized by silt deposition, due to annual flooding and changes in the river course (Remsen & Parker 1983; Salo et al. 1986; Junk et al. 2011). According to Köppen's classification, the climate is tropical humid (Am), with average annual temperature of 24°C, humidity of 85% and average annual rainfall of 2300 mm, with periods of rain between November and May and a dry season between June and October (Dáttilo et al. 2012).

Dung beetle sampling

In October 2010 we sampled seven islands and two points on each side of the mainland, totaling nine sampling localities. At each sampling point we installed a linear set of five pitfalls baited with human dung, spaced 50 m from each other; these remained for 48 h in the field. The pitfall method is widely recommended in studies involving Scarabaeinae dung beetles since it can provide an effective sample of the dung beetle community in a few days (Milhomen et al. 2003; Larsen & Forsyth 2005). All

collected specimens were vouchered at Setor de Entomologia da Coleção Zoológica da Universidade Federal de Mato Grosso, Cuiabá, Brazil (CEMT). Genus level identifications were done using the keys of Vaz-de-Mello, Edmonds, et al. (2011) while species level identifications were done using references cited by this study, and by comparisons with CEMT records.

Data analysis

Since we have few sampled islands and few degrees of freedom to perform powerful ecological analysis of these communities, our approach is restricted to the taxonomic composition. For instance, with a larger number of sampled islands and correct delineation, our study could be tested against the theory of island biogeography (MacArthur and Wilson 1967).

Each species name of our species list was tested and confirmed by morphological, behavioral and geographical characteristics usually found in the species descriptions, collection records, identification keys and/or taxonomic revisions (Wheeler & Valdecasas 2007). Once a given taxonomic name is confirmed, it will bring several biological, ecological and distributional data that can be comparable and discussable among different samples and works.

As an example, *Dichotomius robustus* was confirmed to occur in one of the Juruena River islands, by using the diagnosis and keys of Luederwaldt (1935) and Vaz-de-Mello et al. (2011). Therefore, we could compare several works that provide other ecological information about the same species (e.g. Feer 2008; Larsen 2011; Silva et al. 2014). Rather than just extending the geographic distribution of this species, these works may provide important and useful information concerning this species and its habits. The interpretation of the taxonomic names and the natural history data associated with them leads to questions and comparisons on the similarity and context of these communities.

Species with the prefix “*aff*” (derived from *affinis*, Latin word for similar) before the specific epithet, or lacking the specific epithet (“sp.”), are not comparable with other literature since the names cannot be confirmed (or they constitute new species or their identification cannot be confirmed by the available methods). The natural history data used in the discussion were found in the scientific literature (species with confirmed identification and authors; some records are dissertations or theses) and records of the Setor de Entomologia da Coleção Zoológica da Universidade Federal de Mato Grosso - CEMT, Cuiabá, Mato Grosso, Brazil, of which the fourth author is the curator.

Results and discussion

We collected 41 species from the seven islands and the two mainland points. Nine of them occur exclusively in the islands, 24 exclusively on the mainland, and eight in both (Table 2). All species caught have wide distribution in the South American Amazon. All species in this work were collected in a long-range dung beetle inventory in Cotriguaçu municipality, about 10 km east of the study area (Vaz-de-Mello, Silva, et al. 2011). For this reason we discard the hypothesis that there were insular endemisms among these communities.

Most of the species found on the islands are commonly associated to *várzea* forest habitats in the

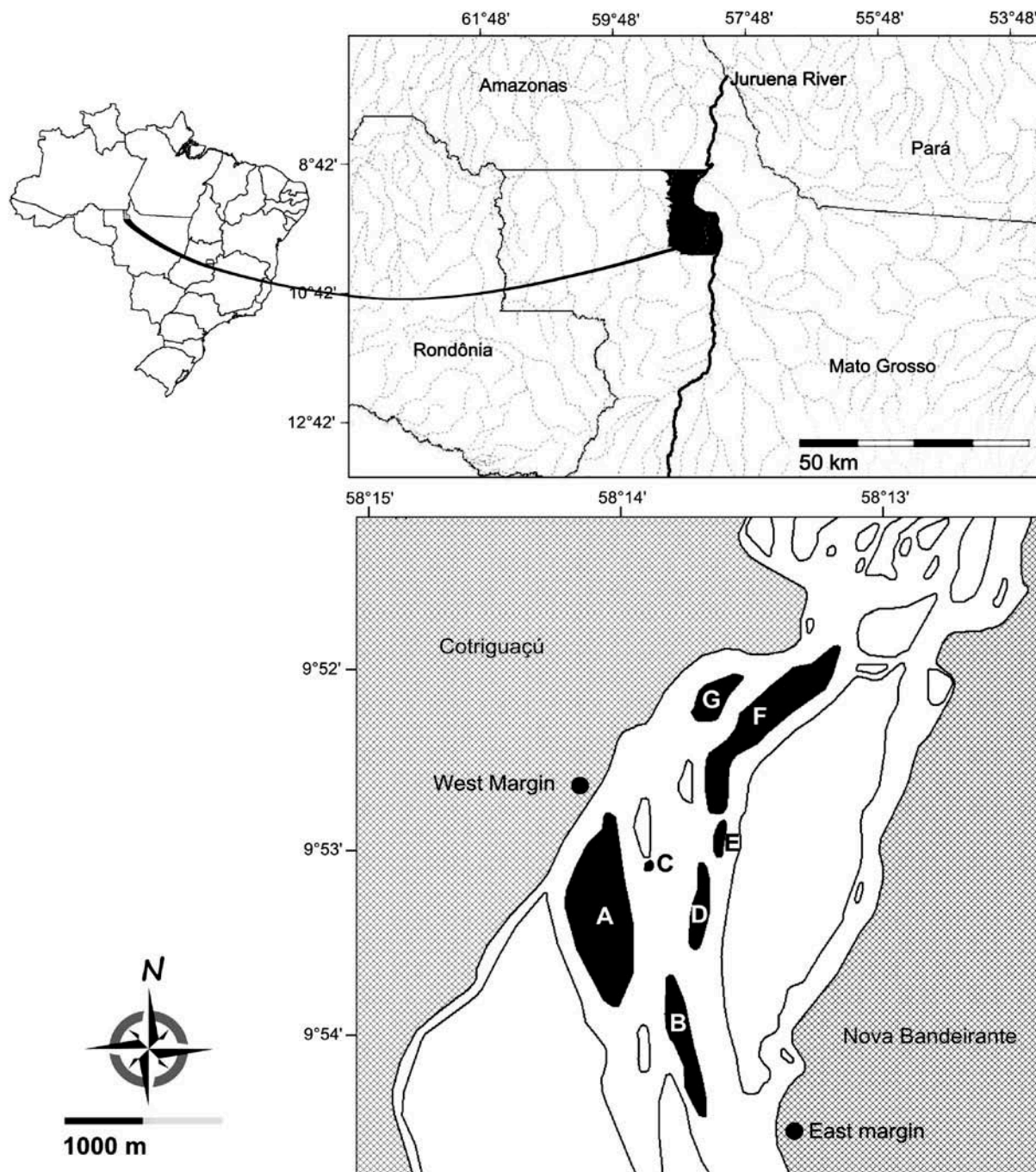


Figure 1. Above, location of the Juruena River and Cotriguaçu municipality (gray) in the state of Mato Grosso, Brazil. Below, sampled islands (A to G) in Juruena River in October 2010.

Brazilian Amazon, as is the case for *Canthidium dohrni*, *Dichotomius carinatus*, *D. robustus*, *D. worontzowi*, *Onthophagus bidentatus* and *O. rubescens* (Vaz-de-Mello, Silva, et al. 2011; Matavelli et al. 2013; Ratcliffe 2013; CEMT (unpublished entomological collection records)). *Canthon juvenicus* is a common element in drier forests at Colombia and Central America (Padilla-Gill &

Halfiter 2007) and, like *Ateuchus substriatus*, *Canthon simulans* and *Phanaeus bispinus*, it is found associated with forest edges, managed forests (mainly *P. bispinus*), clearings or open habitats south of Colombia (Feer 2008; Korasaki et al. 2012; Macedo 2013; Matavelli et al. 2013; Silva et al. 2014; CEMT (unpublished entomological collection records)). *Ontherus azteca* is widely distributed

Table 1. Name, richness, area (ha), distance to west margin and distance to east margin of seven fluvial islands at Juruena river, state of Mato Grosso, Brazil in October 2010.

Island	Richness	Area (ha)	Distance to west margin (m)	Distance to east margin (m)
Island A	6	94.17	360	1890
Island B	7	22.19	770	790
Island C	3	0.2	930	2460
Island D	7	11.07	1580	1780
Island E	8	2.47	1690	1660
Island F	6	66.22	380	1008
Island G	10	15.13	330	2002

Table 2. Ordinate list of species of Scarabaeinae dung beetle collected on October 2010 at islands (A to G) and margins (Ms) of Juruena River, state of Mato Grosso, Brazil.

Species, author	C	A	F	B	D	E	G	Ms
<i>Canthon aff. juvenicus</i> Harold 1868								
<i>Uroxys</i> sp.1								
<i>Canthon aff. simulans</i> (Martínez 1950)								
<i>Dichotomius robustus</i> (Luederwaldt 1935)								
<i>Onthophagus aff. bidentatus</i> Drapiez 1819								
<i>Phanaeus bispinus</i> Bates 1868								
<i>Dichotomius carinatus</i> (Luederwaldt 1925)								
<i>Canthidium dohrni</i> Harold 1867								
<i>Canthidium</i> sp.1								
<i>Deltochilum</i> sp.1								
<i>Ateuchus substriatus</i> (Harold 1868)								
<i>Onthophagus rubrescens</i> Blanchard 1845								
<i>Canthonella</i> sp.1								
<i>Dichotomius worontzowi</i> (Pereira 1942)								
<i>Ontherus azteca</i> Harold 1869								
<i>Canthidium</i> sp.2								
<i>Dichotomius aff. lucasi</i> (Harold 1869)								
<i>Canthon proseni</i> (Martínez 1949)								
<i>Eurysternus atrosericus</i> Génier, 2009								
<i>Eurysternus caribaeus</i> (Herbst 1789)								
<i>Eurysternus hamaticollis</i> Balthasar 1939								
<i>Eurysternus wittmerorum</i> Martínez 1988								
<i>Ateuchus murrayi</i> (Harold 1868)								
<i>Ateuchus</i> sp.1								
<i>Canthidium aff. ardens</i> Bates 1887								
<i>Canthidium gerstaeckeri</i> Harold 1867								
<i>Canthidium</i> sp.3								
<i>Canthidium</i> sp.4								
<i>Canthidium</i> sp.5								
<i>Canthon aff. subhyalinus</i> Harold 1867								
<i>Canthon triangularis</i> (Drury 1770)								
<i>Deltochilum enceladus</i> Kolbe 1893								
<i>Deltochilum orbiculare</i> van Lansberge 1874								
<i>Deltochilum</i> sp.2								
<i>Dichotomius aff. globulus</i> (Felsche 1901)								
<i>Dichotomius aff. cuprinus</i> (Felsche 1901)								
<i>Hansreia</i> sp.								
<i>Onthophagus onorei</i> Zunino and Halffter 1997								
<i>Onthophagus onthochromus</i> Arrow 1913								
<i>Oxysternon macleayi</i> Nevinson 1892								
<i>Phanaeus chalcomelas</i> (Perty 1830)								

in forest areas of the South and Central America (Génier 1996). In Cotriguaçu municipality, few examples of this species were caught in secondary forests (Vaz-de-Mello, Silva, et al. 2011).

The sampled points on the mainland bear a group of species that are not present in the islands, although they are common in *várzea* forest (or river edge) habitats (Table 2). This group is formed by *Ateuchus murrayi*, *Canthon proseni*, *C. triangularis*, *Dichotomius worontzowi*, *Onthophagus onorei*, *Phanaeus chalcomelas* and all species of the genera *Deltochilum* and *Eurysternus* that we caught (Vaz-de-Mello, Silva, et al. 2011; Matavelli et al. 2013; Ratcliffe 2013; CEMT (unpublished entomological collection records)). *Eurysternus* is widely distributed in the Amazon and South America, occurring in great abundance in forest environments (Génier 2009). *Eurysternus caribaeus* is dominant in *várzea* forest habitats or forests constantly disturbed by periodical flooding (Escobar 2000; Scheffler 2005; Louzada et al. 2007), and is one of the few survivors in heavily disturbed forest fragments (Génier 2009). *Eurysternus wittmemorum* and *Eurysternus hamaticollis* are also common in *várzea* forests of the State of Rondônia (CEMT (unpublished entomological collection records)). Unlike the islands, some elements of the mainland are associated to primary or intact forests, e.g. *Onthophagus onthochromus* and *Oxysternon macleayi* (Scheffler 2005; Gardner et al. 2008). *Canthon aff. subhyalinus* is considered to depend on populations of *Allouatta* monkeys to occur (Padilla-Gill & Halffter 2007).

There are two important points about the taxonomic composition of the insular dung beetle fauna of Juruena River Islands. First, it is dominated by elements commonly found in *várzea* forests, forest edges, gaps or clearings in the Amazon. The species found in the *várzea* forest are strong evidence that flooding plays an important role in defining some aspects of these communities. In addition, the presence of species associated with edges or clearings indicates that the insular habitats are constantly being disturbed. This is also shown by the absence of elements from primary forest, found on the mainland (both in our study and in Vaz-de-Mello, Silva, et al. 2011).

Secondly, there is a complete absence of *Deltochilum* and *Eurysternus* species among the insular fauna. Some *Eurysternus* species, e.g. *E. caribaeus*, are among the only survivors at heavily disturbed habitats in almost every forest of the Neotropics (Génier 2009; pers. obs.; CEMT (unpublished entomological collection records)), so an explanation based on disturbance restricting the presence of *Eurysternus* can be discarded. Therefore, when an island is formed, competition is probably one of the main predictors of community, mainly due to the inevitable decrease of available resources (MacArthur & Wilson 1967). In addition, the capability to arrive or disperse through the insular system should also be taken into

account, mainly if we consider the notable variability of hind wing among species of the same genus, for example (Génier 2000; Nunes & Vaz-de-Mello 2013).

In our work, the taxonomic composition indicates that flooding events and associated habitat disturbance, resource competition, differential dispersal capabilities and primate occurrence are the main processes defining the dung beetle communities at some islands in Juruena River.

We are very interested in the dynamics of the factors that define insular dung beetle communities. Each island represents a different ecological and evolutionary context. For instance, if an island is formed due to silt deposition (e.g. Osterkamp 1998; Wyrick & Kinglemann 2011), it has to be colonized, so dispersal power may be essential in the definition of local communities. The situation is very different if an island is formed due to erosion of a land mass and the opening of a channel (Osterkamp 1998; Wyrick & Kinglemann 2011). In this case, there is already an active community, so competition and the capability to live in a disturbed habitat would be decisive processes. Even considering islands with the same origin and age, the presence of an *Allouatta* (primate) population in one of the islands would change the dung beetle community in few years.

We recommend that the investigation of these interesting ecological and evolutionary contexts requires a previous knowledge of the studied community as well data concerning the age, mode of formation (Osterkamp 1998; Wyrick & Kinglemann 2011) and mammal species present on the islands.

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