Entomological Science (2017) doi: 10.1111/ens.12284

ORIGINAL ARTICLE

Diversity of Cetoniidae (Insecta: Coleoptera) in the Cerrado of Central Brazil

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Abstract

Cetoniidae is a diverse family containing approximately 4,000 species, most of which feed on flowers and fruits. In Brazil, 72 species and 24 genera are recorded. Little is known about this family in the Central region of Brazil, and no research has previously been conducted in the ecologically important Cerrado biome. In this study, we evaluated the diversity and temporal variation of the Cetoniidae in an area of the Cerrado in the Federal District (Brazil) and verified whether the abundance and species richness were influenced by climatic variables. The study was carried out in an area of Cerrado *sensu stricto* at Água Limpa Farm in Brasília/DF. Beetles were collected weekly from October 2013 to September 2014 using 40 traps baited with banana and pineapple fermented with sugarcane juice. A total of 398 specimens comprising 8 genera and 15 species were collected. We observed temporal variation in abundance and richness of the Cetoniidae in direct relation to the climatic characteristics of the Cerrado, with a greater number of individuals and species appearing in the rainy season. Climatic variables such as temperature and humidity appear to have a significant effect on the diversity of Cetoniidae. This is the first study conducted on this family in Central Brazil.

Key words: baited trap, Cetoniinae, fermented fruit, flower beetles, species richness, Trichiinae.

INTRODUCTION

Cetoniine beetles (Coleoptera: Scarabaeoidea: Cetoniidae) are known as fruit or flower beetles. There are approximately 4,000 species of Cetoniidae in the world (Krikken 1984; Krajcik 1999), 300 of which occur over the North and South American continents (Orozco 2012). In Brazil, 72 species have been reported, distributed across five tribes and 24 genera (Puker *et al.* 2014a). Adults range from 0.5 to 15.0 cm in length and are bright colored with patterned textures (Kumbhar *et al.* 2012). They feed diurnally on nectar, pollen, exudates, and fruits (Krikken 1984), and fly long distances in search of food and other resources (Le Gall 2010). They can be found in flowers and ripe fruits, and many species are easily collected using traps baited with fermented fruits (Pacheco *et al.* 2006; Rodrigues *et al.* 2013). Larvae and adults of this family play important roles in ecosystems. In many species, adults are considered pollinators (Singer & Cocucci 1997; Micó & Galante 1998; Peter & Johnson 2009). The larvae are important decomposers, developing in decaying vegetable matter, feces and rotting tree trunks, modifying chemically and physically the substrate and facilitating the development of other saproxylic species (Arce-Perez & Morón 1999; Micó & Galante 2003; Micó *et al.* 2011; Sánchez-Galván *et al.* 2014). In some species of Cetoniidae the larvae live associated with social insects (Krikken 1984; Micó *et al.* 2000; Peter & Johnson 2009; Puker *et al.* 2012).

Although some authors have considered this group to be a subfamily of Scarabaeidae, phylogenetic analyses and morphological characters have confirmed the group's monophyly and their status as a family (Micó *et al.* 2008; Cherman & Morón 2014). Currently, Cetoniidae is divided into four subfamilies: Cetoniinae, Trichiinae, Valginae, and Osmodermatinae (Cherman & Morón 2014). A few studies have been

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Received 18 January 2017; accepted 10 August 2017.

conducted on the phenology, population dynamics, habitat associations, and use as ecological indicators (Donaldson 1981; Thomas 1993; Morón 1995; Bouyer *et al.* 2007).

In Brazil, studies have mainly provided descriptions of life stages and species diversity (Vanin & Costa 1984; Ratcliffe & Deloya 1992; Micó *et al.* 2000, 2001; Ratcliffe & Micó 2001; Gonçalves & Louzada 2005; Ratcliffe 2005, 2010, 2011; Orozco 2012; Puker *et al.* 2012), and most of these studies were carried out in the Southern and Southeastern regions of the country. Two further studies were carried out in the Midwest region and nine species were reported (Garcia *et al.* 2013; Rodrigues *et al.* 2013). However, there is no information about this group in the Cerrado of Central Brazil.

The Cerrado biome presents three vegetation environments (forest, savannah, and campestral) in which at least 14 phytophysiognomies occur (Ribeiro & Walter 2008). These phytophysiognomies have different characteristics with regard to the composition of plant species and microclimate. The climate of the Cerrado alternates between well-defined dry and rainy seasons (Silva *et al.* 2008). This seasonal alternation and local vegetation environment are considered to be the main mechanisms regulating abundance, species richness, and behavior of insects (Oliveira & Frizzas 2008; Silva *et al.* 2011). Due to the importance of the Cerrado as a biome with unique characteristics, the threats caused by the increase in agricultural exploitation (Brannstrom *et al.* 2008) and the existence of few areas of conservation, studies on Cetoniidae as diversity indicators could be important in the conservation of this particular biome because of the important functional roles of cetoniid species.

The objective of this study is to evaluate the diversity and temporal variation of Cetoniidae in a Cerrado area (cerrado *sensu stricto*) and to examine whether the abundance and richness of species are influenced by climatic variables. We hypothesize that Cerrado areas, in spite of the low relative density of plant species there, harbor considerable diversity of Cetoniidae. The climate of this biome, with the alternation of dry and rainy seasons varying fruit and flower availability, regulates the populations of these insects and has direct effects on the seasonality of this group of organisms.

MATERIALS AND METHODS

Study area

The study was carried out at Água Limpa Farm (FAL) in Brasilia, Federal District (Brazil) in an area of 1.1 ha of cerrado *sensu stricto* (15°57′24.38″S, 47°56′42.86″W, 1,096 m). The collection site is located in the Primatology area belonging to the University of Brasilia (UnB), comprising 4,500 ha as a part of the Environmental Protection Area (APA) of the "Gama" and "Cabeça de Veado" basins. We chose the cerrado *sensu stricto* (savannah formation) because it presents a large number of fruit species, the main diet of Cetoniidae, and because it has a lower density of trees per unit area compared to forest formations, facilitating easier handling of flight-adept specimens. Climatic data, including temperature, humidity and precipitation, were obtained through the AgroClima Bulletin provided by the Faculty of Agronomy and Veterinary Medicine of University of Brasilia (FAV/UnB), which maintains an experimental area of agroclimatology at Água Limpa Farm (Fig. 1).

Cetoniidae sampling

Adult collection was performed weekly for 12 months, from October 2013 to September 2014, using 40 baited traps that remained uninterrupted in the field. The trap consisted of a 2-L cylindrical plastic bottle with three 8 × 8 cm side windows located 10 cm above the base. Bait (150 mL) consisting of banana or pineapple fermented for 48 h in sugarcane juice was placed in each trap, as per Rodrigues *et al.* (2013) and Puker *et al.* (2014a). A half of the traps used banana-based bait and the other half used pineapple-based bait. The traps were placed in trees about 1.5 m above ground level, distributed along four 80 m transects spaced 20 m apart. Care was taken to avoid edge effects by beginning transects at least 20 m from the entry point into the experimental area.

After collection, the insects were taken to the Laboratory of Entomology of the University of Brasilia, and cetoniid beetles were separated from other insects. Species were identified by one of the authors (FZVM). Vouchers of the collected material are deposited in the Entomological collections of the Department of Zoology of the University of Brasilia and the Department of Biology and Zoology of the Federal University of Mato Grosso.

Data analyses

The experimental design presents pseudo-replicates. Therefore, the Rayleigh Uniformity test, which analyzes the functional relationship of variables under a concept of dimensional homogeneity (Mendoza 1994), was used to analyze temporal variation data. Circular analysis was used to examine the abundance and richness of species in the different months of the year (Agostinelli & Lund 2013). In order to verify whether the abundance and richness of species are influenced by

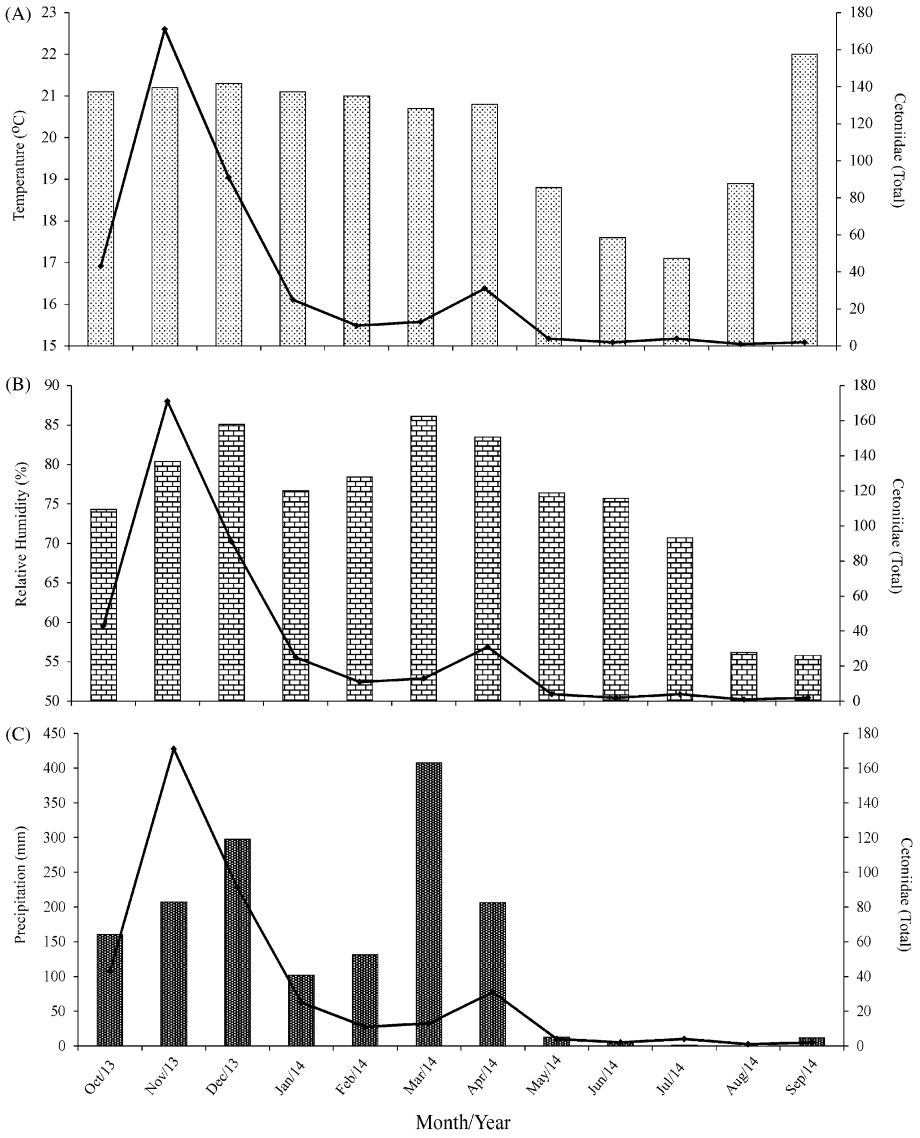

Figure 1 (A) Average monthly temperature (°C) (▭), (B) average monthly relative humidity (%) (▭), (C) monthly total precipitation (mm) (▩), and (—◆—) abundance of Cetoniidae collected at Água Limpa Farm in Brasília/DF in fruit-baited traps, October 2013 – September 2014.

the climatic variables (temperature, humidity and precipitation), analysis of covariance (ANCOVA) was used, with Simpson's diversity as a response variable and climate variables as covariates. To verify the efficiency of the sampling effort in relation to the survey of Cetoniidae diversity, species accumulation curves were constructed based on the number of samplings and number of individuals, using the Jacknife 1 index and 1,000 randomizations. All analyses were performed using R version 3.2.3 (R Core Team 2016) and Oriana (Kovach 2011).

RESULTS

Species accumulation curves, based on the number of samplings and the number of individuals observed approached the asymptote, indicating that the sampling effort was adequate to characterize the local community of Cetoniidae attracted by fermented fruit baits (Fig. 2).

We collected 398 specimens, comprising 8 genera and 15 species, over 50 collection dates. The most abundant species were *Gymnetis rufilateris* (Illiger), comprising 34.4% of the total collected specimens, *Gymnetis hebraica* Drapiez at 33.2%, and *Inca bonplandi* (Gyllenhall) at 13.1% (Fig. 3).

In the pineapple-baited traps, 213 individuals were collected, comprising 13 species. In the banana-baited traps, 185 individuals were collected, comprising 13 species. Eleven of these species were common to both types of baits. *Gymnetis* sp. and *Hologymnetis undulata* Vigors were collected only in banana-baited traps and *Gymnetis rubrocincta* Schürhoff and

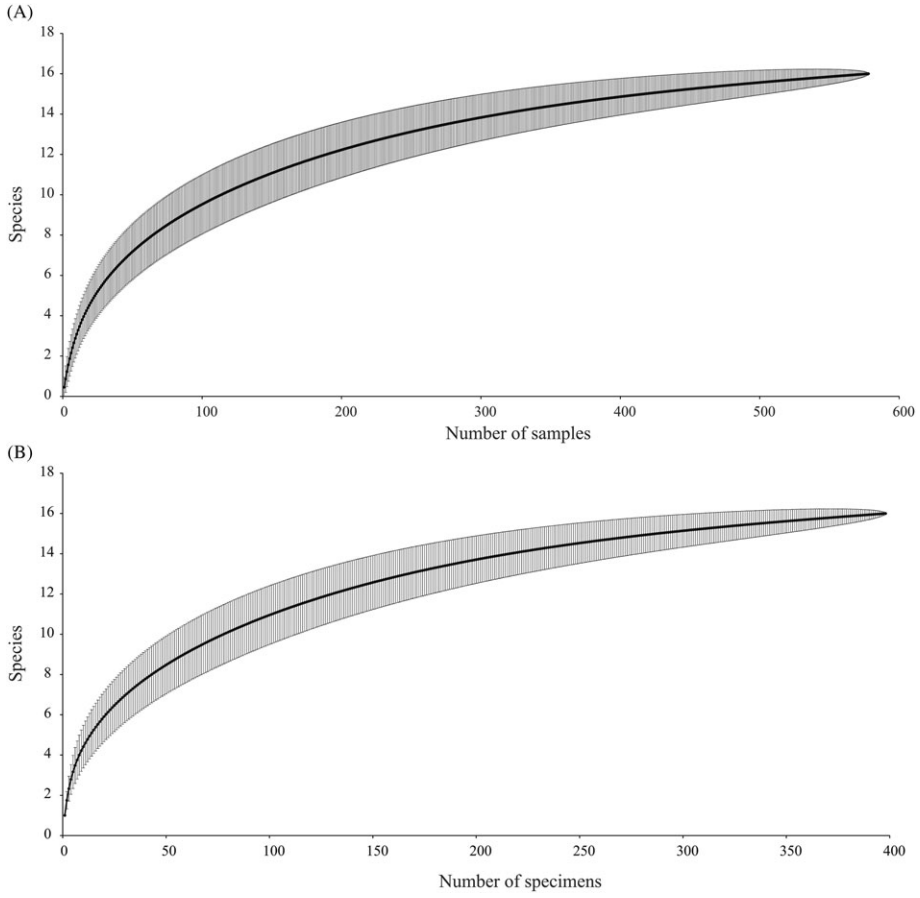

Figure 2 Species accumulation curves of Cetoniidae collected at Água Limpa Farm in Brasília/DF in fruit-baited traps, October 2013 – September 2014, as (A) a function of number of samples (1,000 randomizations) and as (B) a function of the number of individuals (1,000 randomizations). Bars below and above the curves indicate standard deviations.

Marmarina maculosa Olivier were collected only in the pineapple bait.

Cetoniid beetles were collected across all months of the year. The highest abundance (171 individuals) and richness (14 species) was observed in November, while the lowest abundance (1 individual) and richness (1 species) was observed in August. In the rainy season (October to March), 354 individuals (88.9% of the total collected) and 15 species were collected. In the dry period (April to September), 44 individuals (11%) and 5 species were collected (Fig. 3). With the exception of *G. hebraica*, which was collected throughout the year, most species were concentrated in the rainy season. Although April technically falls within the dry season, it represents a transitional period, and 31 individuals and 5 species were collected during this period. Between June and September only *G. hebraica* was collected. Using circular analysis, we identified similarity in the richness and abundance of the collected Cetoniidae (Fig. 4). Peak abundance and richness occurred in the month of November (290°). Although the abundance showed a well-defined peak in November, richness was more evenly distributed throughout the year, but was still concentrated in the rainy season. Using the Rayleigh Uniformity test, we found that there was a significant temporal variation for the abundance and richness of Cetoniidae ($P < 0.0001$). Using ANCOVA, we observed that the three climatic variables were correlated with Cetoniidae diversity, but only temperature and humidity had significant statistical effects on the diversity (Table 1).

Table 1 ANCOVA test for correlation between climatic variables and diversity of Cetoniidae (Simpson index) collected at Água Limpa Farm in Brasília/DF with fruit-baited traps, October 2013 – September 2014

Variable	D.F.	Mean	F-value	*P*
Temperature	1	2.97310353	24.94	<0.0001
Precipitation	1	0.00997493	0.08	0.7725
Relative humidity	1	2.78754018	23.38	<0.0001

DISCUSSION

In Brazil, the family Cetoniidae is currently represented by 72 species and 24 genera (Puker *et al.* 2014a). In the present study, 15 species belonging to 8 genera were

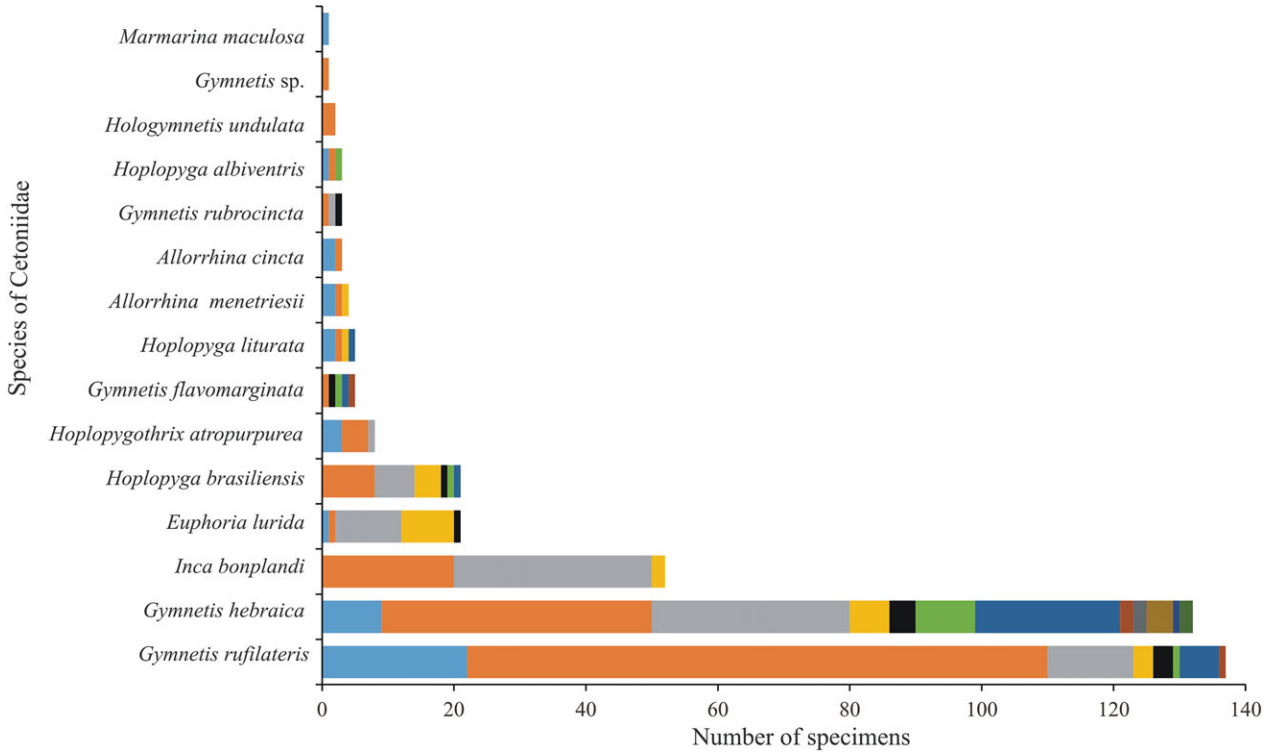

Figure 3 Species of Cetoniidae collected using fruit-baited traps in an area of Cerrado *sensu stricto* at Água Limpa Farm in Brasília/DF, October 2013 – September 2014. Rainy season: (■) October, (■) November, (■) December, (■) January, (■) February, and (■) March. Dry season: (■) April, (■) May, (■) June, (■) July, (■) August, and (■) September.

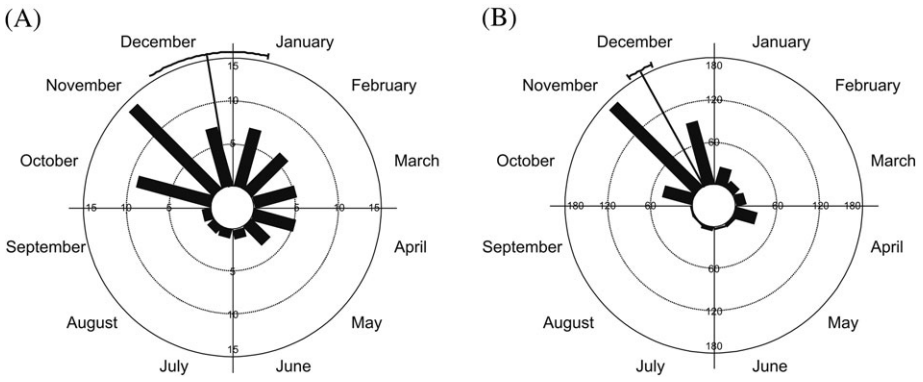

Figure 4 Circular analysis for (A) richness and (B) abundance of Cetoniidae collected at Água Limpa Farm in Brasília/DF in fruit-baited traps, October 2013 – September 2014.

collected, indicating that the cerrado *sensu stricto* of the Federal District contains at least 20.8% of the species and 33.3% of the known genera in the country. The diversity of Cetoniidae obtained using pineapple (13 species and 215 individuals) and banana (13 species and 185 individuals) baits was high and similar, suggesting that these baits are suitable for studies on this group of insects. These baits have been used in several studies on Cetoniidae (Morón 1995; Gonçalves & Louzada 2005; Pacheco *et al.* 2006; Rodrigues *et al.* 2013; Puker *et al.* 2014a). The present study is the most comprehensive among those ever conducted in Brazil to investigate the diversity of this family. The results suggest that the central region of Brazil harbors a fauna comparatively rich in Cetoniidae.

The Brazilian Cerrado has approximately 44% of its endemic flora, representing the most diverse savannah of the planet (Klink & Machado 2005). It contains several endemic fruiting species with rich nutrients and diverse flowers. The Cerrado also has a great diversity of social insects such as ants and termites (Constantino & Acioli 2006; Marques & Del-Claro

2006), allowing that some species of Cetoniidae develop in the nests of these social insects (Puker *et al.* 2012, 2014b), for example, two species, *Hoplopyga albiventris* Gory & Percheron and *Hoplopyga brasiliensis* (Gory & Percheron), whose larvae develop in nests of social insects, were collected, representing 13.3% of the registered species. These factors affect the community of Cetoniidae positively in the biome. However, 64 studies conducted between 1982 and 2012 on Scarabaeoidea diversity in the Cerrado showed that only two focused on Cetoniidae in spite of the ecological importance of adults and larvae of this family (Luçardo *et al.* 2014). More recently two studies, using a methodology similar to that adopted in the present study, approached in an exploratory way this family in Brazil. Nine species of Cetoniidae were found in the Pantanal biome (Mato Grosso do Sul state) (Rodrigues *et al.* 2013), and five species were collected in the Atlantic Forest biome (Minas Gerais state) (Gonçalves & Louzada 2005; Puker *et al.* 2014a). Although there are few studies done with this family in Brazil, the species richness found in the Cerrado is greater than that reported from any other biome. However, due to the great territorial extension of the country, which contains several biomes with numberless conditions of relief, vegetation and climate, coupled with the scarcity of studies on these organisms, the fauna of Cetoniidae may be still underestimated.

Two species (*Gymnetis flavomarginata* Blanchard and *G. rubrocincta*) are reported here for the first time from the Cerrado. *Inca bonplandi*, the third most abundant taxa, is of Trichinae whose larvae develops in rotten trunks. Adults of the genus *Inca* have been observed feeding on the sap flows and rotting fruit (Boos & Ratcliffe 1985). The adults of most of the collected species are concentrated in the rainy season and beginning of the dry season (April/May), a period with ample food availability, mainly flowers and/or fruits. *Gymnetis hebraica* was the second most abundant species and the only one collected throughout the year. This species is an ecological generalist distributed widely. Most of cetoniid larvae can develop in organic matter, animal feces, humus and rotting trunks as observed in *I. bonplandi*, *G. flavomarginata*, *G. rufilateris*, *Hoplopyga liturata* Olivier and *M. maculosa* (Ritcher 1966; Morón 1983; Costa *et al.* 1988; Gara & Onore 1989; Arce-Perez & Morón 1999; Morón & Arce 2002; Neita-Moreno *et al.* 2006; Rodrigues *et al.* 2016). Some species such as *H. albiventris* and *H. brasiliensis*, however, inhabit nests of social insects, mainly termites (Luederwaldt 1911; Puker *et al.* 2012). Adults of many species such as *G. flavomarginata*, *G. rufilateris*, *H. albiventris*, *H. liturata*, *Allorrhina cincta* Gory & Percheron and *Allorrhina menetriesii* (Swederus), generally, feed on rotten or ripe fruits or plant sap (Luederwaldt 1911; Morón 1995; Arce-Perez & Morón 1999; Di Iorio 2014; Ratcliffe 2015; Rodrigues *et al.* 2016). Adults of *Euphoria lurida* Fabricius have been reported as a pest of some crops such as citrus and corn (Bertels & Baucke 1966; Garcia *et al.* 1993). There is no information on the habits of adults or larvae of *H. undulata, G. rubrocincta* and *Hoplopygothrix atropurpurea* Schaum. The great diversity of habits presented by the Cetoniidae species collected in this study demonstrates the ability of the Cerrado to provide food resources, shelter and breeding sites for supporting the high species richness of this family, and reinforces the need for the conservation of this important biome.

We observed that temporal variation of abundance and richness in the Cetoniidae seems to be directly related to the climatic characteristics of the Cerrado, with greater numbers of individuals and species appearing in the rainy season (Fig. 3). For most insects, population dynamics is directly influenced by abiotic factors, among which the distribution of rainfall seems to be of greatest importance. This factor directly influences changes in temperature and relative humidity, and indirectly affects the growth of plants as food sources for herbivores (Oliveira & Frizzas 2008; Silva *et al.* 2011). In the central region of Brazil, rainfall distribution follows a pattern where approximately 87% (1,212 mm) of the rainfall volume occurs between October and March and 13% (185 mm) occurs between April and September (Silva *et al.* 2008). Most insect species in this biome have their adult populations in the first half of the rainy season (Oliveira & Frizzas 2008; Silva *et al.* 2011). The greatest diversity (abundance and species richness) of adult Cetoniidae in the rainy season is likely due to the greater availability of food (sap flows, fruits and flowers) in the Cerrado during this period. In addition, rainfall has been indicated as a "trigger" for the resumption of the development in many groups of insects after periods of inactivity (i.e. diapause), leading to population increase, especially in regions where there is well-defined alternation between dry and rainy seasons (Wolda 1988; Oliveira & Frizzas 2008; Silva *et al.* 2011).

Temperature and humidity had significant effects on the diversity of Cetoniidae (Table 1). Temperature is one of the climatic variables that most influences the activity of many species of insects, determining the developmental rates at immature stages and reproductive activity of adults. Relative humidity also has a strong influence on the temporal variation of tropical insects, but less obviously than temperature. Many studies have failed to demonstrate direct correlations between temporal variations of insect populations and of relative humidity.

It is also important to highlight that the present study was carried out in only one type of cerrado phytophysiognomy (cerrado *sensu stricto*). If other phytophysiognomies are explored, more species of Cetoniidae should be recorded from the Cerrado, reflecting differences in vegetation cover among phytophysiognomies (open areas *vs*. more closed areas); the vegetation cover modifies environmental characteristics such as shade, retention of humidity, and consequently types of flowers and fruits as food sources for most of Cetoniidae species.

ACKNOWLEDGMENTS

We thank Drs Lee Dyer (University of Nevada, Reno) and André Rangel for assisting in statistical analysis, University of Brasilia and Graduate Program in Zoology, and Marcus Vinícius Celani Rocha for the great help in the field. FZVM is a CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico) fellow (302997/2013-0 and 306745/2016-0) and is granted by FAPEMAT (Fundação de Amparo à Pesquisa do Estado de Mato Grosso (PRONEM 568005/2014) and CNPq (405697/2013-9, 440604/2015-0, 484035/2013-4, 400681/2014-5).

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