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## Flight patterns and sex ratio of beetles of the subfamily Dynastinae (Coleoptera, Melolonthidae)



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### ABSTRACT

Dynastinae is one of the most representative subfamilies of Melolonthidae (Scarabaeoidea) and has considerable ecological importance due mainly to interactions with plants of the families Araceae and Annonaceae. This relationship has led to the evolution of nocturnal activity patterns, which are influenced by environmental conditions. In the present study, abiotic factors were investigated to comprehend the influence on the flight patterns and identify the sex ratio of beetles from this subfamily. A study was conducted at Campo de Instrução Marechal Newton Cavalcanti in northeastern Brazil between December 2010 and November 2011. Thirteen species of Dynastinae were identified, most of which were from the genus *Cyclocephala*. Abundance and richness were greater in the dry season. Six species exhibited peak flight activity at specific periods of the night. More females than males were recorded for *Cyclocephala distincta* and *C. paraguayensis*. The present findings suggest that rainfall reduces the flight activity of these beetles and different time schedules may be related to mating behavior, foraging behavior and the avoidance of interspecific resource competition.

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### Introduction

Dynastinae is one of the most remarkable subfamilies of Melolonthidae *sensu* Endrödi (1966). Beetles of this subfamily occur in nearly all major biogeographic regions and are mostly found in the tropics, especially the Neotropics (Ratcliffe, 2003). Adults feed on decomposed fruits, algae, plants roots (obtaining nutritive liquids), leaves, flowers and pollen (Jackson and Klein, 2006; Ritcher, 1958). Nearly all Dynastinae adults are either nocturnal or crepuscular (Ratcliffe, 2003; Riehs, 2006; Ratcliffe and Cave, 2009). Diurnal activity corresponds to the interval of time used for foraging and mating and is defined by the presence of sunlight (Pianka, 1973; Mañosa et al., 2004; Hernández, 2007; González-Maya et al., 2009). In general, peak activity in species is regulated by different factors (Hernández, 2007, 2002; Feer and Pincebourne, 2005; Gillet et al., 2010; Gerber et al., 2012). Predators and food sources, for instance, act as regulators of peak activity, leading to adaptations that result in the success and survival of organisms (Pianka, 1973; Dawkins and Krebs, 1979; Overdorff, 1988; Gill, 1991; González-Maya et al., 2009; Halffter and Halffter, 2009; Valera et al., 2011).

Nocturnal or crepuscular habits are associated with anthophilia, especially for Cyclocephalini (Endrödi, 1985; Gottsberger, 1999, 1986; Maia and Schindwein, 2006; Maia et al., 2012, 2010). The pollination of many tropical fruit trees that have night anthesis, such as *Annona* spp. (Annonaceae), palms (Arecaceae) and aroids (Araceae), is dependent on pollinating beetles, especially species of the genera *Cyclocephala* Latreille and *Erioscelis* Burmeister, which ensure the reproductive success of these trees (Endrödi, 1985; Gottsberger, 1986, 1999; Silberbauer-Gottsberger et al., 2003; García-Robledo et al., 2004; Croat, 2004; Maia and Schindwein, 2006; Ratcliffe, 2008, 2003; Maia et al., 2012, 2010).

In tropical rainforests, insect species are influenced by biotic and abiotic oscillations (Emmel and Leck, 1970; Wolda, 1989; Nair, 2007). Rainfall, food sources and predators exert an influence on the abundance of tropical insects (Wolda, 1988, 1978). Favorable environmental conditions facilitate the growth, reproduction and activity of these organisms (Tauber et al., 1986; Wolda, 1988).

Environmental conditions also exert an influence on the sex ratio of insects (Hamilton, 1967). In response to variations in environmental conditions, the sex ratio of the offspring varies due to changes in fitness (West and Sheldon, 2002). Depending on offspring competition of one sex with another and the parents, a tendency to produce the other sex occurs to avoid the effect of local resource competition (Taylor, 1994; Julliard, 2000). In poor-quality

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environments, parental individuals may increase fitness by biasing their offspring more toward a dispersing sex (Julliard, 2000).

Despite the importance of beetles of the subfamily Dynastinae as pollinators and their role in maintaining healthy edaphic ecosystems, few studies have addressed the biodiversity and natural history of these beetles, especially in the Atlantic Rainforest north of the São Francisco River Basin in northeastern Brazil. Thus, the aim of the present study was to determine the effects of rainfall of beetle communities of the subfamily Dynastinae and identify nocturnal flight activity and the sex ratio of the species collected. The hypotheses are that differences in abundance and richness occur between the dry and rainy seasons; peak flight activity is related to foraging behavior and the sex ratio denotes similar proportions of males and females.

## Material and methods

### Study site

This study was conducted in the municipality of Abreu e Lima (state of Pernambuco, northeastern Brazil) at the Campo de Instrução Marechal Newton Cavalcanti (CIMNC – 7°49′49.39″ S, 35°6′10.20″ W), which is a military site located in the Aldeia-Beberibe Environmental Protection Area, covering 30,000 ha (SEMAS, 2012) (Fig. 1A–C). The CIMNC is located 40 km NW of the coast and has a total of 7324 ha (Andrade et al., 2005; Lucena, 2009). Vegetation consists of open tropical rainforest and semi-deciduous forest, comprising secondary forest with a few remnants of primary forest (Andrade et al., 2005; Lucena, 2009; IBGE, 2012). This site was formerly a sugar cane mill that was intensively exploited until the establishment of the CIMNC in 1944 (Andrade et al., 2005; Lucena, 2009; Guimarães et al., 2012). It is currently preserved by the Brazilian Army (Lucena, 2009).

### Abiotic data

Daily and monthly rainfall indices from 2010 to 2011 were obtained from hydro-meteorological monitoring unit of the Laboratório de Meteorologia de Pernambuco (ITEP/HIDROMET, 2012). Historical mean rainfall and monthly mean temperature were obtained from the Abreu e Lima Station (ITEP/HIDROMET, 2012). Other temperature and humidity data were obtained at the

sampling point using a digital thermo hygrometer. Readings were taken on the sampling day between 5:00 pm and 5:00 am. Considering the historical precipitation index, the rainy season was defined as spanning from March to August (ITEP/HIDROMET, 2012).

### Insect sampling

Beetles of the subfamily Dynastinae were collected monthly from December 2010 to November 2011, except April 2011, due to intense rainfall that prevented access to the collection site. Sampling lasted 12 h and was performed every 30 days. The sample site was established at a distance of 30 m from the edge of the remnant of the Atlantic rainforest.

A light trap was installed to attract beetles from 5:00 pm to 5:00 am the following day. Black light (250 W) and mixed mercury vapor bulbs (250 W) were deployed on opposite sides of a white sheet measuring 2.3 m × 2.0 m, stretched at the collection point (Fig. 2A–C). The beetles were collected manually as they landed on the illuminated sheet.

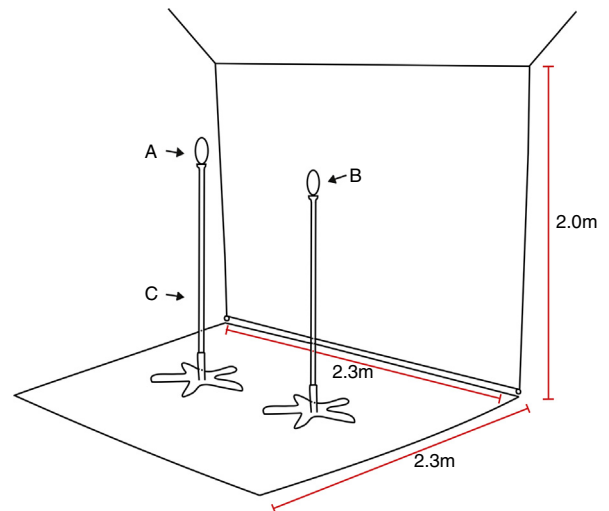


Fig. 2. Light trap model used for beetle sampling: (A) Black light bulb. (B) Mixed mercury bulb. (C) Light support.

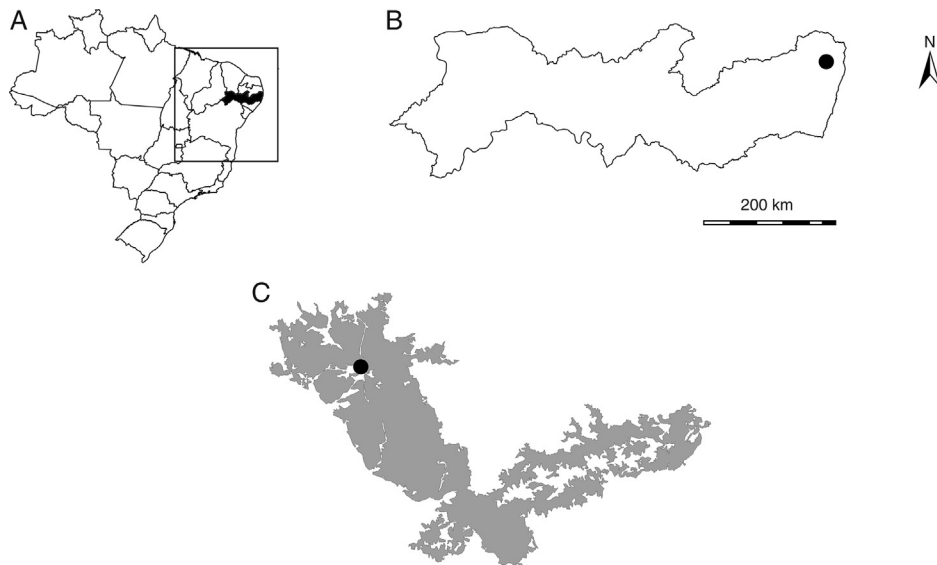


Fig. 1. Map showing sampling site: (A) Pernambuco State represented in black. (B) Black dot representing Campo de Instrução Marechal Newton Cavalcanti, Abreu e Lima, Pernambuco, Brazil. (C) Black dot representing sampling site at Marechal Newton Cavalcanti, Abreu e Lima, Pernambuco, Brazil.

**Table 1**  
Total and relative abundance of nocturnal species of Dynastinae (Coleoptera, Melolonthidae) at Campo de Instrução Marechal Newton Cavalcanti over one year of collection (2010–2011).

Tribe	Species	Abundance	Relative abundance (%)
Cyclocephalini	<i>Cyclocephala cearae</i> Höhne, 1923	19	4.2
Cyclocephalini	<i>Cyclocephala distincta</i> Burmeister, 1847	266	58.3
Cyclocephalini	<i>Cyclocephala paraguayensis</i> Arrow, 1913	63	13.8
Cyclocephalini	<i>Cyclocephala vestita</i> Höhne, 1923	2	0.4
Cyclocephalini	<i>Dyscinetus dubius</i> (Olivier, 1789)	27	6
Cyclocephalini	<i>Dyscinetus rugifrons</i> (Burmeister, 1847)	10	2.2
Cyclocephalini	<i>Chalepides</i> sp.	1	0.2
Cyclocephalini	<i>Stenocrates holomelanus</i> (Germar, 1824)	28	6.1
Pentodontini	<i>Eutheola humilis</i> (Burmeister, 1847)	1	0.2
Pentodontini	<i>Tomarus ebenus</i> (De Geer, 1774)	10	2.2
Pentodontini	<i>Ligyris (Ligyris) cuniculus</i> (Fabricius, 1801)	27	6
Oryctini	<i>Strategus validus</i> (Fabricius, 1775)	1	0.2
Oryctini	<i>Coelosis bicornis</i> (Leske, 1779)	1	0.2
<b>Total</b>		<b>456</b>	<b>100</b>

For each hour of collection, a killing jar (polypropylene jar with ethyl acetate) was used to record of flight period. The samples were taken to laboratory of Taxonomia e Ecologia de Insetos of the Universidade Federal de Pernambuco for taxonomic identification. Abiotic data, abundance, richness and flight period were pooled for the subsequent analyses. Voucher specimens were deposited in Coleção Entomológica da UFPE (CE-UFPE).

#### Data analysis

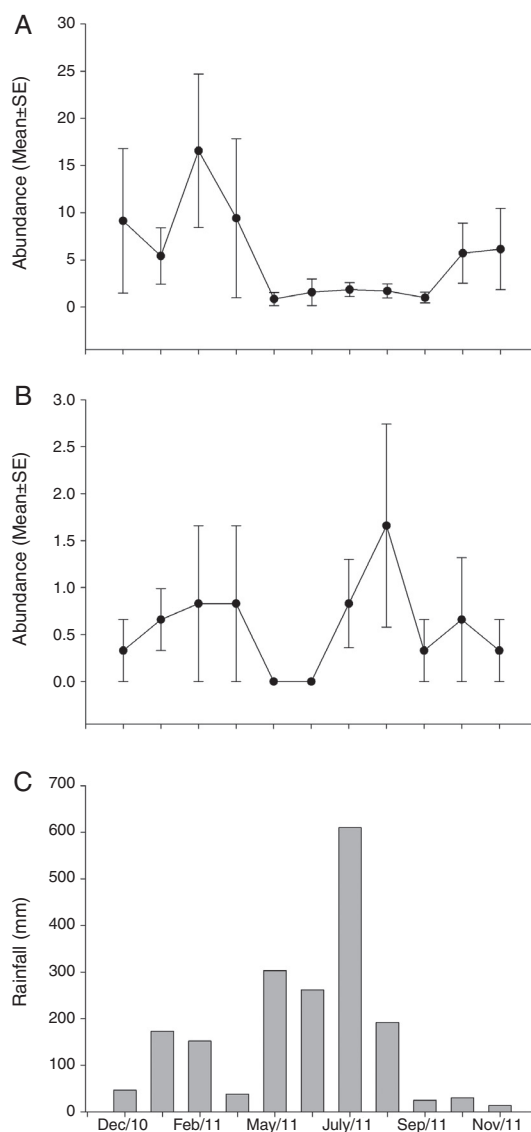
The abundance and richness of the species of Dynastinae sampled in the dry and rainy seasons were compared using one-way ANOVA test with the aid of the STATISTICA 7.0 program (StatSoft, 2004), with significance level set at 5% ( $p < 0.05$ ). Tukey's test was employed for the post hoc evaluations. Abundance and richness values were transformed to LOG + 1. For the determination of sex ratios, differences between males and females were tested using the chi-square ( $\chi^2$ ) test for each species with the aid of the BioEstat 5.0 program (Instituto Mamirauá, 2007). Spearman correlation analysis was performed, with R 3.1.1 program, between rainfall and the most abundant species found (R Development Core Team, 2014). Circular statistics were performed for the flight period with the aid of the ORIANA program, considering the most abundant species ( $n \geq 10$ ) (Kovach Computing Services, 2004).

#### Results

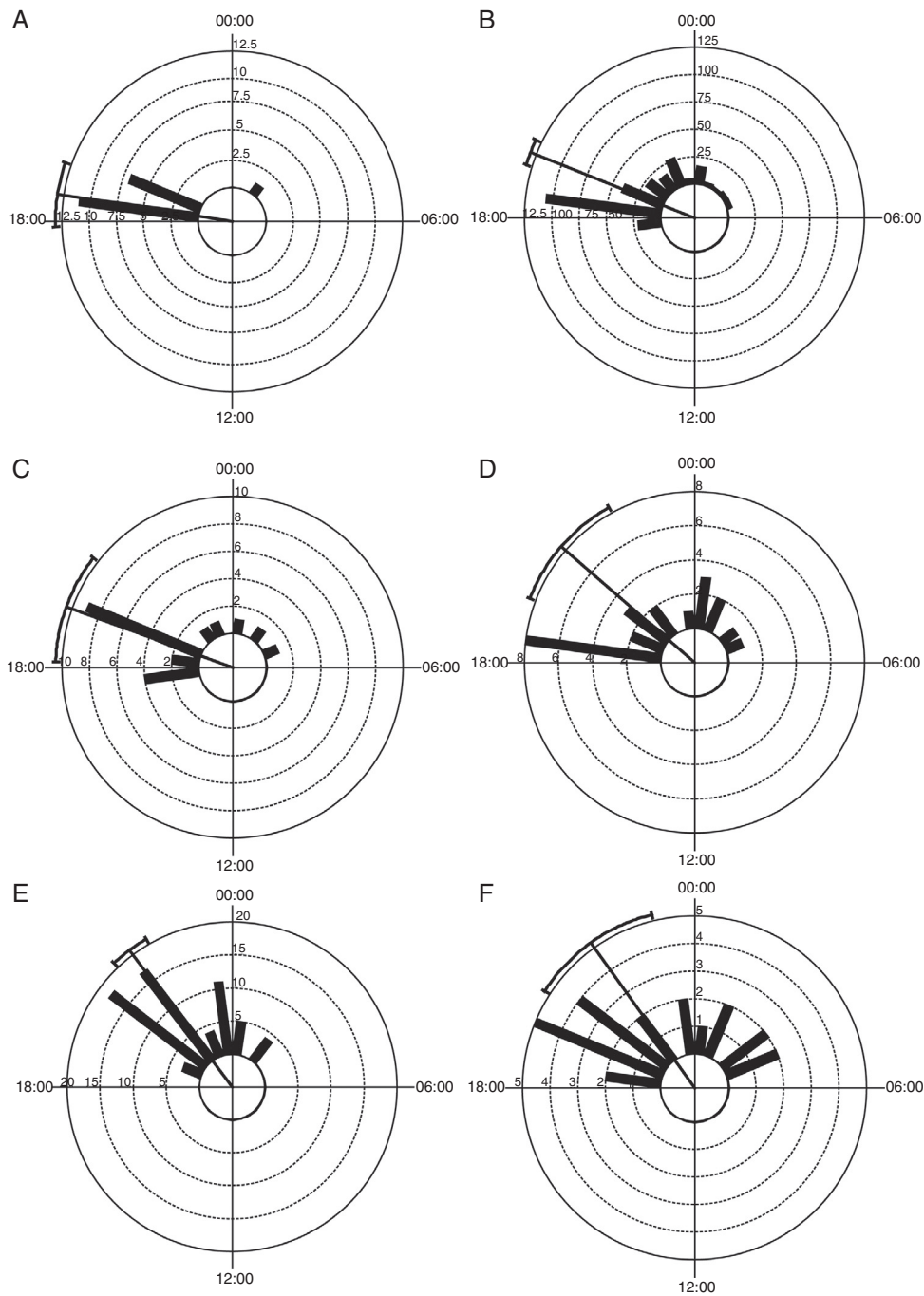
A total of 456 specimens of Dynastinae belonging 13 species, eight genera and four tribes were collected. The most representative tribe was Cyclocephalini, with eight species (approximately 62% of total richness) and 416 specimens (approximately 91% of total abundance) (Table 1), followed by Pentodontini (three species and 38 specimens) and Oryctini (two species and two specimens). *Cyclocephala* Latreille was the most abundant and richest genus, accounting for approximately 31% of the species recorded. *Cyclocephala distincta* Burmeister contributed to the majority of specimens (approximately 58%), followed by *C. paraguayensis* Arrow, which was the second most abundant species.

Significant differences in abundance were found among the sampling months ( $F = 4.75$ ;  $df = 10$ ;  $p < 0.001$ ). The post hoc tests revealed greater abundance in the dry season. Likewise, richness values were significantly higher ( $F = 3.95$ ;  $df = 10$ ;  $p < 0.001$ ) in the dry season.

Rainfall caused greater effect in Cyclocephalini beetles, when compared to Pentodontini (Fig. 3A–C). Species from both tribes had greater abundance during the dry season and beginning of rainy season, however Pentodontini had higher abundances in the



**Fig. 3.** Rainfall effect in the most abundant tribes of Dynastinae (Melolonthidae), during one year of collection using light trap at Campo de Instrução Marechal Newton Cavalcanti, Abreu e Lima, PE, Brazil: (A) Mean abundance of Cyclocephalini beetles, recorded monthly, between December 2010 and November 2011 (except April 2011). (B) Mean abundance of Pentodontini beetles, recorded monthly, between December 2010 and November 2011 (except April 2011). (C) Rainfall, recorded monthly, between December 2010 and November 2011 (except April 2011).



**Fig. 4.** Circular histogram showing peak flight activity of: (A) *Cyclocephala cearae*; (B) *C. distincta*; (C) *Dyscinetus dubius*; (D) *Stenocrates holomelanus*; (E) *C. paraguayensis*; (F) *Ligyris (Ligyris) cuniculus*, during one year of collection using light trap at Campo de Instrução Marechal Newton Cavalcanti, Abreu e Lima, PE, Brazil. Black line = mean vector and confidence interval.

beginning and by end of the rainy season, then an abrupt decrease in the beginning of the dry season. On the other hand, Cyclocephalini had a decrease of abundance after the beginning of the rainy season, maintaining that until the beginning of the dry season.

Regarding flight period, six species, which were the most abundant, were divided in two groups. The first group exhibited flight activity from 6:00 to 8:00 pm and included *Cyclocephala cearae*, *C. distincta* and *Dyscinetus dubius*, with significant peak flight activity at 6:35 pm ( $r=0.919$ ;  $p<0.001$ ) (Fig. 4A), 7:27 pm ( $r=0.818$ ;  $p<0.001$ ) (Fig. 4B) and 7:19 pm ( $r=0.67$ ;  $p<0.001$ ) (Fig. 4C), respectively. The second group exhibited flight activity from 8:00

to 10:00 pm and included *Stenocrates holomelanus*, *Cyclocephala paraguayensis* and *Ligyris (Ligyris) cuniculus*, with significant peak flight at 8:44 pm ( $r=0.698$ ,  $p<0.001$ ) (Fig. 4D), 9:32 pm ( $r=0.895$ ,  $p<0.001$ ) (Fig. 4E) and 9:37 pm ( $r=0.67$ ,  $p<0.001$ ) (Fig. 4F), respectively. The  $\chi^2$  results revealed that the sex ratio of *Cyclocephala distincta* and *C. paraguayensis* differed significantly, with females occurring in greater abundance than males (Table 2).

Regarding the four most abundant species, just *Ligyris (Ligyris) cuniculus*, had sex ratio positively influenced by rainfall (0.68,  $p=0.01$ ) (Fig. 5A), unlike *Cyclocephala distincta* ( $-0.1$ ,  $p=0.75$ ) (Fig. 5B), *C. paraguayensis* (0.21,  $p=0.52$ ) (Fig. 5C), and *Tomarus ebenus* (0.32,  $p=0.33$ ) (Fig. 5D).

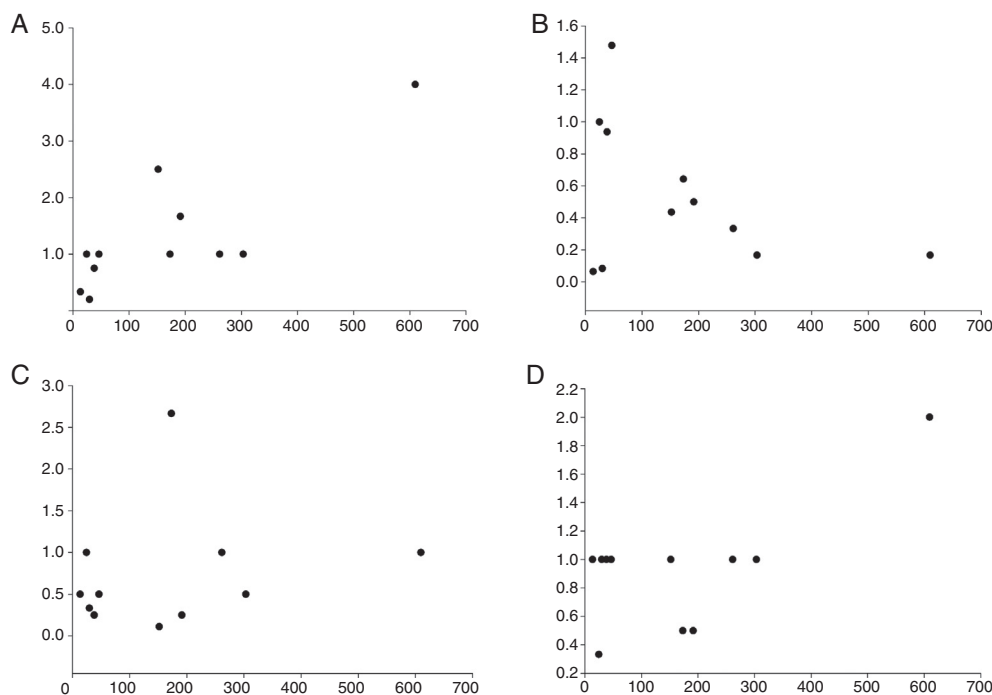


Fig. 5. Spearman correlation between sex ratio and rainfall of: (A) *Cyclocephala distincta*; (B) *C. paraguayensis*; (C) *Tomarus ebenus*; (D) *L. (Ligyris) cuniculus*.

Table 2

Sex ratio of nocturnal species of Dynastinae (Coleoptera, Melolonthidae) at Campo de Instrução Marechal Newton Cavalcanti, during over one year of collection (2010–2011).

Species	Females	Males	$\chi^2$	<i>p</i>
<i>Cyclocephala cearae</i> Höhne, 1923	14	5	4.26	0.066
<i>Cyclocephala distincta</i> Burmeister, 1847	176	90	27.80	<0.001
<i>Cyclocephala paraguayensis</i> Arrow, 1913	50	12	23.29	<0.001
<i>Dyscinetus dubius</i> (Olivier, 1789)	10	10	0	1
<i>Stenocrates holomelanus</i> (Germar, 1824)	13	10	0.39	0.676
<i>Ligyris (Ligyris) cuniculus</i> (Fabricius, 1801)	9	13	0.72	0.522

## Discussion

The present findings indicate that the activity of the Dynastinae community in northeastern Brazil is influenced by rainfall and that some species have specific periods of flight. Furthermore, the group of species belonging the Cyclocephalini tribe was predominant.

Cyclocephalini, the most representative in the present study, is a diverse tribe in the Neotropical region. This group has also been very representative in surveys of Dynastinae beetles conducted in the Amazon region (Andreazze and Fonseca, 1998; Andreazze, 2001; Andreazze and Motta, 2002) and has also been recorded in agro-ecosystems near remnants of the Atlantic Rainforests as well as other rainforests, with some species considered agricultural pests due to the fact that these beetles feed on root systems (Morón, 2001; Pereira and Salvadori, 2006; García-López et al., 2012, 2010). *C. distincta* was the most abundant among the species of this tribe recorded herein. This may be explained by its adaptation to environmental disturbances and the exploitation of new trophic niches, as observed for other species of this genus in the Amazon (Andreazze and Fonseca, 1998). *C. distincta* is widely distributed throughout South America (Endrödi, 1985).

For Cyclocephalini, and *Cyclocephala cearae* especially, the present findings are congruent with emissions of floral scents from *Taccarum ulei* Engl. & K. Krause (Araceae), as the species has been identified as a pollinator of this plant species (Maia et al., 2013). Such nocturnal habits, and period of activity, may be

associated with the cantharophilous pollination of species of Araceae and Annonaceae, which provide special chambers and exudates for feeding and mating (Maia and Schlindwein, 2006; Cavalcante et al., 2009; Maia et al., 2010, 2013). Due to this relationship, some groups have evolved flight periods that are similar to the flowering time of their preferential host plants (Maia and Schlindwein, 2006; Maia et al., 2010). The considerable abundance of *C. distincta* in the present study may be explained by visitations to the flowers of plants of the genus *Attalea* Kunth (Araceae) found in the CIMNC (Voeks, 2002; Lucena, 2009), in which this species mates and forages.

Only two species in the present study exhibited a greater abundance of females than males, differing from the expected 1:1 ratio. Females are known to spend more time foraging and looking for ideal oviposition sites, which may explain this phenomenon (Bedford, 1975).

The Atlantic rainforest, especially in northeastern Brazil, has been suffering from human actions over the past 516 years that have resulted in homogenization of the system (Lôbo et al., 2011). Thus, some species of Dynastinae species may respond to this situation through female dispersal. Another possibility is the adversity caused by high moisture content in the soil in the rainy season. As seen in *Phyllophaga crinita* (Burmeister, 1855) (Melolonthidae: Melolonthinae) (Gaylor and Frankie, 1979), *Cyclocephala distincta* females may remain above ground under such conditions. However, this is not the pattern for *C. immaculata* (Olivier, 1789) (= *C. lurida* Bland, 1863), for which more males than females have been recorded in the field (Potter, 1980), which is likely due to the different perception of the light between sexes (Potter, 1980). Nevertheless, Neiswander (1938) found that natural populations of species of *Cyclocephala* have a sex ratio of 1:1.

## Conclusion

Based on the present findings, we consider that the Dynastinae community is influenced by the rainfall. Furthermore, flight activity has temporal segregation for some species of the subfamily.

## Conflicts of interest

The authors declare no conflicts of interest.

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