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POPULATION SEASONAL VARIATION OF *Gracilinanus agilis* (MAMMALIA: DIDELPHIDAE) IN SEMI-DECIDUOUS FOREST FRAGMENTS

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ABSTRACT. Population fluctuations of small tropical mammals are often related to temporal and environmental variations in resource availability. Here, we aim to associate population variation of *Gracilinanus agilis* with seasonality, and type and position of traps in fragments of semi-deciduous forest in Southern Goiás, Brazil. We conducted a mark-recapture study from August 2013 through August 2014. We set wire-cage and Sherman® traps in four transects, with five stations per transect, during three consecutive nights per month. Each station consisted of 1 wire cage and 1 Sherman® trap, placed alternately on the ground and in the understory (1.5-2 m height). We registered 66 individuals in 121 captures (7.8% capture success). *Gracilinanus agilis* was more abundant during the dry season in the understory. Males were more abundant in the dry season and females in the wet season. Data reported here are of great value for understanding population and behavioral patterns of *G. agilis* in the Brazilian savanna.

RESUMEN. Variación poblacional estacional de *Gracilinanus agilis* (Mammalia: Didelphidae) en fragmentos de bosque semideciduo. Las fluctuaciones poblacionales de los pequeños mamíferos tropicales suelen estar relacionados con las variaciones temporales y ambientales en la disponibilidad de recursos. Aquí, nuestro objetivo es asociar la variación poblacional de *Gracilinanus agilis* con la estacionalidad y el tipo y la posición de las trampas en fragmentos de bosque semideciduo en el sur de Goiás, Brasil. Realizamos el muestreo a través del método de marcado y recaptura, desde agosto de 2013 a agosto de 2014. Establecimos cinco estaciones de captura por transecto, durante tres noches consecutivas por mes. Cada estación de trampas consistió en una jaula de alambre y una trampa Sherman®, colocadas alternativamente en el suelo y sotobosque (1.5-2 m de altura). Se registraron 66 individuos en 121 capturas, lo que resulta en un éxito captura de 7.8%. *Gracilinanus agilis* fue más abundante en la estación seca, en el sotobosque. Los machos fueron más abundantes en la estación seca y las hembras en la estación húmeda. Los datos reportados aquí son de gran valor para la comprensión de los patrones de población y de comportamiento de *G. agilis* en la sabana brasileña.

Key words: Age class. Dry season. Sex class. Sherman® traps. Understory.

Palabras clave: Clase de edad. Clase de sexo. Estación seca. Sotobosque. Trampas Sherman®.

INTRODUCTION

Population fluctuations of small tropical mammals are often related to temporal and environmental variations in resource availability (Bergallo and Magnusson, 1999; Santos-Filho et al., 2008; Andreatzi et al., 2011; Gentile et al., 2012). Variations in rainfall between seasons and years influence the composition and abundance of available food (Bergallo and Magnusson, 1999; Santos-Filho et al., 2008). Thus, species capable of shaping their diet according to such variations are expected to show minor fluctuations in abundance between seasons, while species with restricted or specialized diets may suffer because of resource limitation, which contributes significantly to the population size variance between seasons (Bergallo and Magnusson, 1999; Santos-Filho et al., 2008).

The fluctuation of population density of *G. agilis* has been associated with the wet season, a period with higher abundance of fruits and arthropods (Mares and Ernest, 1995; Camargo et al., 2014a). However, studies with *Marmosops noctivagus*, *Micoureus demerare* and *G. agilis* in seasonal semi-deciduous forest showed higher abundance during the dry period, but the highest availability of the primary food of this group—i.e. arthropods—was recorded during the wet season (Santos-Filho et al., 2008).

In addition, the seemingly inconsistent relationship between population density of small mammals and resource availability can also be a result of sampling artifact. Traps with baits have reduced attractiveness during the wet season (Santos-Filho et al., 2008). Furthermore, most Neotropical marsupial genera are recognized as arboreal or scansorial (Vieira and Camargo, 2012). Thus, variation of the type and position of traps could distort estimates of population abundance and community composition (Astúa et al., 2006; Santos-Filho et al., 2006; Cáceres et al., 2011; Hice and Velazco, 2013).

Deviations in the sex ratio also appear to be related to environmental variation between seasons, as males of the marsupial *Thylamys macrurus* are more abundant in the dry season and females more abundant in the wet season

(Cáceres et al., 2007). This pattern also occurs in *G. agilis* populations, though this can be a result of life history traits and a predisposition of marsupials toward semelparity (Lopes and Leiner, 2015).

Most of the studies within species of *Gracilinanus* have focused on diet composition (Bocchiglieri et al., 2010), variation of feeding habits related to sex, reproductive condition, and seasonality (Camargo et al., 2014b), as well as variations of niche between seasons (Camargo et al., 2014a). However, fundamental data about population variation of this species with respect to seasonality are scarce.

Gracilinanus agilis is a small marsupial with body mass ranging from 13 to 40 g, head and body length between 81 and 115 mm, length of tail always greater than the body, ranging between 110 and 158 mm (Rossi and Bianconi, 2011). This species is classified as insectivorous-omnivorous, with fruits being an important part of their diet. Although it feeds on abundant insects in the environment, there is a higher preference for termites and bedbugs, and a lesser preference toward ants during the dry season. During the wet season, this species tends to feed according to availability of resources in the environment (Camargo et al., 2014b).

We investigated variation in the structure of populations of *G. agilis* during dry and wet seasons in two fragments of semi-deciduous seasonal forest in the Brazilian savanna. We address the following questions in our study: (1) is there a difference of abundance of *G. agilis* between seasons, and type and position of traps? We predicted that *G. agilis* would be more abundant in the dry season, because of life history traits, including a semelparous reproductive strategy (Lopes and Leiner, 2015). We expected the species to be most commonly captured in Sherman® traps in the understory, because of its small body size and arboreal habits (Voss et al., 2005; Cáceres et al., 2011). (2) Does the abundance of *G. agilis* vary seasonally and distinctly between sexes and age classes? Because marsupials are known to exhibit seasonal variation in population density as a result of a well-defined breeding season (Cáceres et al., 2007; Gentile et al., 2012), we

expected to find higher abundance of young individuals during the wet season, with females being more common than males.

MATERIAL AND METHODS

Study area

Samples were taken in two fragments of semi-deciduous forest (F1: 65.11 ha-18°24'51" S and 50°38'46" W, and F2: 48.15 ha-18°26'08" S and 50°38'46" W), which were 2792 m from each other, in the municipality of Quirinópolis, central-west of Brazil. The climate is Tropical semi-humid, markedly seasonal, with dry winter (Aw in Köppen climate classification), with mean annual temperatures of 23 °C (max. 40 °C and min. 14 °C), and mean annual rainfall of around 1600-1900 mm, irregularly distributed in two distinct seasons. The dry season occurs between April and September, and wet season from October to March (Alvares et al., 2014).

Methods

Live traps were set along four transects (two per fragment) during three consecutive nights each month, from August 2013 to August 2014. We installed five trap-stations, 15 m apart, in each transect. Each trap-station consisted of a wire-cage and a Sherman® trap, alternating between placements on the ground and in the understory (1.5-2 m height). We used a mixture of banana, bacon and cod liver oil as bait. We checked the traps daily, and all captured individual were individually marked with numbered ear-tags. This way, we were able to get the type of trap (cage or Sherman®) and catching position (ground or understory). We also recorded the sex (male or female) and age (young or adult). Individuals with incomplete dentition (less than four upper molars)

and deciduous third superior premolars were classified as young (Rossi et al., 2012). Three specimens were collected and deposited in the collection of small mammals of the Laboratory of Ecology and Biogeography of Mammals of the Universidade Estadual de Goiás, Campus Quirinópolis (Appendix 1). The captures were made with the collection permit SISBIO n° 37519/2013.

Data Analysis

Abundance and capture success were used to determine population patterns of *G. agilis*. The number of captured individuals was our proxy for abundance. Capture success is the number of captures divided by the sampling effort multiplied by 100. To verify differences in the total abundance of *G. agilis* between the periods of the year (dry and wet seasons), type (cage and Sherman® traps), and position (ground and understory) of traps, we used chi-square test with Yates correction. To test the dependence of the sex and age classes as a function of seasonality, we used Fisher's exact test. We used the Holm-Bonferroni method to correct the P-values for multiple non-independent comparisons.

RESULTS

From August 2013 to August 2014, 66 individuals of *G. agilis* were captured, including 37 males and 29 females, during 1560 trap-nights (capture success of 7.8%). *Gracilinanus agilis* was more commonly captured in the dry season, in the understory and using Sherman® traps (Table 1). Males were more abundant in the dry season and females in the wet season ($P=0.03$, Fig. 1). However, the abundance of young and adults was not related to seasonality ($P=0.72$, Fig. 1).

Table 1

Capture success of *Gracilinanus agilis* in different seasons, and relative to the type and position of traps in fragments of seasonal forest in southern Goiás.

	Season		Trap type		Trap position	
	Dry	Wet	Wire-cage	Sherman	Ground	Understory
Trap-nights	840	720	780	780	780	780
Abundance	51 ^a	15 ^b	19 ^a	47 ^b	16 ^a	50 ^b
Number of captures	92 ^a	29 ^b	39 ^a	82 ^b	27 ^a	94 ^b
Capture success (%)	11.0	4.0	5.0	10.5	3.5	12.1

*different letters denote statistical differences ($P < 0.001$)

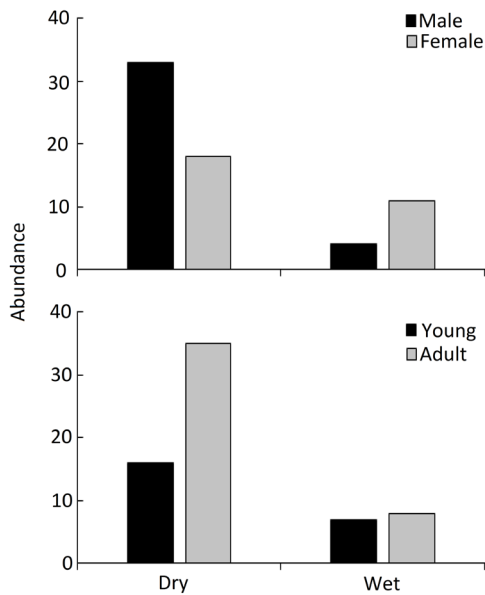


Fig. 1. Comparisons of abundance (number of captured individuals) of *Gracilinanus agilis* between sex and age class in seasonal forest fragments in southern Goiás.

DISCUSSION

General patterns of the population

Gracilinanus agilis was more abundant during the dry season and captured more often in Sherman® traps set in the understory, confirming our initial predictions. This result is concordant with other studies done in areas of the Brazilian Cerrado (Lopes and Leiner, 2015) and Pantanal wetland (Aragona and Marinho-Filho, 2009; Andreazzi et al., 2011). Mating of *G. agilis* begins in July, and around August-September all females are pregnant or lactating, which significantly increases the number of individuals during the dry season, i.e. between June and October (Lopes and Leiner, 2015). However, in gallery forests of Cerrado in central Brazil, peaks of abundance of *G. agilis* occurred during the wet season and population declined during the dry season (Mares and Ernest, 1995). Beyond seasonality, local factors such as competition with morphologically similar species (e.g. *Cryptonanus agricolai*), habitat heterogeneity (gallery forest,

woodland savannah, semi-deciduous forest) and resource availability may play important roles in the variation of abundance of *G. agilis*. In woodland savannah fragments, *G. agilis* and *C. agricolai* tended to occupy the ground and the understory, respectively (Hannibal and Cáceres, 2010). This difference may be explained by competition (Vieira and Camargo, 2012). The peak of individuals of *G. agilis* in the dry season occurred in woodland savannah and semi-deciduous forest (Andreazzi et al., 2011; Lopes and Leiner, 2015), while the peak in wet season occurred in the gallery forest (Mares and Ernest, 1995). *Gracilinanus agilis* feeds heavily on Isoptera and Hemiptera during the dry season, showing that these insects are relevant for its diet, especially in cool-dry season (Camargo et al., 2014b). Therefore, the availability and composition of resources are important to determine the variation in abundance of *G. agilis*.

We had a higher number of captures in Sherman® traps set in the understory than in cage traps in any other position within the fragments. Many other studies have reported similar results (Santos-Filho et al., 2006; Aragona and Marinho-Filho, 2009; Andreazzi et al., 2011). *Gracilinanus agilis* is a species with arboreal habits (Paglia et al., 2012) and commonly uses the arboreal or semi-arboreal forest layer (Voss et al., 2005). Cage traps appear to be more efficient in the capturing of larger species like *Didelphis albiventris* and *Thrychomys pachyurus* (Andreazzi et al., 2011; Cáceres et al., 2011).

Sex and age class composition

We found deviations in the sex ratio of captured individuals between seasons, with males being more commonly captured during the dry season and females more frequently in the wet season. This result may be associated with the life history traits, reproductive patterns and predisposition toward semelparity in *G. agilis* (Aragona and Marinho-Filho, 2009; Lopes and Leiner, 2015). At the end of the dry season, as is typical of didelphids, there is an increase in activity of males searching for females for breeding (Cáceres et al., 2007; Aragona and Marinho-Filho, 2009; Andreazzi et al., 2011).

Right after mating, there is a drastic reduction in the number of adult males, which can result in a complete disappearance of these individuals between November and December—wet season (Lopes and Leiner, 2015). Further, females tend to increase their activity in the wet season to find enough resources for breastfeeding as well as parental care and weaning of the litter (Cáceres et al., 2007; Lopes and Leiner, 2015). There is an association between age class and season, as the abundance of adults is clearly higher in the dry season. Our results contrast with those found elsewhere, which report that juveniles are predominantly captured in the wet season (Mares and Ernest, 1995; Lopes and Leiner, 2015). One possible explanation is trap bias favoring adult trappings. Another conjecture may be the increased abundance associated with low reproductive activity, which could indicate immigration (Andreazzi et al., 2011).

CONCLUSION

This study shows strong evidence of population change over seasons, especially sex ratio which was inversely abundant in each season. Although our study was performed in a small geographic area, data reported here are of great value for understanding population and behavioral patterns of *G. agilis* in the Brazilian Savannah. Intensive studies evaluating the use of ground, understory and canopy levels by *G. agilis* are, to the best of our knowledge, non-existent. Further studies should test 1) the effect of seasonality on the use of vertical strata by *G. agilis*, and 2) the variation of population structure on different vertical strata. Such approaches may be of great importance for better understanding patterns of vertical strata habitat use and its variation in population structure.

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APPENDIX 1

Specimens of *Gracilinanus agilis* collected in a semi-deciduous seasonal fragment, southern Goiás, Brazil. Measurements: W = weight in g and length in mm-HB = head-body, T = tail, HF = hind foot, E = ear.

27.VIII.13, [18°25'44"S; 50°40'32"W], male, W = 45 g, HB = 110.5, T = 133.5, HF = 14.3, E = 20.7, captured in cage trap, on the understory, Hannibal et al. cols. (ZUEG-007). 27.VIII.13, [18°24'58"S; 50°39'22"W], female, W = 29 g, HB = 105.9, T = 126.5, HF = 11.6, E = 20.9, captured in Sherman® trap, on the understory, Hannibal et al. cols. (ZUEG-008). 29.VIII.13, [18°25'33"S; 50°40'23"W], female, W = 28 g, HB = 98.1, T = 108.5, HF = 12.1, E = 21.8, captured in cage trap, on the ground, Hannibal et al. cols. (ZUEG-012).