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Diversity of nonvolant mammals in a Caatinga area in northeastern Brazil

Diversidade de mamíferos não voadores em uma área de Caatinga do nordeste do Brasil

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Abstract

The Caatinga is an exclusively Brazilian biome that covers approximately 11% of the country and is currently vulnerable to a series of impacts. Its biodiversity is relatively poorly-known, and few data are available on most groups of fauna, hampering the reliable identification of priority areas for conservation. The present study describes the species composition and diversity of the nonvolant mammal community from the Serra das Almas Nature Reserve, an advanced outpost of the Caatinga Biosphere Reserve. Data on small mammals (rodents and marsupials) were collected using live traps. Data on medium – and large – bodied mammals were obtained through observations in the field, photographic records, specimens donated by local residents, and indirect evidences. In addition, camera traps were installed along trails and near water bodies. The analysis of 520 individual records yielded a list containing 29 species of nonvolant mammals. Estimated species richness for the study area was 21±8. The species richness recorded in the SANR represents from one-third to one-half of the nonvolant mammals found in the Caatinga, based on the most recent estimates.

Keywords: inventory, camera trap, Serra das Almas, Ceará.

Resumo

A Caatinga é um bioma exclusivamente brasileiro que cobre aproximadamente 11% do território do país, sendo vulnerável a uma série de impactos. Sua biodiversidade é relativamente pouco conhecida, e poucos dados estão disponíveis para vários grupos zoológicos, dificultando a identificação confiável de áreas prioritárias para a conservação. O presente estudo descreve a composição e diversidade de espécies da comunidade de mamíferos não voadores da Reserva Serra das Almas, um posto avançado da Reserva da Biosfera. Dados sobre pequenos mamíferos (roedores e marsupiais) foram coletados utilizando-se armadilhas. Dados sobre mamíferos de médio e grande porte foram obtidos por meio de observações diretas, registros fotográficos e recebimento de material doado por moradores, além de registro de evidências indiretas, como pegadas e fezes. Além disso, foram utilizadas armadilhas fotográficas instaladas ao longo de trilhas e próximas à corpos d'água. A análise de 520 registros individuais resultou em uma lista de 29 espécies de mamíferos não voadores. A riqueza de espécies estimada para a área de estudo foi 21±8, valor que representa de um terço à metade dos mamíferos encontrados na Caatinga, baseado nas mais recentes estimativas.

Palavras-chave: inventário, armadilha fotográfica, Serra das Almas, Ceará.

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Introduction

The loss and modification of habitats resulting directly or indirectly from human activities represents a huge threat to mammal populations throughout the world (Cuarón, 2000). In Brazil, ongoing human activities have exerted increasing pressure on mammal species and the habitats they depend on, creating problems for the conservation of its biodiversity (Rambaldi and Oliveira, 2003).

The Caatinga is an exclusively Brazilian biome that covers approximately 11% of the country, with a population of 27 million inhabitants and vulnerable to a series of impacts, such as hunting, farming, ranching, and the extraction of firewood (Santos *et al.*, 2011; MMA, 2014). The biome has a semi-arid climate and is dominated by seasonally deciduous dry forest in a mosaic of different phytophysiognomies (Albuquerque *et al.*, 2012). Up to 2009, approximately 45.6% of the native vegetation structure of the Caatinga was cleared (MMA, 2011), with large areas being affected by desertification (Drumond *et al*., 2004).

The biodiversity of the Caatinga is relatively poorly-known in scientific terms, and few data are available on most groups of fauna, in particular, medium- and large-bodied mammals (Santos *et al.*, 2011). There are enormous gaps in the understanding of the distribution and ecology of most of its species (Albuquerque *et al.*, 2012). This situation is especially critical in the state of Ceará, where the lack of data on the local mammalian fauna hampers the reliable identification of priority areas for conservation. Over the last century, information on mammals in Ceará was restricted to few publications (Thomas, 1910; Moojen, 1952; Paiva, 1973; Mares *et al*., 1981) and this trend of low investment in research seems to persist even today. The recent review presented by Gurgel-Filho *et al*. (2015) based on museum samples lists nine species of marsupials and 13 Sigmodontinae rodents from 41 Ceará municipalities and regions. In the last two decades only two inventories have been published, recording 35 species of non-flying mammals for the state (Guedes *et al*., 2000; Fernandes-Ferreira *et al*., 2015). The present study reports on a detailed investigation of the diversity and species composition of the mammalian community of a semi-arid area of western Ceará.

Material and Methods

Study site

The present study focused on the Serra das Almas Nature Reserve - SANR (5°15'and 5°00'S; 40°15'and 41°00'E), a Private Natural Heritage Reserve that is classified as an advanced outpost of the Caatinga Biosphere Reserve, a title conferred by UNESCO. The reserve is located in the western of the state, between the municipalities of Crateús, in Ceará, and Buriti dos Montes, in the state of Piauí (Figure 1). It is placed on the Ibiapaba Plateau, which forms the eastern extreme of the basin of the Parnaíba River is this region, sloping gently to the west, into the Parnaíba basin, with a steep escarpment to the east (Santos and Souza, 2012).

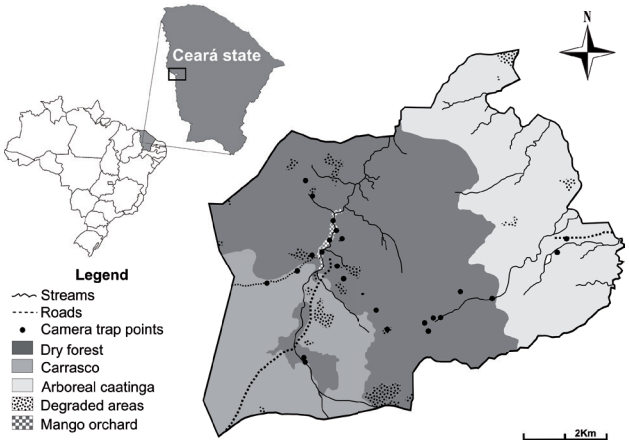

Figure 1. Study area, the Serra das Almas Nature Reserve in Ceará, northeastern Brazil (prepared by Douglas de M. Dias).

The reserve covers a total area of 5,845 ha of Caatinga vegetation at different stages of succession (more details in MMA, 2016). The region's climate is of the *As* type in the Köppen classification system (Alvares *et al.*, 2013), with dry summers. The annual rains are highly irregular, which is typical of the Brazilian semi-arid zone, with long periods of drought punctuated by a brief rainy season, which lasted from February to May during the present study period. Due to its topography and location within the ecotone between the Ibiapaba Plateau (which rises up to 700 m) and the Crateús Peripheral Depression (at 300 m), the SANR is characterized by considerable climatic variation, with relatively amenable temperatures and greater humidity being found at the higher altitudes of the plateau, in comparison with the lower parts of the reserve (Associação Caatinga, 2012).

Three major phytophysiognomies are found within the SANR – dense seasonal scrub (*carrasco*), seasonal thorn forest (arboreal caatinga), and seasonal montane deciduous forest (dry forest). The *carrasco* is found in a long, narrow belt adjacent to the dry forest (Araújo *et al.*, 1999). While there is some disagreement on the phytogeographic classification, Araújo and Martins (1999) define the *carrasco* as a distinct, unstratified vegetation type, with a canopy dominated by lianas and sparse emergent trees. The arboreal caatinga located in the Peripheral Depression is dominated by a canopy with a mean height of 8 m and presents an abundance of cacti and bromeliads (Asso-

ciação Caatinga, 2012). This environment is distinguished from the *carrasco* due to its greater stratification, thicker trunks, and denser vegetation (Araújo and Martins, 1999). The dry forest is a seasonally deciduous forest, in which most of the vegetation loses its leaves during the dry season. In the SANR, this habitat is dominated by trees and shrubs, which form a stratified canopy at heights of between 8 and 12 m (Lima *et al.*, 2009). The dry forest can be distinguished from the arboreal caatinga by the higher density of trees and, while similar in species composition to the *carrasco*, it is physiognomically distinct (Lima *et al.*, 2007, 2009). At the center of the dry forest, there is a mango (*Mangifera indica* L.) orchard, a narrow strip of habitat that coincides with a perennial stream in the middle of the reserve, composed of exotic fruit trees.

Sampling of small mammals

Data on small mammals (rodents and marsupials) were collected in the months of January (rainy season) and July (dry season) of 2000, during the inventory conducted for the production of the SANR management plan. Three different traps were used: Sherman® (23 x 08 x 09 cm) (n = 78), Tomahawk® (26 x 09 x 09 cm) (n = 35) and plastic traps (n = 46), totalizing 159 traps/night, distributed in the three main phytophysiognomies in the study area (53 traps in each, separated by a mean distance of 10 m). They were installed on the ground, inside fallen trunks, and on tree branches, and were baited with banana, cassava, peanut butter and sardine. During each field campaign, the traps were set and baited during 10 consecutive days, being checked every morning.

The collection of specimens was authorized by the Brazilian Institute for the Environment and Renewable Natural Resources (IBAMA) through license number 178/99 (DIFAS). The voucher specimens (Appendix 1) were preserved in 70° alcohol or as filled skins, and were deposited in the mammal collections of the Brazilian National Museum/UFRJ, in Rio de Janeiro, and the Federal University of Ceará, in Fortaleza.

Sampling of medium and large size mammals

Data on medium- and large-bodied mammals (body weight > one kg, following Chiarello, 1999) were obtained during two distinct periods. During two fieldtrips on January and July 2000, data were collected through opportunistic observations in the field during inspections along the reserve trails, and specimens donated by local residents. Indirect evidence was obtained through the occasional collection of feces and skeletons, and the recognition of vocalizations and tracks, which were molded with plaster-of-Paris. The tracks of larger mammals were identified *in loco*, whenever possible, and when necessary, photographs were taken for identification in comparison with the specialized literature (*e.g.*, Becker and Dalponte, 1991; Oliveira and Cassaro, 2006; Borges and Tomás, 2008).

Camera traps (Bushnell® and Super Scouter®) were placed at 24 sampling stations, each equipped with one trap to record the presence of the species over a total of 22 months, including the periods between February and December 2013 (except for April and July), January to October 2014 (except May), and January to April 2015. The camera traps were installed along trails and in the vicinity of water bodies (springs, streams, and artificial troughs). Simultaneously active stations were separated by distances of 0.5-1.0 km. The principal environments found in the RNSA (*carrasco*, arboreal caatinga, dry forest, and mango orchard) were sampled. Sampling effort was determined by multiplying the number of traps by the number of days sampled in each environment. Photographic records obtained at an interval of at least 30 minutes were considered to be independent records (Davis *et al.*, 2011).

Species identification

The taxonomic classification was based on Gardner (2007) for the Didelphimorphia, Pilosa and Cingulata; Bonvicino *et al.* (2008) for the Rodentia; and Reis *et al.* (2011), and Zhou *et al.* (2011) for all other groups. Only native species were registered. The conservation status of each species was obtained from the red lists of the International Union for Conservation of Nature (IUCN) and the Brazilian Environment Ministry (Brasil, 2014).

Mammal species richness (*S*) was estimated from the camera trap data, which were plotted in cumulative species curves, with each monthly sample as the sample unit. The curves were produced in EstimateSWin 9.0 (Colwell, 2013), with 1,000 randomizations using the nonparametric Chao 1 estimator, which was chosen due to its efficiency as a relatively conservative measure of diversity (Magurran, 2013). The index of relative abundance (RA) was calculated by dividing the number of captures (photographic records) of each species by the sampling effort in study area.

Results

Overall, 29 nonvolant mammal species were recorded in the SANR, representing seven orders (Table 1), with 520 individual records. A total of 47 small mammals from 10 species were captured in the live traps, whereas 470 records of 17 species of medium and large size mammals were obtained using camera traps, based on a sampling effort of 3,600 trap-days (Figure 2).

Two additional species – *Euphractus sexcinctus* (Linnaeus 1758) and *Galictis cuja* (Molina 1782) – were also recorded opportunistically during nonsystematic sampling in the study area. A list of captured specimens, and their

Table 1. Mammals recorded at the Serra das Almas reserve in Crateús, Ceará, northeastern Brazil. N = number of records. Environments: Ca = caatinga; Co = *carrasco*; Df = Dry forest; Mo = Mango orchard. Type of record: Ct = camera trap; Do = donation; Lt = Live trap; Tr = track; Vi = visual. Conservation status: EN = Endangered; LC = Least concern; VU = Vulnerable. Notes: [1]Number of specimens captured; [2]Species recorded opportunistically during nonsystematic fieldwork; [3]Specimens observed in captivity.

Taxon	N	Environment	Type of record	Conservation status	
				IUCN	MMA
DIDELPHIMORPHIA					
Didelphis albiventris	4	Df, Mo, Co	Lt (2)[1], Ct	LC	-
Gracilinanus agilis	9	Ca, Df	Lt	LC	-
Monodelphis domestica	11	Ca, Co, Df	Lt	LC	-
PILOSA					
Tamandua tetradactyla	3	Ca, Df, Mo	Ct, Tr(1), Do(1)	LC	-
CINGULATA					
Dasypus novemcinctus	6	Co, Df, Mo	Ct, Do(5)	LC	-
Dasypus septemcinctus	1	Co	Do		
Euphractus sexcinctus[2]	3	Df, Co	Vi, Do(1), Lt(1)	LC	-
CETARTIODACTYLA					
Mazama gouazoubira	58	Ca, Co, Df, Mo	Ct, Do(1)	LC	-
Pecari tajacu	14	Ca, Co, Df	Ct, Vi(1)[3]	LC	-
PRIMATES					
Callithrix jacchus	1	Mo, Df, Co	Ct, Vi(5)	LC	-
Sapajus libidinosus	182	Df, Mo	Ct, Vi(1)[3]	LC	-
CARNIVORA					
Cerdocyon thous	3	Ca	Ct, Vi(3), Do(1)	LC	-
Leopardus pardalis	30	Ca, Co, Df, Mo	Ct	LC	-
Leopardus tigrinus	1	Co	Ct, Do(1)	VU	EN
Puma concolor	28	Ca, Co, Df, Mo	Ct	LC	VU
Puma yagouaroundi	1	Mo	Ct	LC	VU
Conepatus semistriatus	36	Co, Df, Mo	Ct	LC	-
Eira barbara	12	Df, Mo	Ct	LC	-
Galictis cuja[2]	1	Ca	Tr	LC	-
Procyon cancrivorus	4	Ca, Df, Mo	Ct, Tr(1)	LC	-
RODENTIA					
Galea spixii	1	Ca	Vi	LC	-
Kerodon rupestris	15	Df, Mo	Lt (1), Ct	LC	VU
Necromys lasiurus	2	Ca	Lt	LC	-
Oligoryzomys stramineus	2	Ca, Co	Lt	LC	-
Oligoryzomys sp.	8	Ca, Df	Lt	-	-
Wiedomys pyrrhorhinos	3	Ca	Lt	LC	-
Cuniculus paca	47	Df, Mo	Ct	LC	-
Dasyprocta prymnolopha	23	Co, Df, Mo	Ct, Vi(1)	LC	-
Thrichomys apereoides	9	Ca, Co, Df	Lt	LC	-

respective locality and field number is presented in the Appendix 1. The cumulative species analysis produced an estimate of 21±8 species for the SANR, based on the Chao 1 nonparametric estimator, although the curve did not reach the asymptote by the end of the study period (Figure 3).

In the camera trap data, four species were recorded exclusively in one type of environment. These species were *Callithrix jacchus* (Linnaeus 1758) and *Puma yagouaroundi* (É. Geoffroy Saint-Hilaire 1803), recorded only in the mango orchard; *Cerdocyon thous* (Linnaeus 1766), which was captured only in the arboreal caatinga; and *Leopardus tigrinus* (Schreber 1775), which was recorded only in the *carrasco*. Only three species were recorded in all four habitats (Table 1). The most abundant species were *Sapajus libidinosus* (Spix 1823) (RA = 5.11) and *Mazama gouazoubira* G. Fisher 1814 (RA = 1.56), which together represent more than 50% of the records obtained in the SANR (Figure 4).

Discussion

The species richness recorded in the SANR represents 38.1% of the nonvolant mammals found in the Caatinga,

Figure 2. Mammals recorded in the Serra das Almas Nature Reserve, Ceará, northeastern Brazil. A: *Didelphis albiventris*. B: *Euphractus sexcinctus*. C: *Mazama gouazoubira*. D: *Pecari tajacu*. E: *Sapajus libidinosus*. F: *Callithrix jacchus*. G: *Leopardus pardalis*. H: *Puma concolor*. I: *Puma yagouaroundi*. J: *Conepatus semistriatus*. K: *Eira barbara*. L: *Procyon cancrivorus*. M: *Galea spixii*. N: *Cuniculus paca*. O: *Dasyprocta prymnolopha*. Photographs: camera traps (A – E; G - L and O); Alexandre Pinhão da Cruz (F and M).

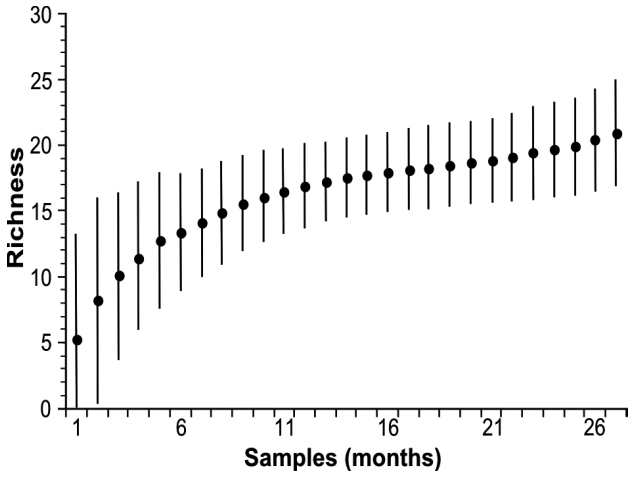

Figure 3. Species accumulation curve obtained by the nonparametric estimator Chao 1 based on data from camera traps (sampling effort in months) in the Serra das Almas Nature Reserve, Ceará, northeastern Brazil. Vertical lines indicate the standard deviation.

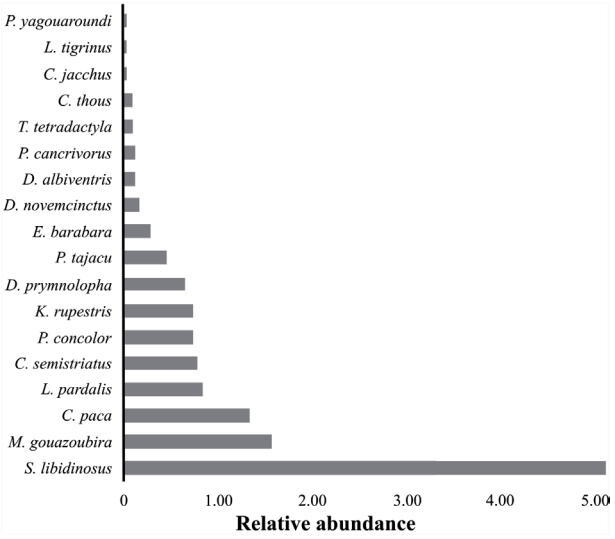

Figure 4. Relative abundance of medium and large size mammals recorded by camera traps in the Serra das Almas Natural Reserve, Ceará, northeastern Brazil.

based on the most recent estimate (Paglia *et al.*, 2012), and almost half of the representative threshold of local diversity in the Caatinga according to Oliveira *et al.* (2003). This threshold would be met, however, if the 23 bat (Chiroptera) species known to occur in the reserve (Silva *et al.*, 2015) are also taken into account, especially considering the degree of preservation of the reserve.

Recent studies in the Brazilian semi-arid zone have recorded between 8 and 24 species of wild mammals. While this variation among sites is at least partly related to differences in study procedures and sampling effort, as well as the degree of conservation of the study areas (*e.g.* Freitas *et al.*, 2011; Bezerra *et al.*, 2014; Dias *et al.*, 2014; Deiciellos, 2016; Dias and Bocchiglieri, 2016), the SANR does appear to host a relatively rich and diversified mammalian fauna in comparison with most other sites. The new record of the rodent *O. stramineus* extended the distribution of the species westwards, to the western frontier of the state, adjacent to Piauí. In addition, four of the species recorded in the study are considered to be threatened with extinction in Brazil: *Puma concolor*, *Puma yagouaroundi*, and *Kerodon rupestris* are listed as vulnerable by the Brazilian Environment Ministry and *Leopardus tigrinus* is listed as vulnerable by the IUCN and as endangered by the Brazilian Environment Ministry.

The cumulative species curve indicated a potentially higher number of species in relation to what was recorded in this study, emphasizing the need for additional sampling effort, to ensure that the curves reaches the asymptote. In general, biological communities have a few abundant species and a large number of rare species (Gotelli, 2007). Considering that it is difficult to record the actual number of species of a community, the cumulative species curve rarely stabilizes. Based on the upper limit of the standard deviation of the Chao 1 estimator, as many as 29 mammal species would be expected in the SANR. This value nevertheless corresponds to the number of species recorded overall, using camera traps, live traps, and nonsystematic sampling. In the present study, recording additional species may demand a considerable increase in sampling effort.

The largest number of species of medium and large size was recorded in the mango orchard. It is clear that the species richness of the orchard did not influence its diversity. In fact, the community recorded in this environment was not well balanced, given that most species were recorded only once or twice, while 57% of the records from this area were *S. libidinosus*. Despite being dependent on forested environments, *S. libidinosus* is ecologically flexible and not restricted to primary habitats, spending more time on the ground and displaying a dependence on tool use for food obtaining (Izar *et al.,* 2012; Wright *et al.,* 2015). The mango orchard may thus represent an important habitat for the local *S. libidinosus* population, providing feeding resources, water, and refuge, especially during the dry season, favoring the large number of records of this mammal.

The abundance of *M. gouazoubira* and *Cuniculus paca* (Linnaeus 1766) is worth mentioning. Currently, the population is diminishing in various locations mainly due to hunting pressure (their meat is very much appreciated), but also to habitat loss (Alves *et al*., 2016). These and other species seem to benefiting from the work to combat illegal hunting developed by the reserve administration (Associação Caatinga, 2012). The small felids (*L. tigrinus* and

P. yagouaroundi) were the least abundant species in the SANR. These carnivores occur in low densities (Almeida *et al*., 2013; Oliveira *et al*., 2013) and frequencies of records (Lyra-Jorge *et al*., 2008; Oliveira *et al*., 2009; Dias *et al*., 2014), usually inhabiting a variety of environments, from dense forests to anthropic areas (Almeida *et al*., 2013; Oliveira *et al*., 2013). In addition, the low densities of these felids may be a reflection of the threat or intraguild predation of *L. pardalis*. The "pardalis effect" (Oliveira *et al.*, 2010) may be a key factor shaping the dynamics of the small-felid community of the Neotropical Region.

The similarity in the species composition of the different environments indicates that most of the local mammals are habitat generalists. This implies that most of the species recorded during the study use the whole area of the reserve. The results of the present study indicate that the environmental heterogeneity of the SANR plays an important role in the maintenance of the region's mammal communities. The current loss and modification of habitats threatens the integrity of ecosystems, and in this context, protected areas play a critical role in the conservation of the regional biodiversity. While protected areas are a primary conservation measure (Ziller and Dechoum, 2013), anthropogenic modifications of the surrounding area can hamper the management of the remnant ecosystems (McDonald *et al.*, 2009). The fragmentation and modification of landscapes lead to the isolation of protected areas, turning them into virtual islands of remnant habitat set within an impacted matrix, making the reserves ever more vulnerable to external processes, such as invasion by exotic species (Spear *et al.*, 2013). In the specific case of the SANR, these problems may be mediated through the implementation of specific conservation and management measures, such as the prevention of wildfires, fencing, hunting controls, and environmental education, initiatives that validate the status of the reserve as an advanced outpost of the Caatinga Biosphere Reserve.

Acknowledgments

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Appendix 1. List of specimens of small mammals captured in live traps in the Serra das Almas Nature Reserve, Ceará, northeastern Brazil, their respective sampling locality and field number.

Didelphimorphia

Didelphidae

Monodelphis domestica - Almas, Crateús, Ceará: RSA014 (M), RSA041 (F), RSA079 (F), RSA080 (M), RSA088 (F). Grajáu, Crateús, Ceará: RSA096 (M), RSA097 (M), RSA102 (M), RSA 119 (F). Melancias, Crateús, Ceará: RSA032 (F).

Didelphis albiventris - Almas, Crateús, Ceará: RSA055 (F), RSA086 (M).

Gracilinanus agilis - Grajáu, Crateús, Ceará: RSA094 (M), RSA098 (M), RSA105 (M), RSA107 (F), RSA108 (M), RSA111(M), RSA113 (F), RSA 117 (M).

Rodentia

Muridae

Oligoryzomys stramineus - Melancias, Crateús, Ceará: RSA002 (M).

Oligoryzomys sp. - Grajáu, Crateús, Ceará: RSA089 (F), RSA093 (M), RSA100 (M), RSA104 (F), RSA109 (F), RSA110 (F), RSA112 (F), RSA118 (M).

Calomys sp. - Grajáu, Crateús, Ceará: RSA101 (F), RSA116 (M), RSA120 (M).

Wiedomys pyrrhorhinos - Grajáu, Crateús, Ceará: RSA103 (F), RSA106 (F), RSA114 (F).

Echimyidae

Thichomys apereoides - Almas, Crateús, Ceará: RSA057 (M). Grajáu, Crateús, Ceará: RSA115 (M). Melancias, Crateús, Ceará: RSA006 (F), RSA074 (M). São Luiz, Crateús, Ceará: RSA021 (M).