



Non-volant mammalian species richness in the ecotonal Brazilian midnorth: checklist for Maranhão State

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Abstract: The state of Maranhão, located in the westernmost portion of the Northeast Region of Brazil, is characterized by a dynamic and unstable ecotone among the Amazon, Caatinga and Cerrado biomes that presents a high degree of biodiversity with high vulnerability to anthropogenic activities. Despite the enormous potential for sheltering high levels of species diversity and abundance, little is known about many aspects the state's biodiversity, especially with regard to mammalian fauna. A capture-recapture methodology using live-traps was employed to inventory the non-volant, small mammal community. In addition, we recorded medium and large mammals based on direct and indirect observations, camera-trap surveys, and interviews. An extensive literature search of published research was also performed to maximize the elaboration of a complete mammal species checklist for Maranhão. A total of 89 non-volant mammal species, representing 9 orders and 27 families were recorded in the state of Maranhão. Of these taxa, 25.84% are included in the Brazilian Red List for endangered species, while 20 are considered as being endemic to Brazil. The preservation status of some areas, coupled with the strong presence of agro-pastoral environments, contributed to some unusual species occurrences, while the state's ecotonal nature was noted by the numbers of species associated with the Amazon (N=65) and Cerrado (N=66) biomes.. Given the rapid development and effects of numerous anthropogenic impacts occurring in the state, it is a crucial time to quantify, even at specific scales, the environmental richness of Maranhão. The significant levels of biodiversity, high degree of endemism, and the presence of numerous rare and endangered species characterizes Maranhão as being among the most biologically important parts of Brazil. Nonetheless, many gaps in our basic knowledge regarding the biodiversity of this area remain, such that the execution of additional biological inventories is imperative, as are greater efforts to clarify certain species limits and necessary taxonomic revisions, most notably that for small mammals.

Keywords: mammals; ecotone; biodiversity; endemism; Maranhão.

Riqueza de espécies de mamíferos não-voadores no meio norte ecotonal brasileiro: checklist para o Estado do Maranhão

Resumo: A denominação de estado ecótono, por estar localizado na região meio-norte do Brasil, entre a Amazônia a Caatinga e o Cerrado, confere ao Maranhão não só áreas ricas e abundantes de espécies, mas também à necessidade de cuidados especiais na sua conservação, por se tratarem de ambientes de dinâmicos e, portanto, pouco estáveis. Apesar de seu enorme potencial para abrigar altos níveis de riqueza e abundância de espécies da flora e fauna, o Maranhão ainda possui uma riqueza biológica pouco conhecida, notadamente quanto à sua mastofauna. A metodologia empregada para inventariar a comunidade de pequenos mamíferos não-voadores foi a de captura-recaptura, utilizando armadilhas do tipo live-traps. Para os mamíferos de médio e grande porte utilizou-se a visualização direta e indireta através da transecção de trilhas pré-estabelecidas assim como entrevistas e uso de armadilhas fotográficas. Para maximizar a busca das espécies já registradas para o estado foram também realizadas buscas de literatura através de plataformas digitais confiáveis. Foram registradas 89 espécies de mamíferos não-voadores no território maranhense, distribuídos em 9 ordens e 27 famílias. Dos táxons listados 25.84% constam na lista brasileira dos animais ameaçados de extinção, enquanto que 20 são endêmicos do território brasileiro. O estado de conservação de algumas áreas aliado à forte presença de ambientes agro-pastoris contribuíram para ocorrências não usuais, enquanto que a natureza ecotonal foi notada pela proximidade do número de espécies associadas aos biomas Amazônia (N=65) e Cerrado (N=66). Em tempos de desenvolvimento aliada a inúmeros impactos antrópicos sobre o meio ambiente é salutar que se quantifique, mesmo que em escalas específicas, a riqueza ambiental do estado. Diversidade expressiva, endemismo, espécies raras e ameaçadas destacam o Maranhão como um dos principais estados do meio norte do Brasil, entretanto são muitas as lacunas de conhecimento, o que torna imperativo não somente novos trabalhos de inventários mas também maiores esforços na precisão taxonômica das espécies, notadamente na de pequenos mamíferos.

Palavras-chave: mamíferos, ecótono, biodiversidade, endemismo, Maranhão.

Introduction

Maranhão is among the least known states of Brazil in terms of its biodiversity, either due to the classic veil line proposed by Preston (1948) or the geographical bias in funding allocated to support biological inventory studies (Magnusson et al., 2016). Nevertheless, its extensive area presents many attributes that allow for high levels of biodiversity, diverse vegetation in particular. Roughly 64.1% of the territory of Maranhão occurs within the Cerrado biome, 34.8% within the Amazon biome and 1.1% is classified as part of the Caatinga biome (Stella 2011).

A total of 138 municipalities in Maranhão occur within the Cerrado biome, 110 within the Amazon biome and 15 within the Caatinga biome. The Amazon represents the largest continuous area of rainforest in the world and is recognized for its extreme ecological importance and essential environmental services (MMA, 2007). Such recognition is supported by the large variety and complexity of ecosystems presented by the biome, which affords progressive increases in species richness (Peres 2005). The Cerrado biome is considered to be the most diverse tropical savanna in the world, also presenting a large variety of habitats and remarkable alternation of species between different phytophysionomies (Medeiros et al. 2011).

Despite the natural richness of these biomes, Maranhão is currently experiencing a period of increasing agriculture, urban expansion and a growing population density, all of which can have direct impacts on local fauna (Stehmann & Sobral 2017). Although it covers about 64.1% of the state territory and presents one of the highest rates of preservation, with 71.9% of its natural vegetation remaining, the Cerrado biome in Maranhão is also considered highly threatened (Stella 2011, Brazil 2015). For example, the MATOPIBA region (an acronym designated by using the initials for the states of Maranhão, Tocantins, Piauí and Bahia) represents a large portion of the Cerrado biome in which the average devoted to cotton, corn and soybean production has grown by 400% between 1990 and 2010 (Lorensini et al. 2015). Historically covering 34.8% of the state territory, the Amazon biome portion of Maranhão is also highly threatened, having been reduced to remnants representing just 23.82% of its original area due to the drastic transformations of forest and non-forest ecosystems, this is the lowest percentage of remaining vegetation among the nine Brazilian Amazon States (Santos 2007, Stella 2011, IMESC 2019).

Mammals occurring in the state of Maranhão are closely linked to the vegetation of the environment and strongly related to the quality and size of habitat remnants (Chiarello 1999, Peres 2000). Despite the extensive literature regarding mammal species composition of the Amazon and Cerrado biomes in general, there is little knowledge about mammalian distributions in Maranhão (i.e. Wallacean Shortfall). Mammal species can influence the entire dynamic of the ecosystems in which they occur, having important ecological roles in the dispersal of seeds, spores and plant propagules, as well as regulating natural prey populations. A proper biological inventory of mammal species for Maranhão is necessary to achieve a better understanding regarding the conservation status of habitat remnants in the state.

Therefore, given that the biodiversity of Maranhão is so rich and equally threatened by trends in socio-economic development, the state deserves special attention setting priorities for the region that result in

positive outcomes for conservation, sustainable use and the benefits derived of this biological diversity for the rest of the country. Part of the conservation concerns for Maranhão are due to a systematic lack of knowledge regarding its fauna, notably that of non-volant terrestrial mammals, including information gaps for many geographic areas and greater degrees of knowledge for certain mammalian orders relative to others.

Currently there is no single checklist for the species of mammals occurring in the state of Maranhão, our comprehensive knowledge is limited to isolated records in a few publications and mostly addressing species composition of the Cerrado and Amazon biomes independently (Ávila-Pires 1989, 1992, Oliveira et al. 2007, 2011). Basic information on the geographic occurrence and abundance of mammal species at various locations, as well as actions seeking to estimate the actual species richness of this region, are needed. Therefore, the main objective of the current study is to present a comprehensive checklist for non-volant mammal species known to occur in the state of Maranhão.

Materials and Methods

1. Study area

The study corresponds to the Brazilian state of Maranhão, with roughly 331,983 km². The state has transitional conditions between the super humid climate of the Brazil's northern region and the semi-arid climate of the northeast region of the country, with a predominance of forest vegetation, open fields and Cerrado habitats, and a large variety of ecosystems including mangroves, sand dunes, estuaries, extensive beaches and lake basins (Köppen, 1948, Maranhão 2002). Additionally, the *Mata dos Cocais* area, a *babassu* palm formation that is classified by IBGE (1992) as an Open Ombrophilous Forest, stands out for its uniqueness and is considered a characteristic landscape of Maranhão (Rios 2001). The average annual temperature for the whole area is 26°C, with a large temperature range between the northern and southern portions of the state, a rainfall regime that is highly correlated with the geographic occurrence of the different biomes, annual precipitation of around 1,100 mm in the southwestern region where the Cerrado biome is dominant and often exceeding 2,000 mm annually in Amazon biome areas (Pinto et al. 2011, Brasil 2013).

2. Data collection

Inventories were realized at 15 study sites throughout the state of Maranhão, selected to include portions of the Amazon and Cerrado regions, as well as transitional areas between the two biomes in the most diverse plant formations (Figure 1). Because the percentage of Caatinga cover in the state is negligible (ca. 1.1%), we decided to only sample sites within the Amazon and Cerrado biomes of the state. Live-traps appropriate for small mammals and camera traps were installed at sampling locations along predetermined transects of varying sizes within each of the study sites. The total sampling effort resulted in 71,082 nights/live-trapping, 1,283 transect km/traveled and 9,639 nights/camera-trapping (Table 1). The data presented here have been collected since 1994, but with greater consistency from 2004-2018. Additional information regarding biological inventories from different parts of Maranhão acquired from the bibliographic survey was also included.

3. Small mammals

The current small mammal survey was performed using the standard methodology of installing live-traps in capture lines along the selected sampling locations at each of the study sites. A capture station consisting of Sherman (8 x 8 x 23 cm) and Tomahawk (14 x 14 x 40 cm) live-traps was established every 20 m, the first type being deployed at each capture station and the second type at alternating stations. In closed-canopy habitats, Sherman live-traps were installed at a height of 1.5–2.5 m above ground at alternate stations to Tomahawk live-traps located on the ground. Peanut butter mixed with banana and/or other fruits was used to bait the live-traps, which were actively deployed for seven consecutive nights (Auricchio & Salomão 2002, Lambert et al. 2006, Umetsu & Pardini 2007). The sampling protocol for small mammals is outlined in Table 1. All marsupial and small rodent species identifications were based on published systematic studies, as well as other important compilations regarding the taxonomy and geographic distribution of these groups (Paglia et al. 2012, Brandão et al. 2015, Gardner 2008, Miranda & Da Silva 2015, Patton et al. 2015, Percequillo et al. 2015, Quintela et al. [in press]). Species identifications were later confirmed by specialists. Voucher specimens were also collected for reference, comparison and confirmation of certain species identifications with other scientific materials and under the appropriate federal government collecting permits including: IBAMA 38/2010, IBAMA 45398-3,

IBAMA 113/2004, IBAMA 2001.009125/2008-67, IBAMA 08/2010, IBAMA 035/2009/CGFAP, IBAMA 036/2009/CGFAP, IBAMA 037/2009/CGFAP, IBAMA 038/2009/CGFAP, IBAMA 39/2009/CGFAP, SEMA/MA 05/2017). Voucher specimens collected during the current study have been deposited in the vertebrate natural history collections of the *Universidade Estadual do Maranhão* and the *Museu Paraense Emilio Goeldi* (Supplementary material).

4. Medium and large-sized mammals

A variety of non-invasive sampling methods were used in the current study to identify medium and large-sized mammal species, including evidence from bones, skin, tracks, carcasses, vocalizations and photographs. To this end, camera-traps were deployed along several walking transects, while additional trails were also surveyed on foot and at different times of the day during the entire data collection period realized at each of the sampling areas, a standard methodology for this type of study (Oliveira et al. 1988, Oliveira & Cassaro 2005, Wilson & Delahay 2001). Whenever necessary, species identifications were supported by consulting several field guide references (Emmons & Feer 1997, Oliveira & Cassaro, 2005, Bonvicino et al. 2008).

The mammal species detected here were also classified by their appropriate threat categories according to criteria of the International Union for Conservation of Nature - IUCN (Version 13 - IUCN, 2017),

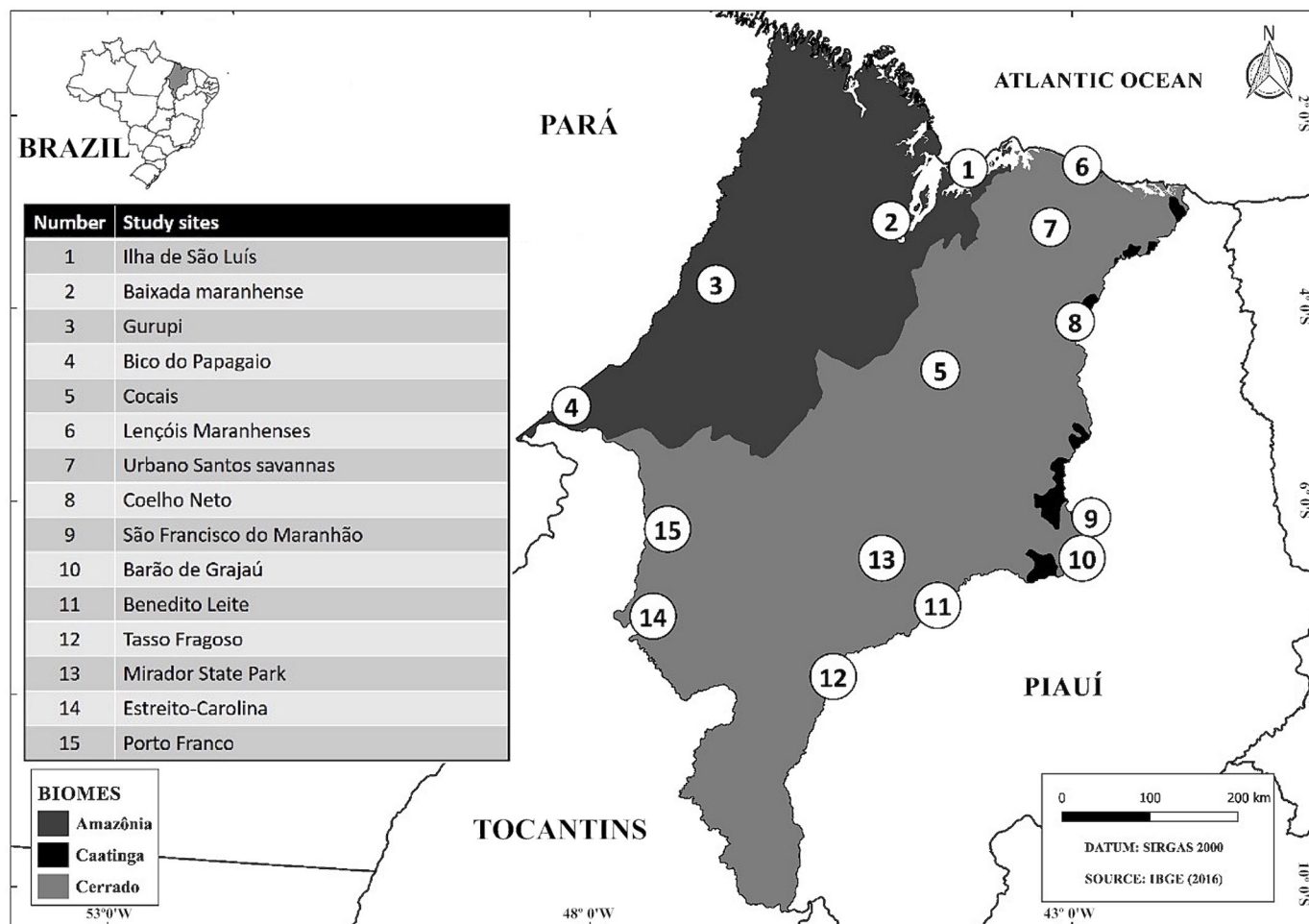


Figure 1. Location of study sites where non-volant mammal species were sampled in the state of Maranhão, Brazil.

Table 1. Geographic locations and sampling efforts for the study sites included in elaborating the current non-volant mammal species checklist for the state of Maranhão, Brazil.

	Sampling locations	Sampling periods	Central geographic coordinates	Sampling effort		
				Live-traps (nights/trapping)	Walking transects (km)	Camera-traps (nights/ trapping)
1	Ilha de São Luís	2010-2015	2°38'43.69" S / 44° 8'55.42" O	21.568	211	5.548
2	Baixada Maranhense	2017-2018	3°11'18.98" S / 44°56'52.29" O	2.520	15	-
3	Região do Gurupi	2003-2014	3°50'50.20" S / 46°45'52.37" O	10.080	98	25
4	Região do Bico do Papagaio e adjacências	1994/2008-2010	5° 6'40.00" S / 48°15'46.26" O	14.173	398	560
5	Região dos Cocais	2012-2013	4°44'19.71"S / 44°26'16.19" O	2.520	17	70
6	Região dos Lençóis Maranhenses	1994	2°36'46.53" S / 42°58'4.05" O	-	30	-
7	Cerrados de Urbano Santos	2005	3°15'21.21" S / 43°17'49.94" O	1.536	15	70
8	Região de Coelho Neto/MA	2008	4°14'5.25" S / 43° 2'27.73" O	2.520	17	70
9	Região de São Francisco do Maranhão	2009	6°15'54.25" S / 42°52'23.11" O	1.688	78	395
10	Região de Barão de Grajaú/MA	2009	6°41'24.58" S / 43° 2'29.19"O	2.110	82	410
11	Região de Benedito Leite/MA	2009	7°10'47.26" S / 44°32'23.00" O	1.960	66	355
12	Região de Tasso Fragoso/MA	2009	7°55'3.55" S / 45°37'18.59" O	1.822	85	420
13	Parque Estadual do Mirador	2013-2018	6°41'17.43" S / 45° 7'5.13" O	3.936	30	1.616
14	Região de Estreito-Carolina/MA	2002	7°17'29.34" S / 47°29'22.82" O	2.651	117	-
15	Região de Porto Franco/MA	2009	6°23'15.13" S / 47°20'17.73" O	1.978	25	100
	Total Effort			71.062	1.283	9.639

these same criteria were also used in the most recent evaluation of the conservation status for threatened fauna in Brazil (ICMBio, 2018).

Results

A total of 89 non-volant, wild mammal species were confirmed as occurring within the state boundaries of Maranhão (Table 2, Figures 2 and 3). Considering mammal species occurrences by biome, a total of 66 species were found to be associated with the Cerrado biome, and 65 species with the Amazon, 5 of which were recorded exclusively in the Amazonian region of the state.

Considering only non-volant mammals that are known to occur in Brazil, species richness in Maranhão represents 12.70% of the total richness proposed by Paglia et al. (2012) and 11.2% of that proposed by Quintela et al. (in press). (Table 3). The mammal species diversity of Maranhão is representative of 27 families and 9 orders. The three most diverse non-volant mammal orders in Brazil are the Rodentia, Primates and Didelphimorphia, although many taxonomic aspects of the first and last of these groupings are still poorly defined. Regarding the mammalian fauna of Maranhão according to the current results,

the order Rodentia is the most representative (24 species), followed by Carnivora (20 species) and relegating Didelphimorphia (13 species) to the rank of third most diverse mammal order for the state.

A total of 23 of the 89 species recorded here, or 25.84%, are included in the Brazilian Red List of threatened and endangered animals (ICMBio, 2018). Of these 23 species, the order Carnivora is the most highly represented (10 species), followed by Primates (5 species) and Artiodactyla (3 species). Regarding IUCN threat of extinction categories, mammal species classified as being Vulnerable (VU) were the most highly represented (18 species).

Discussion

Systematic biological inventories are essential for assessing the conservation status of a region's biodiversity and help in providing guidelines to select priority areas for environmental protections (Diniz-Filho et al. 2004, Jenkins et al. 2015). The current study employed different approaches to collecting information regarding mammal species occurrence in Maranhão in order to create the most comprehensive state checklist possible. Nonetheless, and despite all of

Table 2. Checklist of non-volant mammal species registered as occurring in the state of Maranhão, Brazil.

TaxoN	Threat Category	Common Name	Biome	End Br	Type Of Record	Sampling Location
DIDELPHIMORPHIA						
Didelphidae						
<i>Caluromys philander</i> (Linnaeus, 1758)		Mucuri / Bare-tailed Woolly Opossum	Am, MA, Ce, Pt		C, V, Io	L3, L5, L6, 1, 2, 3, 4, 5, 7, 9, 11, 14
<i>Chironectes minimus</i> (Zimmermann, 1780)		Mucura-d'água / Water Opossum	Am, MA, Ce, Pt, Pp		Io, I	L4, L6, 3, 4
<i>Didelphis albiventris</i> Lund, 1840		Mucura / Guaiba Dwarf Mouse Opossum	Ce, Ca, Pt, Pp		C, V, Io	L3, L5, L6, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
<i>Didelphis marsupialis</i> Linnaeus, 1758		Mucura / Common Opossum	Am		C, V, Io	L3, L5, L6, 1, 2, 3, 4, 5, 7, 9, 10, 11, 12, 14, 15
<i>Gracilinanus agilis</i> (Burmeister, 1854)		Mucuri / Agile Gracile Opossum	Ce, Ca, Pt		C	L3, L4, L5, L6, 1, 3, 4, 5, 7, 9, 10, 11, 12, 13, 14, 15
<i>Marmosa murina</i> (Linnaeus, 1758)		Mucuri / Linnaeus's Mouse Opossum	Am, MA, Ce, Pt		C	L3, L5, L6, 1, 3, 4, 5, 7, 8, 9, 10, 12, 13, 14, 15
<i>Marmosops (Sciophanes) cf. parvidens</i> (Tate, 1931)		Mucuri / Slender Opossum	Am		C	L6, 3, 4
<i>Metachirus nudicaudatus</i>		Mucura / Guianan Brown Four-eyed Opossum	Am, MA, Ce, Pt		C	L4, L6, 3, 4
<i>Marmosa (Micoureus) demerarae</i>		Mucuri / Woolly Mouse Opossum	Am, MA, Ce, Ca		C	L6, 2, 3, 4, 5, 9, 11, 12, 13
<i>Monodelphis americana</i> (Müller, 1776)		Mucuri / Northern Three-striped Opossum	MA, Ce		C	L6, 3, 4
<i>Monodelphis domestica</i> (Wagner, 1842)		Mucuri / Gray Short-tailed Opossum	MA, Ce, Ca, Pt		C	L3, L6, 1, 3, 4, 5, 7, 8, 9, 10, 11, 12, 14, 15
<i>Philander opossum</i> (Linnaeus, 1758)		Mucura-de-quatro-olhos / Gray Four-Eyed Opossum	Am, Ce, Pt		C	L3, L6, 3, 4, 14
<i>Thylamys karimii</i> (Petter, 1968)		Mucuri / Karimi's Fat-tailed Mouse Opossum	Ce, Ca	x	C	L3, 4, 10, 11, 12, 13, 14, 15
PILOSA						
Bradypodidae						
<i>Bradypus variegatus</i> Schinz, 1825		Preguiça / Brown-throated Sloth	Am, MA		V, Io, I	L2, L3, L5, L6, 1, 3, 4, 5, 6, 7, 9, 13, 14, 15
Cyclopedidae						
<i>Cyclopes didactylus</i> (Linnaeus, 1758)		Tamanduá / Silky Anteater	Am, MA, Ce		V, I	L2, L5, L6, 1, 3, 4, 6
Megalonychidae						
<i>Choloepus didactylus</i> (Linnaeus, 1758)		Preguiça-real / Linnaeus's Two-toed Sloth	Am		V, I	L5, L6, 3, 4
Myrmecophagidae						
<i>Myrmecophaga tridactyla</i> Linnaeus, 1758	VU	Tamanduá-bandeira / Giant Anteater	Am, MA, Ce, Ca, Pt, Pp		V, Io, I	L3, L5, L6, 3, 4, 5, 9, 12, 13, 14, 15
<i>Tamandua tetradactyla</i> (Linnaeus, 1758)		Mambira / Tamandua	Am, MA, Ce, Ca, Pt, Pp		V, Io, I	L2, L3, L6, 1, 2, 3, 4, 5, 6, 7, 8, 10, 12, 13, 14, 15
CINGULATA						
Dasypodidae						
<i>Cabassous unicinctus</i> (Linnaeus, 1758)		Tatu-rabo-de-couro / Southern Naked-tailed Armadillo	Am, MA, Ce, Ca, Pt		Io, I	L3, L5, L6, 3, 4, 5, 7, 9, 13, 14, 15
<i>Dasytus kappleri</i> ¹ Krauss, 1862		Tatu-quinze-quilos / Greater Long-nosed Armadillo	Am		Io, I	L4, L6, 3, 4
<i>Dasytus novemcinctus</i> Linnaeus, 1758		Tatu-comum / Nine-banded Armadillo	Am, MA, Ce, Ca, Pt, Pp		V, Io, I	L2, L3, L5, L6, 1, 3, 4, 5, 6, 7, 8, 9, 12, 13, 14, 15
<i>Dasytus septemcinctus</i> Linnaeus, 1758		Tatu-xina / Seven-banded Armadillo	Am, MA, Ce, Ca, Pt, Pp		V, Io, I	L3, L5, 4, 5, 7, 12, 13, 14, 15

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<i>Euphractus sexcinctus</i> (Linnaeus, 1758)		Tatu-peba / Six-banded Armadillo	Am, MA, Ce, Ca, Pt, Pp		V, Io, I	L2, L3, L5, L6, 1, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14, 15
<i>Priodontes maximus</i> (Kerr, 1792)	VU	Tatu-canastra / Giant Armadillo	Am, MA, Ce, Pt		Io, I	L3, L5, L6, 3, 4, 11, 12, 13
<i>Tolypeutes tricinctus</i> (Linnaeus, 1758)	EN	Tatu-bola-da-caatinga / Brazilian Three-banded Armadillo	Ce, Ca	x	Io, I	L3, L4, L5, 7, 13
PRIMATES						
Aotidae						
<i>Aotus azarae infulatus</i> (Kuhl, 1820)		Quatro-olhos / Feline Night Monkey	Am	x	V, Io, I	L3, L6, 3, 4, 5, 7, 11, 13, 14, 15
Atelidae						
<i>Alouatta ululata</i> Elliot, 1912	EN	Capelão / Maranhão Red-handed Howler Monkey	Am, Ca	x	V, Io, I	L2, L3, 3
<i>Alouatta belzebul</i> (Linnaeus, 1766)	VU	Capelão / Red-handed Howler Monkey	Am, MA	x	V, Io, I	L3, L6, 3, 4, 5, 6, 12, 13, 14, 15
<i>Alouatta caraya</i> (Humboldt, 1812)		Capelão / Black-and-Gold Howler Monkey	MA, Ce, Ca, Pt, Pp		V, Io, I	L6, 14
Callitrichidae						
<i>Callithrix jacchus</i> (Linnaeus, 1758)		Soim / Common Marmoset	MA	x	V	L2, L3, 5, 6, 7, 8, 9, 10, 11, 12, 13
<i>Saguinus niger</i> (É. Geoffroy, 1803)	VU	Soim / Black-handed Tamarin	Am	x	V	L6, 3, 4, 15
Cebidae						
<i>Cebus kaapori</i> Queiroz, 1992	CR	Cairara / Ka'apor Capuchin	Am	x	V, Io, I	L6, 3
<i>Sapajus apella</i> (Linnaeus, 1758)		Macaco-prego / Guianan Brown Tufted Capuchin	Am		V, Io, I	L2, L3, L6, 1, 3, 4, 6, 7, 8, 14, 15
<i>Sapajus libidinosus</i> (Spix, 1823)		Macaco-prego / Bearded Capuchin	MA, Ce, Ca	x	V, Io, I	5, 12, 13
<i>Saimiri sciureus</i> (Linnaeus, 1758)		Mão-de-ouro / Common Squirrel Monkey	Am		V, Io, I	L3, L6, 1, 3, 4, 14, 15
Pitheciidae						
<i>Chiropotes satanas</i> (Hoffmannsegg, 1807)	CR	Cuxiú-preto / Black Saki	Am	x	V, Io, I	L6, 3, 4
CARNIVORA						
Canidae						
<i>Cerdocyon thous</i> (Linnaeus, 1766)		Raposa / Crab-eating Fox	MA, Ce, Ca, Pt, Pp		V, Io, I	L2, L3, L6, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15
<i>Chrysocyon brachyurus</i> (Illiger, 1815)	VU	Lobo-guará / Maned Wolf	Ce, Pt, Pp		Io, I	L3, 4, 12, 13, 14, 15
<i>Lycalopex vetulus</i> (Lund, 1842)	VU	Raposa / Hoary Fox	Ce, Pt	x	V, Io, I	L3, 5, 7, 9, 10, 11, 12, 13, 14, 15
<i>Speothos venaticus</i> (Lund, 1842)	VU	Cachorro-do-mato / Bush Dog	Am, MA, Ce, Pt		V, I	L3, L6, 3, 4, 7, 12, 13, 14, 15
Procyonidae						
<i>Nasua nasua</i> (Linnaeus, 1766)		Quati / South American Coati	Am, MA, Ce, Ca, Pt, Pp		V, Io, I	L2, L3, L6, 1, 2, 3, 4, 5, 6, 7, 8, 12, 13, 14, 15
<i>Potos flavus</i> (Schreber, 1774)		Macaco-da-meia-noite / Kinkajou	Am, MA, Ce		I	L6, 3, 4
<i>Procyon cancrivorus</i> (G. Cuvier, 1798)		Guaxinim / Crab-eating Raccoon	Am, MA, Ce, Ca, Pt, Pp		V, Io, I	L2, L3, L6, 1, 3, 4, 5, 6, 7, 9, 11, 12, 13, 14, 15
Mustelidae						
<i>Eira barbara</i> (Linnaeus, 1758)		Papa-mel / Tayra	Am, MA, Ce, Ca, Pt		V, I	L3, L6, 3, 4, 5, 7, 12, 13, 14, 15
<i>Galictis cuja</i> (Molina, 1782)		Furão / Lesser Grison	MA, Ce, Ca, Pp		C, V, Io, I	L3, L6, 3, 4, 5, 7, 12, 13, 15

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Maranhão's non-volant mammals

Continuation...

<i>Galictis vittata</i> (Schreber, 1776)		Furão / Greater Grison	Am, MA, Ce, Ca, Pt	V, Io, I	L6, 3, 14
<i>Lontra longicaudis</i> (Olfers, 1818)		Lontra / Neotropical Otter	Am, Ma, Ce, Pt, Pp	V, I	L2, L3, L6, L7, 3, 4, 5, 6, 7, 9, 11, 12, 13, 14, 15
<i>Pteronura brasiliensis</i> (Gmelin, 1788)	VU	Ariranha / Giant Otter	Am, MA, Ce, Pt	V, Io, I	L6, L9, 3, 4, 7
Mephitidae					
<i>Conepatus semistriatus</i> ² (Boddaert, 1785)		Gambá / Striped Hog-nosed Skunk	Am, MA, Ce, Ca, Pt	C, V, I	L3, L4, L6, 3, 5, 9, 12, 13, 14
Felidae					
<i>Leopardus pardalis</i> (Linnaeus, 1758)		Maracajá-verdadeiro / Ocelot	Am, MA, Ce, Ca, Pt, Pp	V, Io, I	L2, L3, L6, 1, 2, 3, 4, 5, 6, 7, 8, 10, 12, 13, 14, 15
<i>Leopardus tigrinus</i> (Schreber, 1775)	EN	Maracajá-í / Northern tiger cat	Am, MA, Ce, Ca, Pt, Pp	V, Io, I	L2, L3, L6, 3, 4, 5, 6, 7, 9, 10, 12, 13, 14, 15
<i>Leopardus wiedii</i> (Schinz, 1821)	VU	Maracajá-peludo / Margay	Am, MA, Ce, Ca, Pt, Pp	C, V, Io, I	L3, L6, 3, 4, 5, 7, 10, 13, 14, 15
<i>Leopardus colocola</i> (Molina, 1782)	VU	Gato-palheiro / Pampas cat	Ce, Pt, Pp	V, I	L3, 5, 10, 11, 12, 13, 14, 15
<i>Panthera onca</i> (Linnaeus, 1758)	VU	Onça-pintada/preta / Jaguar	Am, MA, Ce, Ca, Pt, Pp	Io, I	L3, L6, 3, 4, 5, 7, 9, 11, 12, 13, 14, 15
<i>Puma concolor</i> (Linnaeus, 1771)	VU	Onça-vermelha / Cougar	Am, MA, Ce, Ca, Pt, Pp	V, Io, I	L3, L6, 3, 4, 5, 7, 12, 13, 14, 15
<i>Herpailurus yagouaroundi</i> (É. Geoffroy, 1803)	VU	Gato-mourisco / Jaguarundi	Am, MA, Ce, Ca, Pt, Pp	V, I	L2, L3, L6, 2, 3, 4, 5, 6, 7, 11, 12, 13, 14, 15
PERISSODACTYLA					
Tapiridae					
<i>Tapirus terrestris</i> (Linnaeus, 1758)	VU	Anta / South American Tapir	Am, MA, Ce, Ca, Pt	V, Io, I	L3, L6, 3, 4, 12, 13, 14, 15
ARTIODACTYLA					
Tayassuidae					
<i>Tayassu pecari</i> (Link, 1795)	VU	Queixada / White-lipped Peccary	Am, MA, Ce, Ca, Pt, Pp	V, Io, I	L3, L6, 3, 4, 12, 13, 14, 15
<i>Pecari tajacu</i> (Linnaeus, 1758)		Caititu / Collared Peccary	Am, MA, Ce, Ca, Pt, Pp	V, Io, I	L2, L3, L6, 3, 4, 5, 6, 7, 12, 14, 15
Cervidae					
<i>Blastocerus dichotomus</i> (Illiger, 1815)	VU	Suçupara / Marsh Deer	Ce, Pt	Io, I	L3, 13, 14
<i>Mazama americana</i> (Erxleben, 1777)		Veado-mateiro / South American Red Brocket	Am, MA, Ce, Pt	V, I	L3, L6, 3, 4, 5, 7, 12, 13, 14, 15
<i>Mazama gouazoubira</i> (G. Fischer, 1814)		Veado-catingueiro / South American Brow Brocket	Am, MA, Ce, Ca, Pt, Pp	V, I	L2, L3, L6, 3, 4, 5, 6, 7, 12, 13, 14, 15
<i>Mazama nemorivaga</i> (F. Cuvier, 1817)		Veado-foboca / Amazonian Brown Brocket Deer	Am	V, I	4
<i>Ozotoceros bezoarticus</i> (Linnaeus, 1758)	VU	Veado-galheiro / Pampas Deer	Ce, Pt, Pp	Io, I	L3, 4, 12, 13, 14
RODENTIA					
Sciuridae					
<i>Sciurus aestuans</i> Linnaeus, 1766		Quatipuru / Brazilian Squirrel	Am	C	L3, L6, L8, 3, 4, 5, 7, 14, 15
Cricetidae					
<i>Calomys expulsus</i> ³ (Lund, 1841)		Rato-do-chão / Caatinga Laucha	Ce, Ca	x C	L3, 4, 7, 9, 10, 11, 12, 13, 14, 15
<i>Cerradomys scotti</i> (Langguth & Bonvicino, 2002)		Rato-do-mato / Lindbergh's Rice Rat	Ce, Pt	C	L3, 5, 9, 10, 11, 13, 14, 15
<i>Hylaeamys megalcephalus</i> (G. Fischer, 1814)		Rato-do-mato / Azara's Broad-headed Rice Rat	Am, MA, Ce, Pt	C	L8, 5, 9, 12

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<i>Holochilus sciureus</i> Wagner, 1842		Rato-d'água / Amazonian Marsh Rat	Am, Ce, Ca		C	L6, 1, 2, 3, 11
<i>Necomys lasiurus</i> (Lund, 1841)		Rato-do-mato / Hairy-tailed Akodont	Am, MA, Ce, Ca, Pt, Pp		C	L3, L6, 1, 3, 4, 7, 8, 11, 12, 13, 14
<i>Nectomys rattus</i> (Pelzeln, 1883)		Rato-d'água / Amazonian Water Rat	Am, Ce, Ca, Pt		C	L3, L6, L8, 3, 4
<i>Oecomys cf. bicolor</i> (Tomes, 1860)		Rato-da-árvore / White-bellied Arboreal Rice Rat	Am, Ce, Pt		C	L3, L6, 3, 4, 5, 9, 11, 12, 13
<i>Oligoryzomys cf. nigripes</i> (Olfers, 1818)		Rato-do-mato / Black-footed Colilargo	MA, Ce, Ca, Pt, Pp		C	L6, L8, 1, 3, 4, 5, 9, 10, 11, 12, 14
<i>Rhipidomys emiliae</i> (J. A. Allen, 1916)		Rato-da-árvore / Eastern Amazon Climbing Mouse	Am	x	C	L3, L6, L8, 3, 4, 9, 13
<i>Rhipidomys cf. macrurus</i> (Gervais, 1855)		Rato-da-árvore / Long-tailed Climbing Mouse	Ce, Ca	x	C	5, 10, 14
<i>Thalpomys cf. lasiotis</i> (Thomas, 1916)		Rato-do-chão / Hairy-eared Mouse	Ce	x	C	13
<i>Wiedomys pyrrhorhinos</i> (Wied-Neuwied, 1821)		Rato-de-fava / Red-nosed Mouse	Ca	x	C	9, 10, 11
Caviidae						
<i>Galea spixii</i> (Wagler, 1831)		Preá / Spix's Yellow-toothed Cavy	Am, MA, Ce, Ca, Pt		V, I	L3, L6, 1, 3, 4, 5, 6, 7, 13, 14, 15
<i>Hydrochaeris hydrochaeris</i> (Linnaeus, 1766)		Capivara / Capybara	Am, MA, Ce, Ca, Pt, Pp		V, Io, I	L3, L6, L8, 2, 3, 4, 5, 12, 13, 14, 15
<i>Kerodon rupestris</i> (Wied-Neuwied, 1820)	VU	Mocó / Rock Cavy	Ca	x	V, I	L3, L4, 9, 11, 12, 13, 14
Cuniculidae						
<i>Cuniculus paca</i> (Linnaeus, 1766)		Paca / Spotted Paca	Am, MA, Ce, Ca, Pt, Pp		V, Io, I	L2, L3, L6, 1, 2, 3, 4, 5, 6, 7, 9, 11, 12, 13, 14, 15
Dasyproctidae						
<i>Dasyprocta prymnolopha</i> Wagler, 1831		Cutia / Black-rumped Agouti	Am, MA, Ce, Ca	x	V, Io, I	L2, L3, L6, L8, 1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14, 15
Erethizontidae						
<i>Coendou prehensilis</i> (Linnaeus, 1758)		Ouriço, porco-espinho / Brazilian Porcupine	Am, MA, Ce, Ca, Pt		V, Io, I	L4, L6, 3, 4, 5, 7, 9, 10, 11, 12, 13, 14, 15
Echimyidae						
<i>Dactylomys cf. dactylinus</i> (Desmarest, 1817)		Toró, rato-do-bambu / Amazon Bamboo Rat	Am		C, V, I	L4, L6, L8, 3, 4, 15
<i>Echimyus chrysurus</i> (Zimmermann, 1780)		Rato-da-árvore / White-faced Spiny Tree-rat	Am		C, V	L1, L3, L4, L6, L8, 3, 4, 7
<i>Makalata cf. didelphoides</i>		Rato-coró / Red-nosed Armored Tree-rat	Am		C, I	L3, L6, L8, 1, 3, 4, 5, 9, 13, 15
<i>Proechimys roberti</i> Thomas, 1901		Rato-de-espino / Robert's Spiny-rat	Am, Ce	x	C, I	L3, L6, L8, 1, 2, 3, 4, 5, 7, 9, 12, 13, 14, 15
<i>Thrichomys laurentius</i> (Thomas, 1904)		Punaré, rabudo / São Lourenço's Punaré	MA, Ca	x	C, I	L3, 5, 7, 8, 10, 11, 12, 13, 14
LAGOMORPHA						
Leporidae						
<i>Sylvilagus brasiliensis</i> (Linnaeus, 1758)		Coelho, tapeti / Tapeti	Am, MA, Ce, Ca, Pt, Pp		V, Io, I	L3, L6, 3, 4, 5, 7, 9, 11, 12, 13, 14, 15

Legend: Species under taxonomic revision: ¹ = *Dasypus beniensis* (Feijo & Cordeiro-Estrela 2016); ² = *Conepatus amazonicus* (Feijó & Langguth 2013); ³ = *Calomys mathevii* (Gurgel-Filho et al. 2015); Threat category (ICMBio, 2018): CR = Critically Endangered, EN = Endangered, VU = vulnerable; Biome: Am = Amazon, MA = Mata Atlântica/Atlantic Forest, Ce = Cerrado, Ca = Caatinga, Pt = Pantanal, Pp = Pampas; End BR = Endemic to Brazil; Type of Record: C = capture, V = direct observation/camera-trap, Io = indirect observation/tracks or remains, I = Interview; Sampling locations: L1 = Oliveira & Mesquita (1998), L2 = Oliveira & Bogéa (2004), L3 = Oliveira et al. (2007a), L4 = Oliveira et al. (2007b), L5 = Gardner et al. (2008), L6 = Oliveira et al. (2011), L7 = Mesquita & Meneses (2015), L8 = Patton et al. (2015), L9 = Prist et al. (2017), 1 = Ilha de São Luís, 2 = Baixada Maranhense, 3 = Região do Gurupi, 4 = Região do Bico do Papagaio e adjacências, 5 = Região dos cocais, 6 = Região dos Lençóis Maranhenses, 7 = Cerrados de Urbano Santos/MA, 8 = Região de Coelho Neto/MA, 9 = Região de São Francisco do Maranhão, 10 = Região de Barão de Grajaú/MA, 11 = Região de Benedito Leite/MA, 12 = Região de Tasso Fragoso/MA, 13 = Parque Estadual do Mirador, 14 = Região de Estreito-Carolina/MA, 15 = Região de Porto Franco/MA.

Maranhão's non-volant mammals

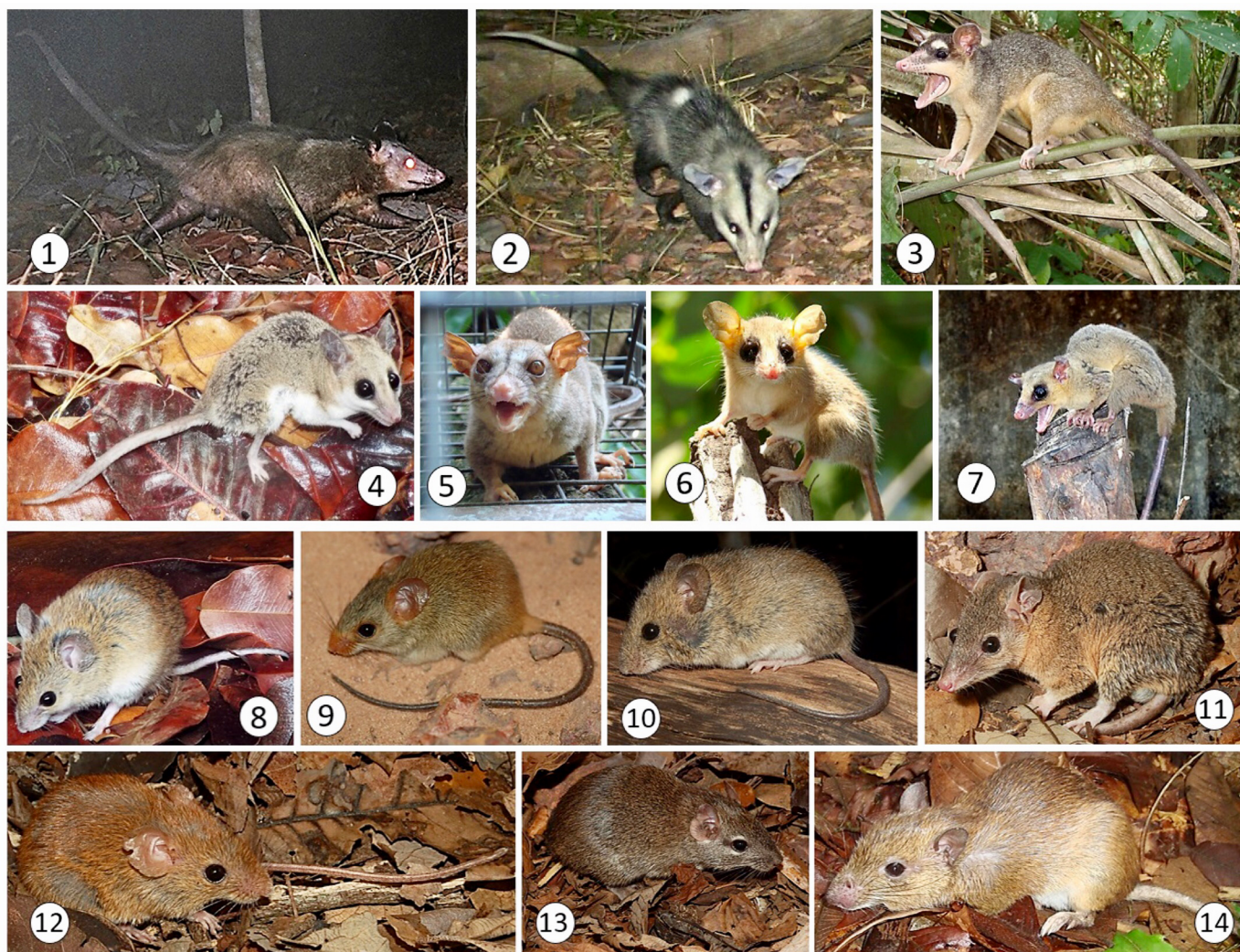


Figure 2. Records of small non-volant mammalian species in Maranhão state, Brazil. 1 = *Didelphis marsupialis*, 2 = *Didelphis albiventris*, 3 = *Phylander opossum*, 4 = *Thylamys karimii*, 5 = *Caluromys philander*, 6 = *Gracilinanus agilis*, 7 = *Marmosa (Micoureus) demerarae*, 8 = *Thalpomys cf. lasiotis*, 9 = *Wiedomys pyrrhorhinos*, 10 = *Calomys expulsus*, 11 = *Monodelphis domestica*, 12 = *Cerradomys scotti*, 13 = *Thrichomys laurentius*, 14 = *Proechimys roberti*

the evidence considered in elaborating the resulting checklist, it is likely that the actual species richness of non-volant mammals for the state of Maranhão is somewhat greater than what is reported here.

Compared to previously published information, the checklist based on the current assessment adds 4 unique records for the state of Maranhão. Oliveira et al. (2007a, 2011) listed 82 species as occurring in Maranhão, while Lima (2009) added one important record of *Tolypeutes tricinctus*, species present in the Nascentes do Rio Parnaíba National Park, the area of which is mostly located within the state boundary of Piauí state and extends into just a small part of Maranhão. Although less representative quantitatively, Oliveira & Mesquita (1998), Oliveira & Bogéa (2004), Oliveira et al. (2007b), Gardner (2008), Mesquita & Meneses (2015), Prist et al. (2017) and Patton et al. (2015) were also consulted, corroborating the occurrence of the species already described for some of the study locations. The last two of these publications represent complete taxonomic revisions and result from international collaborations to most accurately define the identification, distribution and taxonomy of South American mammal species as a whole.

Non-volant mammal species richness in Maranhão in the Amazon (N = 65) and Cerrado (N = 66) regions of Maranhão is similar. This represents 16.3% and 26.3% respectively, of the total species diversity for this group at the national level. Nineteen species were recorded at more than 10 of the study sites, corroborating their characterization as generalists occurring in all of dominant landscapes of Maranhão. Among the 16 that Paglia et al. (2012) listed as being exclusive to the Amazon (Table 2), only *Choloepus didactylus*, *Cebus kaapori*, *Chiropotes satanas*, *Mazama nemorivaga* and *Marmosops cf. parvidens* were recorded exclusively in the Amazonian portion of the state. *Didelphis marsupialis*, *Sapajus apella*, *Aotus azarae infulatus*, and *Sciurus aestuans* were recorded outside the Amazon domain, thus confirming their expected presence in forested areas beyond the Amazon-Cerrado ecotone (Feijó & Langguth 2013, Pinto & Roberto, 2016, Lima et al. 2017, Patton et al. 2015). *Rhipidomys emiliae*, *Dactylomys cf. dactylinus* and *Makalata cf. didelphoides* complete the list of Amazonian species recorded in forested areas within savanna landscapes, thus highlighting the role of these forests as corridors that allow the expansion of small Amazonian mammals into the Cerrado (Redford & Fonseca 1986, Costa 2003, Carmignotto 2005).



Figure 3. Records of medium and large non-volant mammalian species in Maranhão state, Brazil. 1 = *Tamandua tetradactyla*, 2 = *Myrmecophaga tridactyla*, 3 = *Priodontes maximus*, 4 = *Dasypus novemcinctus*, 5 = *Cyclops didactylus*, 6 = *Eira barbara*, 7 = *Lycalopex vetulus*, 8 = *Cerdocyon thous*, 9 = *Speothos venaticus*, 10 = *Nasua nasua*, 11 = *Procyon cancrivorus*, 12 = *Conepatus semistriatus*, 13 = *Galictis cuja*, 14 = *Galictis vitatta*, 15 = *Lontra longicaudis*, 16 = *Leopardus colocola*, 17 = *Herpailurus yagouaroundi*, 18 = *Puma concolor*, 19 = *Leopardus wiedii*, 20 = *Leopardus tigrinus*, 21 = *Leopardus pardalis*, 22 = *Panthera onca*, 23 = *Sapajus apella*, 24 = *Aotus azarae infulatus*, 25 = *Chiropotes satanas*, 26 = *Cebus kaapori*, 27 = *Alouatta caraya*, 28 = *Callithrix jacchus*, 29 = *Saguinus niger*, 30 = *Ozotoceros bezoarticus*, 31 = *Mazama americana*, 32 = *Mazama gouazoubira*, 33 = *Tayassu pecari*, 34 = *Pecari tajacu*, 35 = *Tapirus terrestris*, 36 = *Dasyprocta prymnolopa*, 37 = *Cuniculus paca*, 38 = *Coendou prehensilis*, 39 = *Hydrochaeris hydrochaeris*

Table 3. Comparison of non-volant mammal species richness for recent in Brazil and the states of Maranhão (MA), Mato Grosso do Sul (MS), Mato Grosso (MT), São Paulo (SP), Rio de Janeiro (RJ) and Santa Catarina (SC).

Order	Brazil		State					
	Paglia et al. (2012)	Quintela et al. (in press)	MA	MS	MT	SP	RJ	SC
Didelphimorphia	55	59	13	17	31	24	14	17
Pilosa	8	12	5	2	5	3	4	4
Cingulata	11	12	7	7	9	5	5	5
Primates	118	125	11	6	26	10	9	3
Carnivora	33	35	20	20	21	17	17	26
Perissodactyla	1	2	1	1	1	1	1	1
Artiodactyla	10	10	7	6	7	8	4	7
Rodentia	234	255	24	33	67	58	49	54
Lagomorpha	1	2	1	1	1	1	1	1
Total	471	512	89	93	168	127	104	118

MA = this paper; MS = Tomas et al. (2017); MT = Brandão et al. (2019); SP = Vivo et al. (2011); RJ = Rocha et al. (2004); SC = Cherem et al. (2004);

Echymys chrysurus is the last Amazonian species to reach the forest formations in the Cerrado biome, between the municipalities of Urbano Santos and Vargem Grande, clearly because of the deciduous forests in that region (Oliveira & Mesquita, 1998).

Maranhão state houses 20 species endemic to Brazil (Table 2). It is worth noting the case of Primates, with four out of five species being associated to the Amazonian portion of the state, which currently faces a critical conservation outlook (Oliveira et al. 2011). *Cebus kaapori* and *Chiropotes satanas* were recorded in areas of primary and disturbed forests, besides this they are both rare and highly threatened throughout their range (Almeida & Vieira 2010). *Saguinus niger* has a range similar to *C. kaapori* and *C. satanas* within the state, nevertheless the species was recorded more often in disturbed habitats, and this species tends to be common in anthropic environments (Mendes-Oliveira 1996). *Thylamys karimii*, has been reported on the western portion of Maranhão state in the Bico do Papagaio region, yet its single record was in a marginal portion of that region, in open areas of Cerrado savanna as expected (Carmignotto & Monfort 2006, Gardner 2008). *Lycalopex vetulus* and *Thalomys lasiotis* were recorded only in the Cerrado portion of the state; both species are typically associated to the central Cerrado further south, however *L. vetulus* has been expanding its range towards the north and northeast regions of the country, and the same seems likely for *Thalomys lasiotis* (Marinho-Filho et al. 2002, Dalponte 2009, Lemos et al. 2013). Three species were recorded marginally outside their typical biomes, *Wiedomys pyrrhorhinos*, *Kerodon rupestris* and *Callithrix jacchus*, the first two outside the Caatinga (Oliveira et al. 2003, Gonçalves et al. 2005, Oliveira & Bonvicino 2011), while the last one outside the Atlantic Forest. *C. jacchus* is an introduced species (Da Rosa et al. 2017) that has reached the central part of the Maranhão Babaçú Forest ecoregion, this area has witnessed major habitat destruction particularly in the Itapecuru river basin (Silva Jr. 1999).

Certain species that are most often associated with open habitats in the state, such as *Cerdocyon thous* (recorded at all sampling points), *Lycalopex vetulus* and *Galictis cuja*, showed that their actual distributions can extend beyond the proposed limits of savanna or grassland type environments. Nonetheless, these unusual occurrences may be best explained by the effects of expanding agro-pastoral environments on the displacement of both generalists and highly specialized species, which show some tendencies to disperse from

disturbed areas through open habitat formations (Michalski & Peres 2005, Umetsu & Pardini 2007, Oliveira 2009).

Among the rare species for Maranhão, *Blastocerus dichotomus* stands out with its distribution reaching the southern limits of the state where there are well-preserved areas of Cerrado near Chapada das Mesas and Nascentes do Parnaíba National Parks. *Tolypeutes tricinctus*, a threatened species that is relatively sensitive to anthropogenic disturbances, was documented by means of personal interviews in the region of Urbano Santos and Mirador State Park, though in the latter, it has apparently not been seen for 20 years. *Alouatta ululata* is usually found in open and transitional babaçu forests (Gregori, 2006), yet we recorded this species in the Amazonian region, far west than its known distribution limit. The occurrence of species outside of their proposed distributions, according to the literature, highlights the ecotone effects of the terrestrial environment in Maranhão, which also contributes to the high levels of biodiversity and shows that this transitional zone among several biomes can appear to be much more species rich than when considering these biomes separately (Marimon et al. 2006, Mews et al. 2012, Marimon et al. 2014).

Considering only the list of species, independent of the size of the sampling areas, Oliveira et al. (2010) recorded 57 non-volant mammal species in an inventory of Mato Grosso state, which is also characterized as a transitional area between the Amazon and Cerrado biomes and is located in the middle of a region known as the Amazonian Deforestation Arc for its high deforestation rates. Comparing these biomes separately, an inventory conducted in Amazonia National Park, located in the state of Pará, compiled a list of 86 species in an area 10 times smaller than the territory of Maranhão (Oliveira et al. 2016), while 52 species were registered just in Mirador State Park, which includes only 2% of all Cerrado vegetation occurring in the state of Maranhão (Oliveira et al. 2014).

In spite of the diverse criteria, as well as constant updates to the list, the Amazon and Cerrado biomes support at least 399 and 251 mammal species, respectively (Paglia et al. 2012). However, it is also observed that states closer to major urban centers, and where most researchers are concentrated, register numbers of species close to those observed in the current study. For example, in Mato Grosso do Sul, a very large state territory presenting a diversity of biomes, including Cerrado, Atlantic Forest and Pantanal, Tomas et al. (2017) compiled a list of 93 species. Recently Brandão et al. (2019) listed 168 non-volant mammals for Mato

Grosso, a state straddling the Amazon-Cerrado ecotone. Cherem et al. (2004) elaborated a list of 118 non-volant species occurring in the state of Santa Catarina, while Rocha et al. (2004) documented 104 species for the state of Rio de Janeiro, the latter presenting fewer biomes and fauna typical of Atlantic Forest. In São Paulo, a state with a much greater tradition of executing biological inventories, Vivo et al. (2011) compiled a list of 127 non-volant mammal species, which suggests that the species diversity so far recorded for the state of Maranhão is representative, although with significant gaps in the effort to sample such an enormous habitat diversity as that presented by the two dominant biomes. It should also be mentioned that very few scientific studies of non-volant mammals occurring in the state of Maranhão have been published in the primary literature, with much of the available information on this subject having appeared in unconventional outlets and/or formats, such as technical and research reports, dissertations, theses and congress proceedings with restricted disclosure and dissemination, contributing to our collective lack of comprehensive information about this group of animals.

The interaction between geomorphological and climatic aspects typical of ecotones favors the evolutionary process of genetic and ecological diversification in communities and populations (Brasil, 2007). Thus, the relatively large number of mammal species presented here as occurring in Maranhão is a direct reflection of the state being located in a transitional region between three major biomes, the Amazon, Caatinga and Cerrado. Because of this high-level of species richness and diversity of habitats, Maranhão requires special consideration in conserving the integrity of these dynamic and not very stable environments (Marimon et al. 2014). The presence of such an ecological stress zone would also justify the observation of a non-diminishing west-east trend in species richness, whereby the most diverse mammal communities are located in lowland forests along the Amazon basin to the Andes and less species diversity is characteristic of the drier, more easterly boundaries of the region toward Pará-Maranhão (Eisenberg & Redford, 1999).

Finally, it is noteworthy that Maranhão is currently being subject to intense habitat fragmentation, primarily due to the impacts of expanding commercial farming and livestock activities. The study sites sampled for the current study correspond to habitat remnants that act as vital refuges for non-volant mammals and countless other wildlife species. Considering that landscape integrity is a good indicator of biodiversity, conservation actions in such areas, even fragmented landscapes, are of fundamental importance to the protection of natural resources and the variety of flora and fauna (De Araújo et al. 2016, Brazil 2018). Additional studies of the mammalian fauna of Maranhão, and other parts of the Northeast region of Brazil, are necessary for a better understanding of species diversity, abundance and distribution. The lack of information, both taxonomic and geographical, regarding non-volant mammals of Maranhão also reinforces the need for further work, such as that presented here, which can result in more accessible scientific publications that document the important biodiversity occurring in this rapidly changing landscape.

Supplementary material

The following online material is available for this article:

Table S1 - Specimen identification numbers for individuals that were collected and donated to vertebrate collections at each institution.

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Author Contributions

Ogley Quixaba Vieira: contributed to the conception and design of this study, contribution to data collection data collection, contribution to data analysis and interpretation, contribution to manuscript preparation.

Tadeu Gomes de Oliveira: substantial contribution in the concept and design of the study, contribution to data collection data collection, contribution to data analysis and interpretation, contribution to manuscript preparation, contribution to critical revision, adding intellectual content.

Conflicts of Interest

The authors declares that they have no conflict of interest related to the publication of this manuscript.

Ethics

Data obtained from interviews are in fact reports and accounts from local people without any standardized structure. Some of the data presented were collected starting in 1994 (see Table 1 of paper), which was before the implementation of “Plataforma Brasil” and the Resolution N°466/12/CNS. The later deals with information obtained, partially or wholly, from humans.

Data availability

This research is part of an ongoing doctoral dissertation with the proposed analyses unfinished as of right now. Therefore data archiving in public repositories is partially unavailable at the moment. Notwithstanding, the development of the databases within this research project is being done jointly with the Ecologic-Economic Zoning of Maranhão State project (ZEE Maranhão) using Geographic Information Systems (GIS). As such, some of the data are available for public use on the official website of ZEE Maranhão.

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