Checklist of large and medium-bodied mammals from four areas of Tocantins state, Central Brazil

Lista de espécies de mamíferos de médio e grande porte em quatro áreas no estado do Tocantins, Brasil central

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Abstract: The state of Tocantins is located in Central Brazil. The northern extreme of this state corresponds to the southeastern portion of the Amazon biome, while it is covered primarily by Cerrado savanna, as well as the transition area between these two biomes. We provide a checklist of large- and medium-bodied mammals from four localities in Tocantins, update the list of species for the state, and compile the available information on their geographic distribution. We surveyed mammals at four sites during different periods (between 2010 and 2018), using camera traps and opportunistic observations. In spite of the differences in the sampling effort among the sites, we recorded 42 mammal species belonging to eight orders and 20 families. Our list includes rare and threatened species, such as the jaguar (*Panthera onca*), the giant anteater (*Myrmecophaga tridactyla*), and the lowland tapir (*Tapirus terrestris*). One species (*Galictis cuja*) was recorded in the state for the first time and the known range distribution of two others (*Speothos venaticus* and *Alouatta caraya*) was updated.

Keywords: Camera trapping. Geographic distribution. *Galictis cuja.* Mammalia.

Resumo: O estado do Tocantins está localizado na região central do Brasil, em área de contato entre os biomas Amazônia e Cerrado. O extremo norte do estado corresponde ao bioma amazônico, mas a maior parte do território corresponde ao Cerrado, assim como a áreas de transição entre esses biomas. Fornecemos uma lista de espécies de mamíferos de médio e grande porte de quatro localidades ao longo do estado. Atualizamos a lista de espécies da região e compilamos informações a respeito de suas distribuições geográficas. A amostragem de mamíferos ocorreu em quatro localidades, em diferentes períodos (entre 2010 e 2018). Através do uso de armadilhas fotográficas, obtivemos informações sobre as espécies de mamíferos e também realizamos observações oportunistas nas áreas amostradas. Apesar da diferença de esforço amostral entre as localidades, foi possível registrar considerável diversidade de mamíferos. Foram registrados 42 táxons de mamíferos de médio e grande porte, pertencentes a oito ordens e 20 famílias, incluindo espécies raras e ameaçadas, como a onça-pintada (*Panthera onca*), o tamanduá-bandeira (*Myrmecophaga tridactyla*) e a anta (*Tapirus terrestris*). O furão (*Galictis cuja*) foi registrado pela primeira vez no estado, e a distribuição geográfica de duas espécies (*Speothos venaticus* e *Alouatta caraya*) foi atualizada.

Palavras-chave: Armadilha fotográfica. Distribuição geográfica. *Galictis cuja.* Mammalia.

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INTRODUCTION

The Brazilian state of Tocantins has a total area of 277,600 km^2 and is located in central Brazil, where it is bordered by six other states (Pará, Maranhão, Mato Grosso, Goiás, Piauí, and Bahia). Tocantins is part of the 'MATOBIPA' region, which also includes portions of Maranhão, Piauí, and Bahia states, where the Cerrado savanna has suffered high rates of deforestation for the cultivation of soybean (Carvalho *et al*., 2019). Tocantins encompasses two principal biomes (IBGE, 2004a), the Amazon (tropical forest), in the far north of the state, and the Cerrado (Neotropical savanna), which covers approximately 87% of the state. The Cerrado and Amazon biomes come together in a transition zone, which is characterized by a mosaic of dense and open vegetation, distributed throughout the southern Amazonia, with a highly dynamics vegetation (IBGE, 2004b). In Tocantins, this zone extends over an area of 250 km^2 (Marimon *et al*., 2014; Valadão *et al*., 2016; Marques *et al*., 2019).

The Cerrado biome is considered to be a global hotspot of biodiversity and a priority area for conservation (Myers *et al*., 2000; MMA, 2001), but unfortunately, it is under considerable pressure from farming, wildfires, and the introduction of African grasses, which combine to reduce the diversity of the biome (Klink & Machado, 2005; Marques *et al*., 2019). The Amazon is the richest Brazilian biome for mammalian species, with 399 species and 231 endemic taxa, while the Cerrado is the third richest, with 251 mammal species, of which 32 are endemic (Paglia *et al*., 2012; Percequillo & Gregorin, 2017). Despite its biological relevance, only a limited amount of data is available on the occurrence of the medium- and large-bodied mammal that occur in Tocantins state, and the available species inventories are all restricted to the area of Cerrado (Carmignotto & Aires, 2011; Marinho-Filho *et al*., 2002; Lima *et al*., 2005; Nogueira *et al*., 2011).

Medium- and large-bodied mammals are relatively conspicuous animals, although recent taxonomical reviews (*e.g.*, Bornholdt *et al*., 2013; Mercês *et al*., 2015; Nascimento & Feijó, 2017; Feijó *et al*., 2018) and online database (Percequillo & Gregorin, 2017) indicate that the mammalian diversity of areas of ecological ecotone are underestimated. Here, we present the results of mammal surveys conducted at four sites in Tocantins state between 2010 and 2018, which include one site in the ecotone between the Amazon and Cerrado biomes, and three in the Cerrado. With this, we update the database on the diversity and distribution of mammals in this region and highlight the importance of this area for conservation.

MATERIAL AND METHODS

STUDY AREA

We obtained data from four areas in Tocantins state, with three sampling points at each site (see Figure 1 for map of the localities and coordinates), between 2010 and 2018. The localities are distributed throughout the state, with one located in the northern extreme of the state, encompassing four municipalities: Araguatins, Augustinópolis, Esperantina, and Tocantinópolis - denominated AAET here (fieldwork: 2012–2016); one in the central portion of state, in the municipality of Pedro Afonso (fieldwork: 2010–2012); one in the state's central-eastern portion, in Novo Acordo municipality (fieldwork: 2016–2018), and one in the southeastern extreme of the state, in Arraias municipality (fieldwork: 2011–2014). At AAET, the vegetation is dominated by open rainforest interspersed with enclaves of open vegetation, characteristic of the Amazon-Cerrado ecotone zone. The municipalities of Pedro Afonso, Novo Acordo, and Arraias are dominated by Cerrado savanna.

We considered medium- and large-bodied mammals to include all species with a body mass of greater than 1 kg, thus excluding all relatively small, terrestrial mammals (Benchimol, 2016). However, we did include *Sylvilagus brasiliensis* (Linnaeus,1758) in the species list, because it is commonly detected using the methods adopted in the present study.

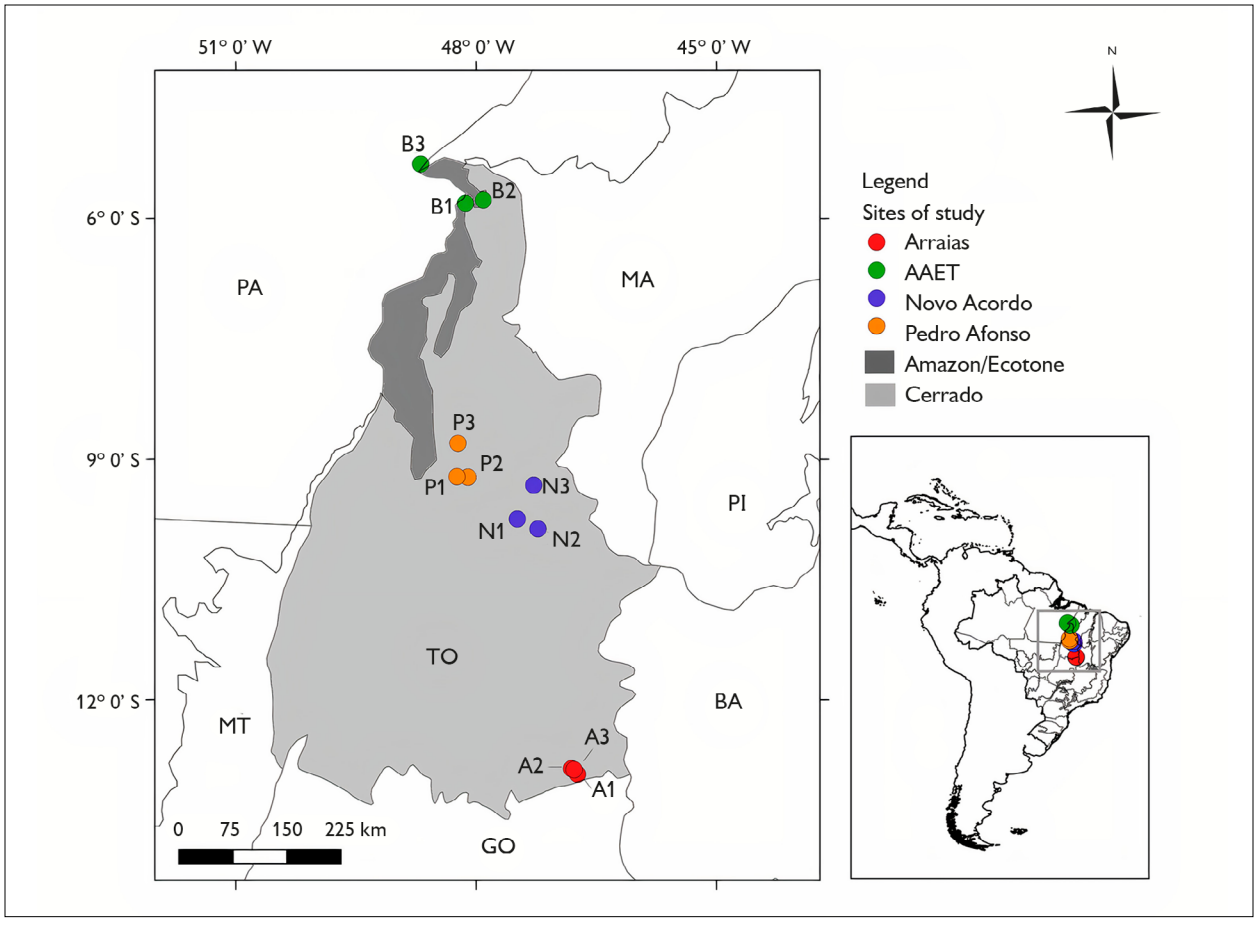

Figure 1. Map of the sites surveyed in the present study. Acronyms: BA = Bahia, GO = Goiás, MA = Maranhão, MT = Mato Grosso, PA = Pará, PI = Piauí, TO = Tocantins. AAET = municipalities of Araguatins, Augustinópolis, Esperantina, and Tocantinópolis (green dots): B1 = Cristalino (5° 48' 35" S, 48° 08' 04" W), B2 = Araguari (5° 46' 08" S, 47° 54' 45" W), B3 = Buriti (5° 12' 37" S, 48° 41' 37" W). Pedro Afonso municipality (orange dots): P1 (9° 13' 35" S, 48° 06' 12" W), P2 = Cana (9° 13' 11" S, 48° 06'12" W), P3 = Tupira (8° 48' 09" S, 48° 13' 42" W). Novo Acordo munipality (purple dots): N1 = Lobo (9° 44' 51" S, 47° 29' 14" W), N2 = Lizarda (9° 52' 12" S, 47° 13'46" W), N3 = Mansinha (9° 19' 30" S, 47° 16' 57" W). Arraias municipality (red dots), A1 = Sítio (12° 55' 53" S, 46° 44' 08" W), A2 = Captação (12° 51' 39" S, 46° 48' 41" W), A3 = GLAPA (12° 52' 23" S, 46° 46' 43" W).

SAMPLING PROCEDURES

We surveyed mammals using camera traps (15 Bushnell® camera traps), which we deployed randomly within each area. In the first year (2010) at Pedro Afonso, we used Tigrinus® analogical traps, but during the subsequent years, we used Bushnell digital traps. We installed the traps at approximately 45 cm above the ground in different habitats, prioritizing sites such as dirt roads, tracks, and sources of food (*e.g.*, fruiting trees), and water. The cameras were programmed to operate 24 hours per day, with an interval of 5 seconds between each record during each sequence, and no more than three photographs from any given event. Total sampling effort at each site was calculated as: the number of camera traps × the number of sampling days (1 d = 24 h) x number of field surveys. Camera-trapping provides is a non-invasive tool that permits the detection of many mammals, including cryptic species, under most field conditions (Srbek-Araujo & Chiarello, 2005; Tobler *et al.*, 2008). The geographical coordinates of each camera trap site were recorded using a handheld GPS.

We also obtained opportunistic records during each survey, including photographs and indirect evidence of the presence of mammals, such as tracks, feces, and carcasses. While these records were included in the inventory, the sampling effort cannot be quantified.

We identified all the photographs and informal records to the lowest possible taxonomic level, adopting the nomenclature proposed by Paglia *et al*. (2012), with modifications for some groups (as follows). We considered Acosta *et al*. (2020) for the family Tayassuidae, Nascimento (2010) and Nascimento & Feijó (2017) for the genus *Leopardus* Gray, 1842, the review of Bornholdt *et al*. (2013) for the genus *Galictis* Bell, 1826, and Patton & Emmons (2015) for *Dasyprocta* Illiger, 1811. In the case of the primates, we followed Rylands *et al*. (2013) and Schneider & Sampaio (2015) for all genera except *Saimiri* Voigt, 1831, where we adopt the classification of Mercês *et al*. (2015). We also adopted Merino & Rossi (2010) for the genus *Mazama* Rafinesque, 1817, Feijó *et al*. (2018) for *Dasypus* Linnaeus, 1758, and Feijó & Langguth (2013) for *Cabassous* McMurtrie, 1831.

We considered the data available at IUCN web site (IUCN, 2020) for the global conservation status of each species, except in the case of *Saimiri*, for which we had access to the latest assessment (IUCN SSC Primate Specialist Group, 2015). For the Brazilian conservation status, we considered the list of threatened mammal species of Brazil published by ICMBio (2018).

DATA ANALYSIS

We compiled species rarefaction curves in EstimateS, version 9.1 (Colwell *et al*., 2012), from the number of camera trap records collected in each study area, with a species richness estimator based on 1,000 randomizations. These curves represent the cumulative number of species recorded after a given sampling effort (number of field surveys). We selected the Jackknife 2 estimator to calculate expected richness because it provides the most reliable results for communities with low species equitability, as observed in the present study (Brose *et al*., 2003).

RESULTS & DISCUSSION

Sampling effort consisted of 300 camera-days (six field trips) at AAET and Novo Acordo, 1800 camera-days (12 field trips) at Pedro Afonso, and 1050 camera-days (seven field trips) at Arraias. The rarefaction curves obtained for all four study areas (Figure 2) were still rising slightly by the end of the sampling period, which indicates that the number of species recorded during the study is lower than that estimated for each area. That is, the camera traps did not record all the species expected to occur in each area. Only one primate, the bearded capuchin, *Sapajus libidinosus* (Spix, 1823), was recorded by a camera trapping, while all the other primate species were recorded by visual observations.

SPECIES RICHNESS AND TAXONOMIC GROUPS

We recorded a total of 42 taxa of large- and medium-bodied mammals in the four study areas in Tocantins state (Table 1), distributed in the following orders: Artiodactyla (5 species), Carnivora (16 species), Cingulata (5 species), Lagomorpha (1 species), Perissodactyla (1 species), Pilosa (3 species), Primates (5 species), and Rodentia (6 species). Fifteen species were only observed at the Cerrado localities, while three (*Bradypus variegatus* Schinz, 1825, *Alouatta belzebul* (Linnaeus, 1766), and *Saimiri collinsi* Osgood, 1916) were exclusive to the ecotone site.

Our data from the Cerrado localities indicated the presence of 38 taxa (Table 1). This number is much higher than 17 medium- and large-bodied mammalian species recorded by Carmignotto & Aires (2011) in the Cerrado of Tocantins state, but similar to the 36 species recorded by Lima *et al*. (2005), also in Tocantins.

The species richness of the AAET (22 species) correspond to approximately ~56 % of the terrestrial mammalian fauna recorded at four localities in northeastern Pará state by Stone *et al*. (2009). This difference may be related to relatively reduced sampling effort at AAET, as well as the fact that Pará state study was conducted in Amazon forest proper, rather than the ecotonal environment of the AAET.

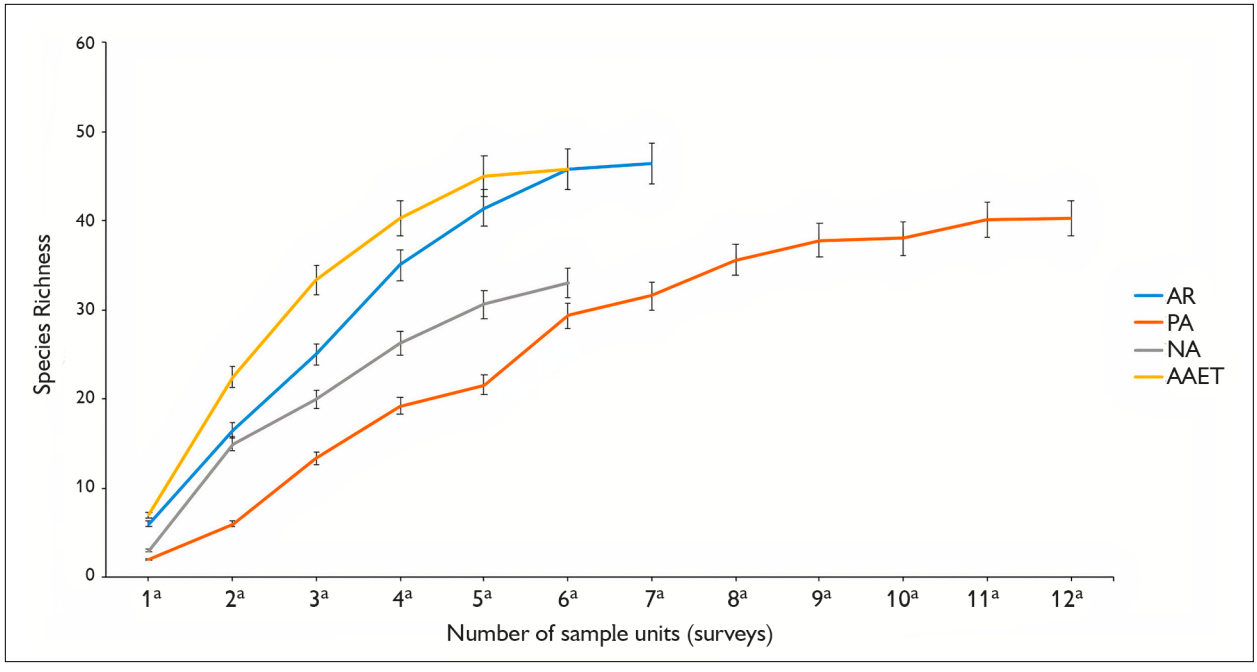

Figure 2. Species accumulation curves based on the rarefaction approach for the four localities in the Tocantins state (Brazil), surveyed in the present study by the camera trapping. AAET (yellow) = Araguatins, Augustinópolis, Esperantina, and Tocantinópolis municipalities, NA (gray) = Novo Acordo municipality, PA (orange) = Pedro Afonso municipality, AR (blue) = Arraias municipality.

Table 1. Mammal species recorded during the present study in Tocantins state, Brazil, showing the respective locality (AAET = Araguatins, Augustinópolis, Esperantina, and Tocantinópolis; AR = Arraias; PA = Pedro Afonso; NA = Novo Acordo), type of record (CT = Camera Trap; CC = Carcass; VI = Visualization; VOC = Vocalization), and conservation status categories [IUCN and ICMBio - Brazil] (LC = Least Concern; NT = Near Threatened; VU = Vulnerable; E = Endangered; DD = Data deficient). Previous studies in region, sources: 1 = Carmignotto & Aires (2011), 2 = Lima *et al*. (2005), and 3 = Stone *et al*. (2009). (Continue)

Taxa	Localities				Conservation Status		Previous Studies		
	AAET	AR	PA	NA	IUCN	ICMBio	Tocantins[1]	Tocantins[2]	Pará[3]
ARTIODACTYLA									
CERVIDAE									
Mazama americana (Erxleben, 1777)	VI	CT	VI	VI, CT	DD	DD	X	X	X
Mazama gouazoubira (Fischer, 1814)	VI	CT, VI	CT, VI	VI	LC	LC	X	-	X
Blastocerus dichotomus (Illiger, 1815)	-	VI, CT	-	VI	NT	VU	X	-	-
Ozotocerus bezoarticus (Linnaeus, 1758)	-	VI, CT	-	VI	NT	VU	X	-	-
TAYASSUIDADE									
Dicotyles tajacu (Linnaeus, 1758)	CT	CT	VI, CT	CT	LC	LC	-	X	X

Table 1. (Continue)

Taxa	Localities				Conservation Status		Previous Studies		
	AAET	AR	PA	NA	IUCN	ICMBio	Tocantins[1]	Tocantins[2]	Pará[3]
CARNIVORA									
CANIDAE									
Cerdocyon thous (Linnaeus, 1766)	VI, CC	VI, CT	VI, CT	VI, CT	LC	LC	X	X	X
Chrysocyon brachyurus (Illiger, 1815)	VI	VI, CT	VI, CT	VI, CT	NT	VU	X	X	-
Lycalopex vetulus (Lund, 1842)	VI	VI	CT	VI, CC	NT	VU	X	-	-
Speothos venaticus (Lund, 1842)	-	CT	VI	-	NT	VU	-	X	X
MEPHITIDAE									
Conepatus sp.	-	-	-	FP	-	-	-	-	-
MUSTELIDAE									
Eira barbara (Linnaeus, 1758)	-	CT	VI, CT	VI	LC	LC	X	X	X
Galictis cuja (Molina, 1872)	-	-	VI	-	LC	LC	-	-	-
Lontra longicaudis (Olfers, 1818)	-	-	VI	-	LC	LC	-	-	-
FELIDAE									
Herpailurus yagouaroundi (É. Geoffroy Saint-Hilaire, 1803)	-	CT	CT	FP	LC	LC	-	X	X
Leopardus braccatus (Cope, 1889)	-	CT	-	VI	NT	VU (=*L. colocolo*	-	-	-
Leopardus emiliae (Thomas, 1914)	CT	CT	VI, CT	-	-	-	X (= *L. tigrinus*)	X (= *L. tigrinus*)	-
Leopardus pardalis (Linnaeus, 1758)	-	CT	VI, CT	-	LC	LC	-	X	X
Panthera onca (Linnaeus, 1758)	-	-	CT	-	NT	VU	-	X	X
Puma concolor (Linnaeus, 1771)	VI	CT	VI, CT	FP	LC	VU	X	X	X
PROCYONIDAE									
Nasua nasua (Linnaeus, 1766)	VI, CC	VI, CT	VI, CT	VI, FP	LC	LC	-	X	X
Procyon cancrivorus (Cuvier, 1798)	FP	CT	VI, CT	VI, FP	LC	LC	-	X	-
CINGULATA									
DASYPODIDAE									
Dasypus novemcinctus Linnaeus, 1758	VI	CT	VI, CT	CT	LC	LC	-	X	X

Table 1. (Continue)

Taxa	Localities				Conservation Status		Previous Studies		
	AAET	AR	PA	NA	IUCN	ICMBio	Tocantins[1]	Tocantins[2]	Pará[3]
Dasypus septemcinctus Linnaeus, 1758	-	-	VI	VI	LC	LC	-	X	X
CHLAMYPHORIDAE									
Cabassous tatouay (Desmarest, 1804)	-	-	VI	VI	LC	DD	-	-	-
Cabassous unicinctus (Linnaeus, 1758)	-	-	VI	-	LC	LC	X	X	X
Euphractus sexcinctus (Linnaeus, 1758)	VI	VI, CT	VI	CC	LC	LC	-	X	X
LAGOMORPHA									
LEPORIDAE									
Sylvilagus brasiliensis (Linnaeus, 1758)	VI	VI	VI	VI	LC	-	-	-	X
PERISSODACTYLA									
TAPIRIIDAE									
Tapirus terrestris (Linnaeus, 1758)	VI, CT	FP	VI, CT	CT, FP	VU	VU	X	X	X
PILOSA									
BRADYPODIDAE									
Bradypus variegatus Schinz, 1825	VI	-	-	-	LC	LC	-	-	X
MYRMECOPHAGIDAE									
Myrmecophaga tridactyla Linnaeus, 1758	-	-	VI, CT	FP	VU	VU	-	X	X
Tamandua tetradactyla (Linnaeus, 1758)	VI	VI, CT	VI	VI	LC	LC	-	X	X
PRIMATES									
ATELIDAE									
Alouatta belzebul (Linnaeus, 1766)	VI	-	-	-	VU	VU	-	-	X
Alouatta caraya (Humboldt, 1812)	-	VI	VI, VOC	VOC	NT	NT	X	X	-
CEBIDAE									
Saimiri collinsi Osgood, 1916	VI	-	-	-	NT	LC	-	-	X (= *S. sciureus*)
Sapajus libidinosus (Spix, 1823)	VI	VI	VI, CT	VI	NT	NT	X (= *C. apella*)	-	-

Table 1. (Conclusion)

Taxa	Localities				Conservation Status		Previous Studies		
	AAET	AR	PA	NA	IUCN	ICMBio	Tocantins[1]	Tocantins[2]	Pará[3]
CALLITHRICHIDAE									
Callithrix penicillata (É. Geoffroy, 1812)	-	VI	VI, VOC	VI	LC	LC	-	X	-
RODENTIA									
CAVIIDAE									
Hydrochoerus hydrochaeris (Linnaeus, 1766)	FP	-	VI	FP	LC	-	X	X	X
CUNICULIDAE									
Cuniculus paca (Linnaeus, 1766)	FP	CT	CT	FP	LC	-	X	X	-
DASYPROCTIDAE									
Dasyprocta leporina (Linnaeus, 1758)	VI	VI, CT	-	-	LC	-	-	X	X
Dasyprocta azarae Lichtenstein, 1823	-	CT	VI, CT	-	DD	-	-	-	-
Dasyprocta sp.	-	-	-	CT	-	-	-	-	-
ERETHIZONTIDAE									
Coendou prehensilis (Linnaeus, 1758)	-	VI	CC	-	LC	-	-	X	X
Species richness	22	29	33	29	-	-	17	36	42

Despite the smaller number of species recorded by Carmignotto & Aires (2011), they did record two species – *Tolypeutes tricinctus* (Linnaeus, 1758) and *Tayassu pecari* (Link, 1795) – which were not observed in the present study. Similarly, Lima *et al*. (2005) registered three species, *Leopardus wiedii* (Schinz, 1821), *Atelocynus microtis* (Sclater, 1883), and *Galictis vittata* (Schreber, 1776), not recorded in the present study. By contrast, we recorded four species – *Galictis cuja* (Molina, 1782), *Cabassous tatouay* (Desmarest, 1804), *Sapajus libidinosus*, and *Saimiri collinsi* – not recorded by either Carmignotto & Aires (2011) or Lima *et al*. (2005).

ARTIODACTYLA

The number of deers and peccaries observed in the present study (n = 5) corresponds to half of the species known to occur in Brazil (Paglia *et al*., 2012). Two of the three even-toed ungulate families found in South America were recorded, that is, the Tayassuidae (one species) and the Cervidae (with three genera and four species). *Mazama americana* (Erxleben, 1777), *Mazama gouazoubira* (Fischer, 1814), and *Dicotyles tajacu* (Linnaeus, 1758), which are widely distributed in Brazil (Black-Décima *et al*., 2010; Gongora *et al.*, 2011; Black-Décima & Vogliotti, 2016), were observed in all localities. While *M. gouazoubira* appears to be substituted by *Mazama nemorivaga* (Cuvier, 1817) in the Amazon biome (Rossi, 2000), this species was not recorded in the present study, even at AAET.

The marsh deer, *Blastocerus dichotomus* (Illiger, 1815), inhabits seasonally flooded areas (Piovezan *et al*., 2010), and the populations observed in the present study, in central Tocantins, are probably isolated by the

advance of agricultural frontiers in the region. The global distribution of the species has declined by 65% in recent years (Weber & González, 2003). The pampas deer, *Ozotocerus bezoarticus* (Linnaeus, 1758), was recorded in the central and southern localities. This species was once widely distributed (González *et al*., 2010, 2016), but habitat loss, especially in open areas of the Cerrado, has led to the isolation of most populations. The two records presented here are thus specially important, considering the fragmentation of the region's populations.

The absence of white-lipped peccary *Tayassu pecari* from all our study sites was unexpected, given that this species has an ample geographic distribution, and has been recorded previously in the east and southeastern of Tocantins (Carmignotto & Aires, 2011; Lima *et al*., 2005). In the Cerrado this peccary has relatively low survival rates due to the fragmentation of its populations, which are better adapted to the conditions available in the Amazon forest (Altrichter *et al*., 2011). The lack of records of *T. pecari* in the present study is unlikely to have been a consequence of inadequate sampling effort, although it is still unclear whether the species is in fact absent from all four study sites.

CARNIVORA

A total of 16 carnivore species were recorded in the present study, which is more than the number observed in the Serra Geral do Tocantins Ecological Station (n = 6) by Carmignotto & Aires (2011) and the 14 species recorded by Stone *et al*. (2009) in northeastern Pará. However, Lima *et al*. (2005) also recorded 16 carnivores in the Serra do Espírito Santo, in the Jalapão region of eastern Tocantins.

Two canid species, the maned wolf, *Chrysocyon brachyurus* (Illiger, 1815), and the hoary fox, *Lycalopex vetulus* (Lund, 1842), were recorded in all four study areas. Both these canids typically inhabit savannas and other open areas and, while northern Tocantins is an area of ecotone, the presence of Cerrado species would not be totally unexpected. In fact, the range of the maned wolf is expanding into deforested areas of the Atlantic Forest (Queirolo *et al*., 2011) and a similar process may be occurring in the southern Amazon.

The bush dog, *Speothos venaticus* (Lund, 1842), a highly cryptic species, was observed only in the Cerrado (Appendix 1). The two records (one camera trap record and one visualization) represent an extension of the known distribution of the bush dog in the Cerrado, toward the center of Tocantins, given that Oliveira (2009a) recorded the species in the eastern extreme of the state.

Three species of the family Mustelidae were recorded in the present study. The lesser grison, *Galictis cuja*, which is much smaller than the greater grison, *Galictis vittata*, could be identified through both direct observations and photographic records (Appendix 2), based on the review of Bornholdt *et al*. (2013). The observer WSP had already observed *G. vittata* in the field, in Amapá state, and was able to identify *G. cuja* through the direct observation of two individuals (possibly a pair) in Pedro Afonso. This observation increases the known distribution (Bornholdt *et al*., 2013) of the species 800 km to the north, to central Tocantins state, and indicates that it occurs in savanna habitat. Oliveira (2009b) observed both *G. vittata* and *G. cuja* in Maranhão state, and proposed that the range of *G. cuja* was expanding due to the clearance of rainforest, which its conversion into open habitats.

The Neotropical otter, *Lontra longicaudis* (Olfers, 1818), is associated with aquatic environments and was recorded near the Bezerra River in Arraias. This species is amply distributed in Brazil, occurring throughout most of Brazil, and appears to be absent only from the semiarid zone the northeastern region, even though the limits of the distribution of the species in this region have yet to be defined (Rheingantz *et al*., 2017). *Lontra longicaudis* nevertheless appears to be tolerant of some level of habitat degradation (Rheingantz *et al*., 2017).

Kasper *et al*. (2009) recorded the Amazonian hog-nosed skunk, *Conepatus semistriatus* (Boddaert, 1785), in

the Brazilian states of Maranhão, Minas Gerais, São Paulo, and Bahia, and in the Federal District, encompassing a large part of the Cerrado. We recorded a single track of *Conepatus* sp. Due to the lack of direct observation and/or photographs we were not able to confirm the identification of the species responsible for this.

We also observed three species of the genus *Leopardus*, the ocelot, *Leopardus pardalis* (Linnaeus, 1758) (Figure 3), which was recorded at two Cerrado sites. This species occurs in a wide variety of habitats, including rainforest, mangrove, savanna, and grassland. The eastern tigrina *Leopardus emiliae* (Thomas, 1914) is a small felid considered to be endemic to Brazil, where it occurs in the Cerrado, Caatinga, Atlantic Forest, and Amazon biomes. We recorded *L. emiliae* in both the ecotone and the Cerrado. The small pampas cat, *Leopardus braccatus* (Cope, 1889), was recorded at two Cerrado localities.

The other felid species recorded in the present study was the jaguarundi, *Herpailurus yagouaroundi* (É. Geoffroy Saint-Hilaire, 1803), which was observed only in the Cerrado. Despite its ample distribution (from Mexico to southern South America) and preference for open areas, this species typically occurs at low densities (Almeida *et al*., 2018).

Figure 3. Camera trap still of an ocelot (*Leopardus pardalis*) taken in Pedro Afonso municipality, Tocantins state, Brazil. Photograph: W. S. de Paula.

CINGULATA

We recorded five armadillos belonging to two families in the present study. These species include both a forest specialist, *Cabassous unicinctus* (Linnaeus, 1758), and open area-generalists – *Dasypus novemcinctus* Linnaeus, 1758, *D. septemcinctus* Linnaeus, 1758, *Cabassous tatouay*, and *Euphractus sexcinctus* (Linnaeus, 1758). *Dasypus novemcinctus* was observed at all four localities (ecotone and Cerrado) through direct observation and camera trap records, while *D. septemcinctus* was recorded only in Cerrado, through direct observation. *Dasypus septemcinctus* occurs in the eastern Amazon and Cerrado, Atlantic Forest, and Caatinga biomes. The two species were identified through diagnostic characters, i.e., number of movable bands, provided by Feijó *et al*. (2018).

Even though *Cabassous unicintus* is a forest-dwelling species, we recorded it in the Cerrado and at the same locality as *C. tatouay* (Pedro Afonso). These two species can be distinguished reliably by the absence of a clear border in the carapace of *C. tatouay* (Figure 4) and by the large size of *C. tatouay* (Feijó & Langguth, 2013).

Figure 4. Specimen of greater naked-tailed armadillo (*Cabassous tatouay*) from Pedro Afonso municipality, Tocantins state, Brazil. Photograph: W. S. de Paula.

PERISSODACTYLA

The lowland tapir, *Tapirus terrestris* (Linnaeus, 1758), is the only species of the order Perissodactyla found in Brazil (Paglia *et al*., 2012). *Tapirus terrestris* was observed in both ecotone and Cerrado areas. This species is classified as vulnerable by the IUCN (Varela *et al*., 2019) and the Brazilian Red List (Medici *et al*., 2018). Our records from all four localities are especially relevant for the conservation of the species, given that they indicate that the species persists in areas under intense anthropogenic pressure.

PILOSA

The Pilosa is represented by three species in the study area, including the giant anteater, *Myrmecophaga tridactyla* Linnaeus, 1758, and the southern tamandua, *Tamandua tetradactyla* (Linnaeus, 1758). These two anteaters were also observed by Lima *et al*. (2005) in the Jalapão region of Tocantins and by Stone *et al*. (2009) in eastern Amazonia, and both species are found in forested and open habitats (Gardner, 2008 [2007]). By contrast, the brown-throated sloth, *Bradypus variegatus*, is an arboreal species found only in forest, and was thus recorded only at AAET (ecotone).

PRIMATES

Three families of Neotropical monkeys were recorded in the present study (Atelidae, Cebidae, and Callitrichidae), comprising four genera and five species. This diversity is not evenly distributed in the state, however. One species, *Callithrix penicillata* (É. Geoffroy, 1812), is endemic to the Cerrado, and was observed only at the central and southeastern sites, while *Sapajus libidinosus* is endemic to both the Cerrado and the Caatinga (Gutiérrez & Marinho-Filho, 2017), and was observed at the ecotone and Cerrado sites. Rylands & Mittermeier (2013) note that *Callithrix penicillata* occurs to the east of the Araguaia River, which includes Tocantins state.

Two of the other species are either endemic to the Amazon biome (*Saimiri collinsi*) or found predominantly (*Alouatta belzebul*) in this biome and other forested environments in northern Brazil (Mercês *et al*., 2018; Gregorin, 2006), and were recorded only in the ecotone, as expected. The fifth species, the black-and-gold howler monkey *Alouatta caraya* (Humboldt, 1812), is the most widespread species of the genus *Alouatta* Lacépède, 1799 (Gregorin, 2006), and inhabits savannas, floodplains, and forests patches in open areas. As expected, *A. caraya* was recorded only in the Cerrado. *Alouatta caraya* and *A. belzebul* can be easily distinguished by the coloration of their pelage, given that *A. caraya* presents sexual dimorphism, with entirely black males and pale-yellow females, while *A. belzebul* is almost entirely black, with reddish coloration, primarily on the hands, feet, and tail (Gregorin, 2006). Our records increase the known distribution of *Alouatta caraya* (Figure 5) within a region that was previously identified as a distributional gap between these two howler species. Gregorin (2006) and Fernandez-Duque *et al*. (2008) recorded *A. caraya* in Mato Grosso and Maranhão, but not in Tocantins, although Cornejo *et al*. (2013) did propose that *A. caraya* may occur in southern Tocantins. Our record nevertheless confirms its occurrence at the three different sites in central and southeastern Tocantins.

Figure 5. Female specimen of black-and-gold howler monkey (*Alouatta caraya*) observed in Arraias municipality, Tocantins state, Brazil. Photograph: W. S. de Paula.

RODENTIA

Four rodent families (Caviidae, Cuniculidae, Dasyproctidae, and Erethizontidae) were confirmed in the study area, representing the largest of the rodents, including six species and four genera. The genera *Hydrochoerus* Brisson, 1762 and *Cuniculus* Brisson, 1762 are represented by widespread species, *H. hydrochaeris* (Linnaeus, 1766) and *C. paca* (Linnaeus, 1766) (Paglia *et al*., 2012).

In the case of the genus *Dasyprocta*, we were able to identify the red-rumped agouti, *Dasyprocta leporina* (Linnaeus, 1758), at two study sites of, one in the ecotone and the other in the Cerrado. This species is widespread in eastern South America, between eastern Amazon basin and the coast of eastern Brazil (Emmons & Reid, 2016). We observed Azara's agouti *Dasyprocta azarae* Lichtenstein, 1823 at two Cerrado sites. This species can be distinguished from *D. leporina* by its homogenous yellow-olivaceous coloration with grayish to blackish grizzling (Patton & Emmons, 2015). A third morphotype was observed at Novo Acordo, but we were unable to identify the species.

We recorded the Brazilian porcupine, *Coendou prehensilis* (Linnaeus, 1758), at two Cerrado sites, which was as expected, given the ample distribution of this species in Brazil, where it inhabits dry forests and savannas (Voss *et al*., 2013).

CONSERVATION

Overall, 12 of the 42 taxa recorded in the present study are classified as vulnerable by either the IUCN (2020) and/or the ICMBio (2018). This represents 26% of the mammalian species richness recorded in the present study, and approximately 9% of the threatened mammals in Brazil (ICMBio, 2018).

The order Carnivora has the highest number of vulnerable species (n = 7), followed by two Artiodactyla (ICMBio, 2018). In our study sites along Tocantins state 23% (IUCN) and 7% (ICMBio) of the species are near threatened. Thus only 9% of the species recorded are vulnerable (IUCN), while for ICMBio evaluation 28% of the species are is this category of threat.

This difference might be related because some of the IUCN data are outdated (*e.g*., *Speothos venaticus*, De Matteo *et al*., 2011) and many more recent evaluations have not yet been published. The number of vulnerable species (ICMBio) was higher in Cerrado (26%, 11 species) than in ecotone (11%, 6 species). This was also observed in species considered least concern with Cerrado (n = 13) and ecotone (n = 9). One species (*Alouatta belzebul*) classified as vulnerable by the ICMBio (2018) was observed only in the ecotone, while six listed as vulnerable [*Blastocerus dichotomus*, *Ozotocerus bezoarticus*, *Speothos venaticus*, *Leopardus braccatus*, *Panthera onca* (Linnaeus, 1758), and *Myrmecophaga tridactyla*] were observed only in the Cerrado. The occurrence of these species highlights the importance of efforts for the conservation of the Cerrado in Tocantins state, in order to maintain their remaining populations.

Tocantins state is one of the Cerrado states with highest rates of deforestation for soybean cultivation (Carvalho *et al*., 2019). This process entails two major threats for Brazilian mammals, habitat loss and fragmentation (Costa *et al*., 2005). One other threat is hunting. De Paula *et al*. (2017) reported the subsistence hunting of 387 individuals of 23 mammal species by a Xerente indigenous community over a 12-month period, with mammals representing 97% of the total biomass obtained (5,878 kg). This exemplifies the direct impact of hunting, without even considering the negative interactions between the region's farmers and the local carnivores, peccaries, and cervids.

We recorded the two largest Neotropical felids, *Panthera onca* and *Puma concolor* (Linnaeus, 1771), in the present study. The jaguar, *Panthera onca* is classified as near threatened globally (Quigley *et al*., 2017) and as vulnerable in Brazil (Morato *et al*., 2018), while *Puma concolor* is listed as least concern globally (Nielsen *et al*., 2015), and vulnerable in the Brazilian Red List (Azevedo *et al*., 2018).

Leopardus emiliae and *Leopardus braccatus* were classified as valid species only recently (Barstow & Leslie Jr., 2012; Nascimento & Feijó, 2017), and in the global assessment, *L. braccatus* (=*L. colocolo*) is listed as near threatened, whereas in Brazil, it is vulnerable (ICMBio, 2018), while *L. emilae* is a more recent revalidation, and has yet to be evaluated at either level (Nascimento & Feijó, 2017). *Lycalopex vetulus* is endemic to the Cerrado and is considered vulnerable in Brazil (Lemos *et al*., 2018), and near threatened globally (Lemos *et al*., 2020).

Saimiri collinsi is endemic to the Amazon and was assessed as near threatened by the IUCN SSC Primate Specialist Group (2015), while *Alouatta belzebul* is classified as vulnerable by both the IUCN and the ICMBio (Valença-Montenegro *et al*., 2018, 2019). The record from Tocantins may thus be relevant to the conservation of this species.

The marsh deer, *Blastocerus dichotomus*, was recorded at the two central localities (Pedro Afonso and Novo Acordo). This species is classified as vulnerable by both the IUCN and the ICMBio (Duarte *et al*., 2016, 2018).

CONCLUSIONS

The results of the present study added one mammal species– *Galictis cuja* – to the inventory for the Brazilian state of Tocantins, and also extend the known geographic distributions of two other species, *Speothos venaticus* and *Alouatta caraya*, in the state. Our analysis of species richness nevertheless indicates that the number of species recorded is underestimated at all four study localities.

Even so, the species richness (42 taxa) was higher than that recorded in other inventories in the Cerrado (36 species; Lima *et al*., 2005) of Tocantins state, but lower when compares with eastern Amazonia (46 species). The presence of vulnerable species (n = 12) is noteworthy. In particular, our data highlight the importance of the ecotonal zone, where both Amazonian (*e. g., Saimiri collinsi*) and Cerrado species (*e. g.*, *Lycalopex vetulus*) were recorded, and the areas of Cerrado which still support a considerable diversity of medium- and large-bodied mammals, such as the 33 found in Pedro Afonso. These findings are encouraging, considering that the region is under increasing pressure from farming and wildfires. The absence of the white-lipped peccary *Tayassu pecari* nevertheless reinforces the need for more attention, in particular, the more systematic monitoring of the region's mammal populations, considering the relentless advance of anthropogenic pressure. Overall, four (*Blastocerus dichotomus*, *Tapirus terrestris*, *Myrmecophaga tridactyla*, and *Alouatta belzebul*) species are listed globally as vulnerable, and 12 are considered vulnerable in Brazil.

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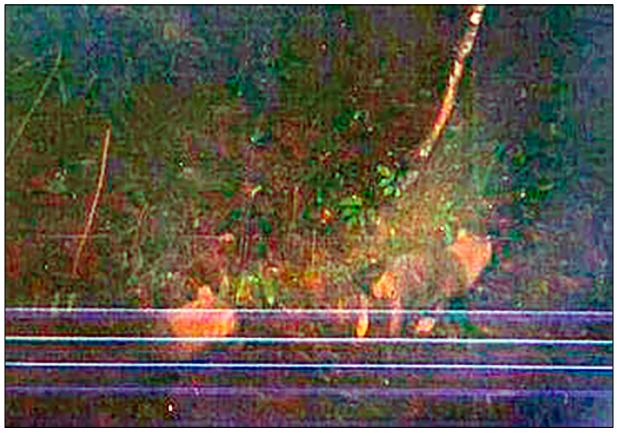
Appendix 1. Two specimens of bush dog (*Speothos venaticus*) from Arraias municipality, Tocantins state, Brazil. Photograph: W. S. de Paula.



Appendix 2. One specimen of lesser grisson (*Galictis cuja*) from Pedro Afonso municipality, Tocantins state, Brazil. Photograph: W. S. de Paula.