Bridging gaps on population knowledge of giant armadillos: importance of intensify sampling efforts in highly-modified landscapes to accurately estimate species occurrence

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Running head:

Giant armadillo occurrence in Central Brazil

Abstract

Studies on threatened species in highly modified and unprotected landscapes are necessary to the development of appropriate conservation and management policies. This is particularly important for species with large home-ranges, such as the giant armadillo (*Priodontes maximus*), whose occurrence in anthropogenic landscapes is poorly understood despite its status as endangered to extinction species. We searched for giant armadillos within human-modified areas in Central Brazil using direct and indirect methods (camera trapping, occasional sightings, recovered carcasses of road-killed and poached animals, burrows and tracks) across a wide region dominated by diverse farming environments and scattered natural remnants. We amassed 52 records of giant armadillos during a 13-year period within 10 municipalities of Minas Gerais and Goiás States, constituting the largest sampling effort and scale for this species to date. Records were mostly distributed in private natural fragments, while some were in protected units. Native vegetation covered most of the occurrence points (85%), while a small portion of records (15%) occurred in anthropic environments (pastures and roads). Our results upheld the suggested distribution for *P. maximus* while amending previous assumptions regarding this species absence in parts of the studied region in Central Brazil. More importantly, we confirmed the presence of giant armadillos within a wide, intensely human-altered region, likely as result of the extinction debt. These results indicate that Cerrado and Atlantic Forest remnants in human-modified landscapes in Central Brazil have been playing an important role as refuges for this armadillo species, as their use of anthropic environments such as pastures is much less frequent as evidenced by the occurrence records and behavioral patterns. As the giant armadillo can serve as prey to large carnivores as well as help controlling the density of herbivore insects while acting as ecosystem engineers, they play an essential role in community dynamics and merit urgent and decisive conservation efforts.

Key-words:

Agro-ecosystems, Atlantic Forest, biodiversity loss, Cerrado, Cingulata, fragmented landscapes, Neotropical savannas, *Priodontes maximus*, wildlife conservation

Introduction

In recent decades researchers have intensively surveyed the demography, ecological interactions, environmental requirements and anthropogenic threats for Neotropical wildlife. These data have been used in management strategies of several species (e.g., Sanderson *et al.*, 2002; Medici *et al.*, 2007; ICMBio, 2015a). While data accuracy and generality are paramount for the establishment of realistic conservation and management goals, most studies are context-dependent, either concentrated in regions dominated by pristine ecosystems or in medium to large protected areas (Fazey, Fischer & Lindenmayer, 2005). In addition, most researchers are interested in generating assessments consistent with the natural biology of studied species (i.e., not affected by human activities). For threatened species, however, studies across landscapes actively modified and managed by humans are fundamental for the development of appropriate conservation policies (Chazdon *et al.*, 2009). Nonetheless, the responses of several species to man-altered environments remain poorly understood, especially when ecological conditions for survival are minimal.

Armadillos (Cingulata: Dasypodidae) have a geographical distribution limited to the Neotropical region (Wetzel, 1985) and some species are sensitive to environmental changes (Abba & Superina, 2010). Of 11 species recorded in Brazil (ICMBio, 2015b), the giant armadillo *Priodontes maximus* (Kerr, 1792) is classified as threatened (category Vulnerable A2cd) by the International Union for the Conservation of Nature (IUCN, 2016). Populations of this armadillo – and all co-specific species – are quickly decreasing due to habitat loss, poaching, road-kills and the indiscriminate use of fire to remove natural vegetation or induce regrowth of pastures (Abba & Superina, 2010; Martins *et al.*, 2015). The scarcity of knowledge about the giant armadillo hinders the implementation of conservation actions, especially those focused on human-dominated landscapes (Meritt Jr, 2006; Superina & Abba, 2014). For instance, the predicted range of *P. maximus* spreads from Venezuela to northern

Argentina, including a large portion of the Brazilian territory (Anacleto *et al.*, 2014; Chiarello *et al.*, 2015). However, this predicted distribution encompasses wide regions without official records. In addition, the species has been considered extinct in areas with high levels of urbanization/agricultural activities or without official records (Chiarello *et al.*, 2008; Srbek-Araujo *et al.*, 2009). Although the giant armadillo is the largest Cingulata species (with 30-50 kg; Superina & Abba, 2014), individuals are rarely seen in the wild due to their naturally low densities and elusive behavior (i.e., nocturnal-fossorial; Noss, Peña & Rumiz, 2004; Silveira *et al.*, 2009; Srbek-Araujo *et al.*, 2009). Therefore, the absence of records of this mammal in highly altered regions is potentially and partially due to the reduced sampling efforts in non-protected areas.

Central Brazil is entirely included in the distribution of *P. maximus* (Anacleto *et al.*, 2014; Chiarello *et al.*, 2015). The region is dominated by the Cerrado biome and also harbors portions of the Atlantic Forest biome, represented by several enclaves of seasonal forest along large watercourses (e.g., Paranaíba river basin; Ribeiro *et al.*, 2009). As a result, a rich mosaic of physiognomies – ranging from open grasslands to forest patches – can be found in this portion of Brazil, which increases habitat diversity and favors a high regional biodiversity (Lopes *et al.*, 2012). However, agricultural activities and urbanization over the past 4-5 decades resulted in areas with more than 50% of the natural vegetation was replaced by anthropic environments (Machado *et al.*, 2004). By this, the current landscape comprises a matrix of exotic pastures and crops surrounding numerous fragments located mainly on higher slopes or rough areas (Klink & Machado, 2005; Carvalho, Marco-Júnior & Ferreira, 2009). The occurrence of *P. maximus* in this fragmented portion of Central Brazil is still poor known and is information crucial to the species conservation (Martins *et al.*, 2015).

Herein, we present records of giant armadillos within modified landscapes in the Cerrado biome and ecotone areas with the Atlantic Forest biome, between the states of Goiás

(GO) and Minas Gerais (MG). We also add information to the species natural history presenting data on its activity period and habitat use.

Material and methods

Our study sites were located in ten municipalities of GO and MG States (Supplementary Material - Table S1; Fig.1) in a region where 70-80% of the area was covered by cattle ranches with exotic pastures, while the remainder was comprised by scattered natural patches of savanna (Cerrado) and mesophytic seasonal forest (Atlantic Forest). The regional climate is markedly seasonal (Alvares *et al.*, 2013), with mean annual temperature and precipitation varying between 23-25°C and 1600-1900 mm, respectively.

Data on *P. maximus* occurrence in these areas were obtained from 2003 to 2016 in natural remnants (NR) from farmlands, private reserves and protected areas (Table S1). Methods used for data collection were camera trapping (Fig. 2a), occasional sighting (Fig. 2b) and evidence records (i.e., tracks and fresh burrows; Fig. 3a, b). Camera trapping surveys were carried out between 2009 and 2016 in remnants located in the Araguari river basin (Araguari-MG), between 2010 and 2011 in the Serra de Caldas Novas State Park (Caldas Novas-GO), and in 2014 and 2015 in the private reserve Pé do Morro Farm, owned by the Universidade Federal de Goiás (Catalão-GO). Camera trapping records in different months at the same coordinates were accounted separately, providing evidence of species persistence in the area. In addition, we also included data from road-kills (Fig. 4a) and poaching by local people (reported voluntarily during occasional visits to farms; Fig. 4b).

To determine habitat use we classified the vegetation in each recorded coordinate into four categories: open savanna (OS), woody savanna (WS), forest (FO) and pasture (PA). OS represented natural habitats with a predominance of native grasses and scattered shrubs as in *campo sujo* and *cerrado ralo* vegetation physiognomies. WS comprised habitats with a dense

shrub-tree layer and reduced herbaceous cover as in *cerrado típico* and *cerrado denso* physiognomies. FO consisted of habitats with large trees taller than 12 m and canopy formation such as the *cerradão* physiognomy, seasonal forests, riverine forests and gallery forests (Oliveira-Filho & Ratter, 2002).

Data collection followed the procedures recommended by the American Society of Mastozoology (Sikes & Gannon 2011), and were approved by the Brazilian government (Instituto Chico Mendes de Conservação da Biodiversidade – ICMBio/SISBIO license number 14576-2 of 2008-2015), and the Ethics Committees on Animals Using (CEUA) of Universidade Federal de Goiás (UFG; process number 086/14) and Universidade Federal de Uberlândia (UFU; process number 089/14).

Results

During the 13-year study period we registered 27 records of *P. maximus* in 16 private farmlands, 10 records in a private reserve, 10 records in three protected areas, three animals road-killed in paved-roads and two animals poached (N = 52; Table S1). Most records were located next to the southeastern border of Goiás and Minas Gerais (Fig. 1). The first two records of the giant armadillo were obtained in 2003 during a mammal survey in the Galheiro Private Reserve of Natural Heritage (RPPN Galheiro) located in the municipality of Perdizes-MG. In Araguari-MG, we registered eight records between 2013 and 2016 in a single fragment (NR 1) of Atlantic Forest present in the Araguari River basin (Fig. 1). There was no evidence of giant armadillo presence in other fragments up to 40 km West from NR 1 during the period. An additional record occurred in 2013 in a Cerrado fragment (NR 2) and one animal was reported by villagers as road-killed in 2006 on the BR-050 highway.

In Cumari-GO, six records occurred in fragments (NR 3-5) or in close proximity to pastures, while two other records corresponded to animals poached in 2011 in Cumari-GO

(NR 6) and 2013 in the neighboring municipality of Goiandira-GO (NR 7). In Catalão-GO, 10 records were obtained from 2014 to 2015 in the Pé do Morro Farm (FPM) and another record was registered in a fragment (NR 8) less than 4 km East from FPM. Two road-killed animals (2012 and 2015) were registered in the GO-330 highway, close to the limit between Catalão-GO and Ipameri-GO (Fig. 2c). In addition, 10 records were registered between 2014 and 2016 in fragments (NR 9-15) located near Ipameri-GO, Campo Alegre-GO and Urutaí-GO. Furthermore, seven records were obtained in Caldas Novas-GO in 2008 and from 2010 to 2011 in the Serra de Caldas Novas State Park (PESCaN). Finally, one record was registered in the Mata Atlântica State Park (PEMA) near Água Limpa-GO.

More than 40% of the records were obtained directly, mainly via camera trapping (n = 13), carcasses (n = 5) and sightings (n = 3). The remainder (n = 30 records) were obtained indirectly via burrows and tracks often found on trails or at the edge of dirt roads. Camera trap records and sightings occurred exclusively during nocturnal periods, between 18h22min and 05h49min (n = 16). Furthermore, most records were registered in areas with native vegetation cover (84.3%), especially FO (n = 20), followed by OS (n = 14) and WS (n = 9). In the municipalities of Cumari-GO and Catalão-GO, some records occurred in PA (n = 5). Records from anthropic environments – including that of road-killed animals – were usually obtained less than 0.45 km away from natural habitat remnants.

Discussion

Widely distributed in Central Brazil (Anacleto *et al.*, 2014; Chiarello *et al.*, 2015), elder rural residents report it was not unusual to find tracks or spotting giant armadillos in their properties in the past. However, *P. maximus* has been rarely sighted in recent years, mostly due to intense habitat loss combined with road-killing and poaching (Chiarello *et al.*, 2008). Despite their ecological importance and conservation status, only recently intensive

mammal surveys have been conducted in natural remnants across our study region (e.g., Bruna *et al.*, 2010; Araújo *et al.*, 2015; Estrela *et al.*, 2015; Gomes *et al.*, 2015; Rocha, Soares & Pereira, 2015). By this, our study represents the largest (N = 52) and longest (13 years) sampling effort to acquire records of *P. maximus* in Central Brazil, covering 192 km^2 of Cerrado and Atlantic Forest natural remnants.

Protected areas in the east of MG and ES states were considered the last strongholds for *P. maximus* in the Atlantic Forest (Srbek-Araujo *et al.*, 2009). However, our findings indicate that this mammal is still present in Atlantic Forest remnants along the basins of Paranaíba and Araguari rivers in Central Brazil. A record from Vale do Encantado Private Reserve of Natural Heritage (RPPN Vale do Encantado) in Uberaba-MG expands the currently expected occurrence of giant armadillos further to the South (Martinelli et al. 2014; Fig. 1). Previous studies in Southeast GO registered six records of *P. maximus* from 2004 to 2014 (Araújo *et al.*, 2015; Chiarello *et al.*, 2015; Estrela *et al.*, 2015; Gomes *et al.*, 2015), while the present study registered 39 records in 17 different private reserves and protected areas. Based on the home range of a giant armadillo (500 to 1,500 ha; Silveira *et al.*, 2009)) we assume that at least one animal was living in remnants surrounding the record points. Thus, despite the lack of individual abundance estimates, results of this study in combination with previous records potentially indicate the persistence of a single or multiple populations of this species in natural patches across a large section of agro ecosystems in Central Brazil. However, there are many potentially suitable remnants for this species within the area that remain unstudied.

Our results also corroborate previously identified natural history traits of giant armadillos. First, individuals showed essentially nocturnal activity (Noss *et al.*, 2004; Silveira *et al.*, 2009; Srbek-Araujo *et al.*, 2009), as all camera trapping records or sightings occurred between 18h and 06h. Armadillo records were registered in savanna as well as in forest

habitats, although their frequency varied among localities. In Araguari-MG, we found most records (80%) in forest habitats, which is the predominant habitat type remaining in surveyed areas. Similarly, all records from Caldas Novas-GO were found in savanna habitats, which cover the majority of studied reserve. These findings corroborate that giant armadillos can be found in open and closed habitats, but their habitat usage tends to reflect habitat availability in the landscapes (Silveira *et al.*, 2009). Moreover, we have repeatedly crossed extensive areas of pastures in the matrix between surveyed natural patches. However, the low frequency of records (< 10%) in these areas suggests that exploration of human-modified habitats is unusual for giant armadillos even in predominantly altered landscapes. Therefore, although giant armadillos can be found in highly modified environments, they mainly explore natural patches within these areas (Silveira *et al.*, 2009).

Habitat fragmentation often results in vegetation patches decreasing in size and increasing in number and isolation (Fahrig, 2003), negatively affecting species with large spatial requirements such as the giant armadillo (Chiarello, 1999). However, 26 of our records occurred in small fragments (25 to 288 ha) allegedly unsuitable to harbor even a single individual of giant armadillo. Such pattern may be explained by a delay in the extinction of giant armadillos in these areas (the extinction debt; revised by Kuussaari *et al.*, 2009), potentially due to two factors. First, the relatively long life expectancy of *P. maximus* individuals (12-15 years; Nowak, 1999) highlights low population turnover and may mask the long-term effects of fragmentation. Second, the irregular topography of the landscape in Southeast GO and West MG results in habitat remnants being very close to each other and not completely isolated due to inter-connecting habitat strips in slopes. This patch network could allow giant armadillos to forage in small areas and still survive within fragmented landscapes for a limited time. More than a sad fate, this extinction delay may represent an opportunity of

recovery for this species via habitat restoration and landscape management (Kuussaari *et al.*, 2009).

The Southeast GO and West MG have experienced intensive landscape modification (up to 80%) in Central Brazil, and less than 2-3% of natural remnants are inside protected areas (Carvalho *et al.*, 2009). In this region, the high degree of landscape modification and the expensive price of land are challenges to the establishment of protected areas large enough to ensure the conservation of large-sized mammals. Besides, recent changes in the Brazilian Forest Act amnestying landowners for illegal logging, allowing mandatory legal reserve areas to include sites previously prohibited from being deforested, and reducing the deforestation-free zone around rivers contribute to the decrease of biological connection between natural remnants and potentiate biodiversity loss (Michalski, Norris & Peres, 2010; Paul *et al.*, 2010). Thus, it is essential that we intensify ecological studies and urgently carry educational actions with landowners and rural communities to conserve threatened mammals in unprotected anthropogenic landscapes. In this scenario, efficient conservation actions may be achieved using integrated landscape management. As such, strategies could be adopted to 1) encourage proper conservation of natural remnants by landowners and 2) increase restoration efforts focusing on the establishment of biological connections between natural patches, private reserves and protected areas (Chazdon *et al.*, 2009).

The decline of giant armadillo populations (at least 30% in the last two decades; ICMBio 2015) may influence community diversity and vegetation structure in habitat remnants. Giant armadillos are regarded as ecosystem engineers (Leite-Pitman *et al.*, 2004; Desbiez & Kluyber, 2013) due to their digging behavior, changing physical soil properties and constructing burrows inhabited or used as refuge by several species (Desbiez & Kluyber, 2013). They are also important as prey for large-carnivores such as jaguars (*Phantera onca*) and pumas (*Puma concolor*). Furthermore, armadillos are specialized insect-predators and

heavily consume termites and ants (Anacleto, 2007). The absence of such top-down effect on insect herbivores, especially on those abundant as leaf-cutter ants (Costa & Vieira-Neto 2016), may lead to strong impacts on vegetation structure and dynamics in modified environments (Terborgh *et al.*, 2001; Silva *et al.*, 2012).

Conservation of threatened species also requires in-depth knowledge of their ecology and natural history, especially within anthropogenic landscapes. Our records of *P. maximus* indicate that the giant armadillo may still be present in highly-modified areas across the Central Brazil and others regions, remaining undetected due to a low sampling effort. Besides the habitat loss, we confirm that road-kills and poaching pose as serious threats to giant armadillos in in this part of Brazil, and urgent conservation actions are necessary to minimize human impacts and facilitate persistence of *P. maximus* in this region.

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References

Abba, A.M. & Superina, M. (2010). The 2009/2010 Armadillo Red List Assessment. *Edentata* **11**, 135–184.

Alvares, C.A., Stape, J.L., Sentelhas, P.C., Gonçalves, J.L.M. & Sparovek, G. (2013). Köppen's climate classification map for Brazil. *Meteorol. Zeitschrift* **22**, 711–728.

Anacleto, T.C.S. (2007). Food habits of four armadillo species in the Cerrado area, Mato Grosso, Brazil. *Zool. Stud.* **46**, 529–537.

Anacleto, T.C.S., Miranda, F., Medri, I., Cuellar, E., Abba, A.M. & Superina, M. (2014). *Priodontes maximus*. *IUCN Red List Threat. Species*. URL http://www.iucnredlist.org/apps/redlist/details/18144/0

Araújo, G.R., Silva, P.M., Estrela, D.C. & Castro, A.L.S. (2015). Mamíferos de médio e grande porte em um fragmento florestal de Cerrado no município de Ipameri - GO. *Multi-Science J.* **1**, 55–61.

Bruna, E.M., Guimarães, J.F., Lopes, C.T., Duarte, P., Gomes, A.C.L., Belentani, S.C.S., Pacheco, R., Facure, K.G., Lemos, F.G. & Vasconcelos, H.L. (2010). Mammalia, Estação Ecológica do Panga, a Cerrado protected area in Minas Gerais state, Brazil. *CheckList* **6**, 668–675.

Carvalho, F.M.V., Marco-Júnior, P. & Ferreira, L.G. (2009). The Cerrado into-pieces: Habitat fragmentation as a function of landscape use in the savannas of Central Brazil. *Biol. Conserv.* **142**, 1329–1403.

Chazdon, R.L., Harvey, C.A., Komar, O., Griffith, D.M., Ferguson, B.G., Martínez-ramos, M., Morales, H., Nigh, R., Soto-pinto, L., van Breugel, M. & Philpott, S.M. (2009). Beyond Reserves : A Research Agenda for Conserving Biodiversity in Human-modified Tropical Landscapes. *Biotropica* **41**, 142–153.

298 Chiarello, A.G. (1999). Effects of fragmentation of the Atlantic forest on mammal
299 communities in south-eastern Brazil. *Biol. Conserv.* **89**, 71–82.

300 Chiarello, A.G., Aguiar, L.M.S., Cerqueira, R., Melo, F.R., Rodrigues, F.H.G. & Silva,
301 V.M.F. (2008). Mamíferos. In *Livro vermelho da fauna brasileira ameaçada de*
302 *extinção*: 680–880. Machado, A.B.M., Drummond, G.M. & Paglia, A.P. (Eds). Brasília:
303 MMA / Biodiversitas.

304 Chiarello, A.G., Röhe, F., Miranda, F.R., Mourão, G.M., Silva, K.F.M., Vaz, S.M. &
305 Anacleto, T.C.S. (2015). Avaliação de Risco de Extinção de *Priodontes maximus* (Kerr,
306 1792) no Brasil. *Série Estado Conserv. da Fauna Bras.* **2**, 209–222.

307 Costa, A.N. & Vieira-Neto, E.H.M. (2016). Species turnover regulates leaf-cutter ant
308 densities in environmental gradients across the Brazilian Cerrado. *J. Appl. Entomol.* **140**,
309 474–478.

310 Desbiez, A.L.J. & Kluyber, D. (2013). The role of giant armadillos (*Priodontes maximus*) as
311 physical ecosystem engineers. *Biotropica* **45**, 537–540.

312 Estrela, D.C., Souza, D.C., Souza, J.M. & Castro, A.L.S. (2015). Medium and large-sized
313 mammals in a Cerrado area of the state of Goiás, Brazil. *Check List* **11**, 1–6.

314 Fahrig, L. (2003). Effects of Habitat Fragmentation on Biodiversity. *Annu. Rev. Ecol.*
315 *Environ. Syst.* **34**, 487–515.

316 Fazey, I., Fischer, J. & Lindenmayer, D.B. (2005). What do conservation biologists publish?
317 *Biol. Conserv.* **124**, 63–73.

318 Gomes, L.P., Rocha, C.R., Brandão, R.A. & Marinho-Filho, J. (2015). Mammal richness and
319 diversity in Serra do Facão region, Southeastern Goiás state, Central Brazil. *Biota*
320 *Neotrop.* **15**, 1–11.

321 ICMBio. (2015a). *Sumário Executivo do Plano de Ação Nacional para a Conservação do*

Cachorro-vinagre. Brasília: Instituto Chico Mendes de Conservação da Biodiversidade.

ICMBio. (2015b). *Avaliação do risco de extinção dos Xenartros Brasileiros*. Brasilia: Instituto Chico Mendes de Conservação da Biodiversidade.

IUCN. (2016). The IUCN Red List of Threatened Species. Version 2016-3. URL http://www.iucnredlist.org

Klink, C.A. & Machado, R.B. (2005). Conservation of the Brazilian Cerrado. *Conserv. Biol.* **19**, 707–713.

Kuussaari, M., Bommarco, R., Heikkinen, R.K., Helm, A., Krauss, J., Lindborg, R., Öckinger, E., Pärtel, M., Pino, J., Rodà, F., Stefanescu, C., Teder, T., Zobel, M. & Steffan-dewenter, I. (2009). Extinction debt: a challenge for biodiversity conservation. *Trends Ecol. Evol.* **24**, 564–571.

Leite-Pitman, R., Powell, G., Cruz, D., Escobedo, M., Escobar, K., Vilca, V. & Mendoza, A. (2004). Habitat use and activity of the giant armadillo (*Priodontes maximus*): preliminary data from Southeastern Peru. In *Annual meeting of the Society for Conservation Biology*: 1–8. New York.

Lopes, S. de F., Schiavini, I., Oliveira, A.P. & Vale, V.S. (2012). An Ecological Comparison of Floristic Composition in Seasonal Semideciduous Forest in Southeast Brazil: Implications for Conservation. *Int. J. For. Res.* **2012**, 1–14.

Machado, R.B., Ramos-Neto, M.B., Pereira, P.G.P., Caldas, E.F., Gonçalves, D.A., Santos, N.S., Tabor, K. & Steininger, M. (2004). *Estimativas de perda da área do Cerrado brasileiro*. Brasília: Conservation International.

Martinelli, A.G., Costa, W.R., Neto, R.S., Fonseca, P.H.M., Martins, G. & Silva, V.M. (2014). *Priodontes Maximus* (Cingulata, Dasypodidae) in the Reserva Particular do Patrimônio Natural Vale Encantado, Triângulo Mineiro, Southeastern Brazil. *Acta*

Zoológica Mex. **30**, 716–722.

Martins, A.B., Silva, K.F.M., Fialho, M. de S. & Miranda, F.R. (2015). Avaliação do Estado de Conservação de Pilosa e Cingulata no Brasil. *Série Estado Conserv. da Fauna Bras.* **2**, 7–11.

Medici, E.P., Desbiez, A.L.J., Gonçalves da Silva, A., Jerusalinsky, L., Chassot, O., Montenegro, O.L., Rodríguez, J.O., Mendoza, A., Quse, V.B., Pedraza, C., Gatti, A., Oliveira-Santos, L.G.R., Tortato, M.A., Ramos Jr., V., Reis, M.L., Landau-Remy, G., Tapia, A. & Morais, A.A. (Eds.). (2007). *Workshop para a conservação da anta brasileira (*Tapirus terrestris*): Relatório final*. Sorocaba: IUCN/SSC Tapir Specialist Group (TSG) & IUCN/SSC Conservation Breeding Specialist Group (CBSG).

Meritt Jr, D.A. (2006). Research Questions on the Behavior and Ecology of the Giant Armadillo (*Priodontes maximus*). *Edentata* **7**, 30–33.

Michalski, F., Norris, D. & Peres, C.A. (2010). No retorn from biodiversity loss. *Science.* **329**, 1282.

Noss, A.J., Peña, R. & Rumiz, D.I. (2004). Camera trapping *Priodontes maximus* in the dry forests of Santa Cruz, Bolivia. *Endanger. Species Updat.* **21**, 43–52.

Nowak, R.M. (1999). *Walker's Mammals of the World*. 6th ed. Baltimore & London: The Johns Hopkins University Press.

Oliveira-Filho, A.T. & Ratter, J.T. (2002). Vegetation Physiognomies and Woody Flora of the Cerrado Biome. In *The Cerrados of Brazil: Ecology and Natural History of a Neotropical Savanna*: 91–120. Oliveira, P.S. & Marquis, R.J. (Eds). New York: Columbia University Press.

Paul, J., Lewinsohn, T.M., Joly, C.A., Luciano, M., Martinelli, L.A. & Rodrigues, R.R. (2010). Brazilian law: full speed in reverse? *Science*. **329**, 276–277.

Ribeiro, M.C., Metzger, J.P., Martensen, A.C., Ponzoni, F.J. & Hirota, M.M. (2009). The Brazilian Atlantic Forest: How much is left, and how is the remaining forest distributed? Implications for conservation. *Biol. Conserv.* **142**, 1141–1153.

Rocha, E.C., Soares, K.L. & Pereira, I.M. (2015). Medium and large-sized mammals in Mata Atlântica State Park, southeastern Goiás, Brazil. *Check List* **11**, 1–7.

Sanderson, E.W., Redford, K.H., Chetkiewicz, C.B., Medellin, R.A., Rabinowitz, A.R., Robinson, J.G. & Taber, A.B. (2002). Planning to Save a Species : the Jaguar as a Model. *Conserv. Biol.* **16**, 58–72.

Silva, P.S.D., Leal, I.R., Wirth, R., Melo, F.P.L. & Tabarelli, M. (2012). Leaf-cutting ants alter seedling assemblages across second-growth stands of Brazilian Atlantic forest. *J. Trop. Ecol.* **28**, 361–368.

Silveira, L., Jácomo, A.T.A., Furtado, M.M., Torres, N.M., Sollmann, R. & Vynne, C. (2009). Ecology of the Giant Armadillo (*Priodontes maximus*) in the Grasslands of Central Brazil. *Edentata* **8**–**10**, 25–34.

Srbek-Araujo, A.C., Scoss, L.M., Hirsch, A. & Chiarello, A.G. (2009). Records of the giant-armadillo *Priodontes maximus* (Cingulata: Dasypodidae) in the Atlantic Forest: are Minas Gerais and Espírito Santo the last strongholds of the species? *Zool.* **26**, 461–468.

Superina, M. & Abba, M. (2014). What do we know about armadillos? An analysis of four centuries of knowledge about a group of South American mammals, with emphasis on their conservation. *Mamm. Rev.* **44**, 69–80.

Terborgh, J., Lopez, L., Nuñez, P. V, Rao, M., Shahabuddin, G., Orihuela, G., Riveros, M., Ascanio, R., Adler, G.H. & Lambert, T.D. (2001). Ecological meltdown in predator-free forest fragments. *Science.* **294**, 1923–1926.

Wetzel, R.M. (1985). The identification and distribution of recent Xenarthra. In *The evolution*

and ecology of armadillos, sloths, and vermilinguas: 5–21. Montgomery, G.G. (Ed). Washington, DC: Smithsonian Institution Press.

Figures

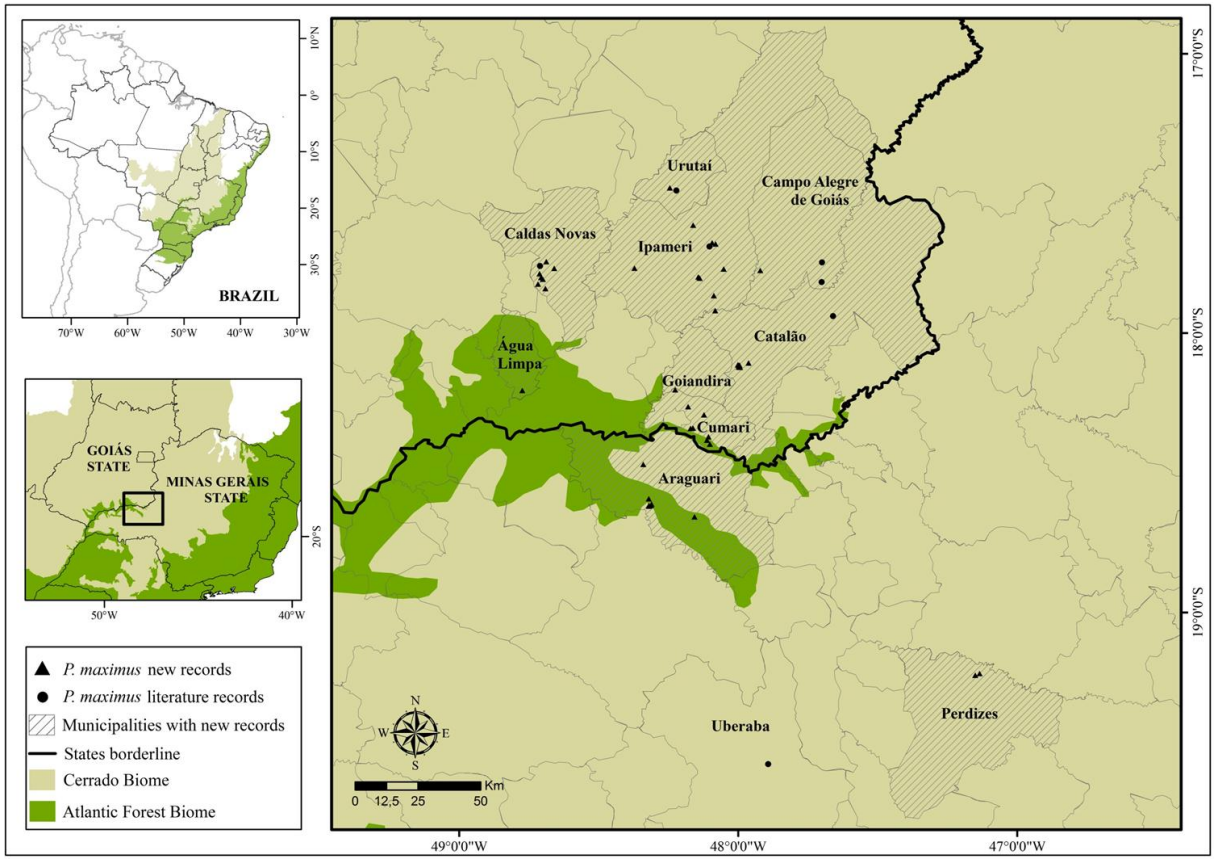
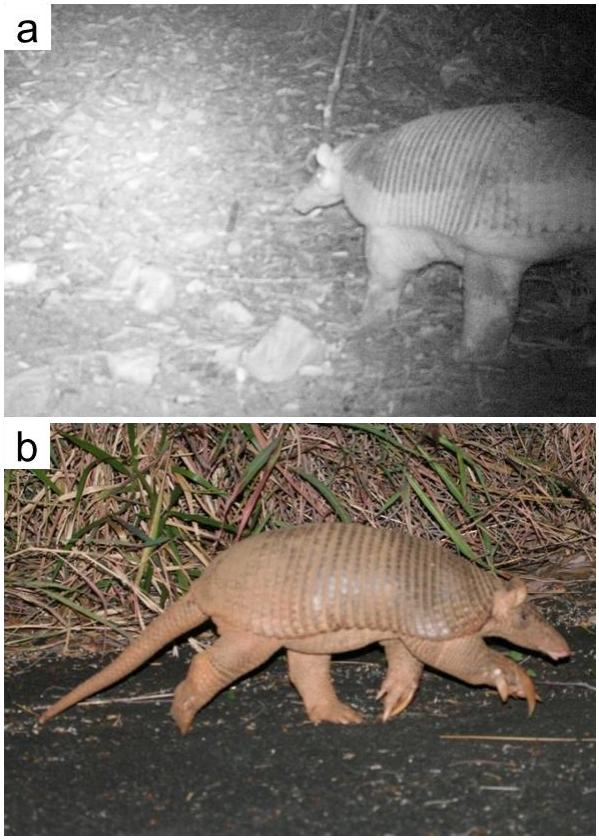


Figure 1. Occurrence of giant armadillos (*Priodontes maximus*) in 10 municipalities in the states of Goiás and Minas Gerais, Brazil. Literature records obtained in Martinelli et al. (2014); Araújo et al. (2015); Chiarello et al. (2015); Estrela et al. (2015); Gomes et al. (2015); Rocha et al. (2015).



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409 Figure 2. Giant armadillos (*Priodontes maximus*) recorded by (a) camera trapping and (b)

410 sighting in Pé do Morro Farm reserve and Serra de Caldas Novas State Park (respectively),

411 located in the state of Goiás, Brazil. Photos: Frederico G. Lemos and Alan N. Costa,

412 respectively.

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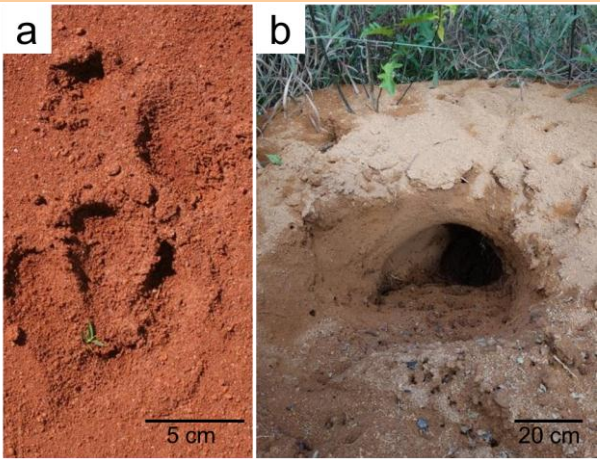

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416 Figure 3. Typical evidences of giant armadillos (*Priodontes maximus*) used to record the
417 species presence in Cerrado remnants and anthropic environments surveyed in 10
418 municipalities located in the states of Goiás and Minas Gerais states, Brazil. (a) Track and (b)
419 fresh burrow on a leaf-cutter ant nest. Photos: Frederico G. Lemos and Alan N. Costa,
420 respectively.

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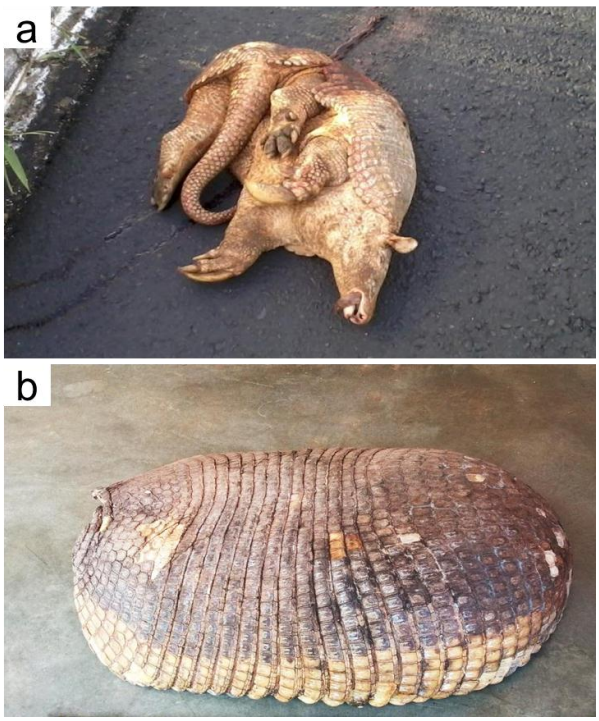

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424 Figure 4. Carcasses of giant armadillos (*Priodontes maximus*) registered in the state of Goiás,

425 Brazil. (a) A road-killed animal at GO-330 highway, and (b) carapace of a poached animal.

426 Photos: Ednaldo C. Rocha and Frederico G. Lemos, respectively.