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RESEARCH GAPS IN THE ENDANGERED XENARTHRANS OF THE BRAZILIAN CERRADO AND IMPLICATIONS FOR CONSERVATION

LACUNAS DE PESQUISA NOS XENARTHRA DO CERRADO BRASILEIRO AMEAÇADOS DE EXTINÇÃO E IMPLICAÇÕES PARA CONSERVAÇÃO

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Abstract: The present study aims to characterize the scientific production about endangered species of the xenarthrans, a group that occurs in the Brazilian Cerrado. This descriptive and quantitative research was conducted using the Scopus database. The study species were selected using the International Union for Conservation of Nature (IUCN) red list of endangered species.

Four species of endangered xenarthrans occurring in the Cerrado were identified. 205 publications were cataloged until 2017, including 99 (48%) publications on *Myrmecophaga tridactyla* (giant anteater), 73 (36%) publications on *Bradypus variegatus* (brown-throated sloth), 27 (13%) publications on *Priodontes maximus* (giant armadillo) and six publications (3%) on *Tolypeutes tricinctus* (Brazilian three-banded armadillo). The areas of knowledge in general biology with the highest number of publications were ecology (22%), zoology (22%) and morphology (20%). Only 9% of the publications included genetic studies, moreover there is no genetic study on the Brazilian three-banded armadillo and on the giant armadillo in Brazil. Brazil had the highest number of published articles (112) (54%), the University of São Paulo (USP) (20 publications), the Federal University of Goiás (UFG) (12 publications) , the State University of São Paulo (UNESP) (9 publications), the University of Brasilia (UnB) (9 publications) and Federal University of Pernambuco (UFPE) (8 publications) stood out, with 58 scientific publications combined. Therefore, it was possible to determine an urgent need for further studies about these species, especially genetic for being fundamental in conservation programs, since a low genetic diversity compromises long-term viability, reduction or risk of extinction.
Keywords: Brown-throated sloth. Giant anteater. Brazilian three-banded armadillo. Giant armadillo.

Resumo: O presente estudo tem como objetivo caracterizar a produção científica sobre espécies de Xenarthra ameaçadas de extinção, um grupo que ocorre no Cerrado brasileiro. Esta pesquisa descritiva e quantitativa foi realizada usando o banco de dados Scopus. As espécies estudadas foram selecionadas usando a lista vermelha de espécies ameaçadas da União Internacional para a Conservação da Natureza (IUCN). Foram identificadas quatro espécies de Xenarthra ameaçadas de extinção que ocorrem no Cerrado. Foram catalogadas 205 publicações até 2017, a maioria da ordem Pilosa (n = 172, 84%), sendo n = 99 (48%) sobre *Myrmecophaga tridactyla* (tamanduá-bandeira) e n = 73 (36%) sobre *Bradypus variegatus* (preguiça-de-garganta-marrom). Na ordem Cingulata, as publicações se restringiram ao *Priodontes maximus* (tatu-canastra, n = 27, 13%) e ao *Tolypeutes tricinctus* (tatu-bola, n = 6, 3%). As áreas de conhecimento em biologia geral com maior número de publicações foram ecologia (22%), zoologia (22%) e morfologia (20%). Apenas 9% das publicações incluíam estudos genéticos; além disso, não há estudos genéticos sobre o tatu-bola e o tatu-canastra no Brasil. O Brasil teve o maior número de artigos publicados (112) (54%), com destaque para a Universidade de São Paulo (USP) (20 publicações), Universidade Federal de Goiás (UFG) (12 publicações), a Universidade Estadual de São Paulo (UNESP) (9 publicações), a Universidade de Brasília (UnB) (9 publicações) e a Universidade Federal do Pernambuco (UFPE) (8 publicações) que somaram 58 publicações científicas sobre espécies de Xenarthra ameaçadas de extinção. Portanto, foi possível determinar uma necessidade urgente de mais estudos sobre essas espécies, especialmente em genética, por serem fundamentais em programas de conservação, uma vez que, a baixa diversidade genética compromete a viabilidade de populações em longo prazo, aumentando o risco de extinção.
Palavras-chave: Preguiça-de-garganta-marrom. Tamanduá bandeira. Tatu-bola. Tatu canastra.

INTRODUCTION

The mammalian superorder Xenarthra is an essentially Neotropical group, currently represented by armadillos (order Cingulata), anteaters, and sloths (order Pilosa) (PEREIRA JUNIOR, 2007). According to the Chico Mendes Institute for Biodiversity Conservation (ICMBio) (2012), 19 species of xenarthrans occurs in Brazil, and one-fifth of them have been included on the International Union for Conservation of Nature's (IUCN) Red List of Threatened Species.

All four Brazilian species of Xenarthra listed by IUCN (*Priodontes maximus*, *Myrmecophaga tridactyla*, *Tolypeutes tricinctus*, and *Bradypus variegatus*) are found in the Cerrado, which is the second most extensive biome in South America, occupying about 21% of the Brazilian territory and bearing one of the richest biodiversities in the world. The Cerrado has a tropical climate characterized by two distinct seasons, the rainy period between October to March, with an average temperature of 22 °C and an annual rainfall average of 1500 mm, and the dry season, which extends from April to September, with temperatures averaging around 27 °C (KLINK; MACHADO, 2005). The cerrado vegetation presents a wide physiognomic variation, and according to Coutinho (1976) the physiognomic gradient ranging from campo limpo (open grassland), campo sujo (grassland with some shrubs), campo cerrado (shrub savanna), cerrado sensu strict (woodland savanna) to cerradão (closed woodlands).

The giant armadillo (*Priodontes maximus*) is the largest armadillo and can reach a length of 1.5 m (head, body, and tail), is primarily insectivore, and has nocturnal and semi fossorial habits. It is typical to the Cerrado but can also be found in other areas and biomes of Latin America, including Pantanal (seasonally flooded plains), and Atlantic Forest (CHIARELLO et al., 2008). This species is threatened by hunting and habitat loss, and it is estimated that the population has declined about 30% in the last generations and it is classified as a vulnerable species (ANACLETO et al., 2014).

The giant anteater (*Myrmecophaga tridactyla*) is an insectivorous mammal that can reach a length of 2.20 m, and occupy diverse habitat types including open grasslands, savannas, and forests (CHIARELLO et al., 2008). It is classified as a species vulnerable to extinction due to the significant habitat loss usually caused by farming and fire, especially during the dry season. Moreover, individuals of *Myrmecophaga tridactyla* are also victims of roadkills and hunting (MIRANDA, BERTASSONI, ABBA, 2014).

The Brazilian three-banded armadillo, *Tolypeutes tricinctus*, is endemic to Brazil occurring only in the Cerrado and Caatinga biomes. *T. tricinctus* is not fossorial, generally nocturnal, and has the habit, when threatened, of rolling into a ball (CHIARELLO et al., 2008). It is listed as Vulnerable on the IUCN Red List of Threatened Species mainly due to hunting pressure and degraded and destroyed habitat. Also, they can be captured fairly easily, and have a low reproduction rate (CHIARELLO et al., 2008; MIRANDA et al., 2014).

The brown-throated sloth (*Bradypus variegatus*) is an arboreal folivorous and has a wide distribution, occupying forested areas of the Amazon, Atlantic forest, and possibly in the contact zones between these biomes and Cerrado (MORAES-BARROS, CHIARELLO, PLESE, 2014). According to the IUCN, the brown-throated sloth is classified as Least Concern in view of the wide distribution area of the species and its occurrence in a number of protected areas. Furthermore, the decline of *B. variegatus* population is increasing due to severe habitat degradation and fragmentation (SUPERINA et al., 2010; MORAES-BARROS, CHIARELLO, PLESE, 2014).

As can be seen, the superorder Xenarthra is a group with threatened species in the Cerrado, and, therefore, it was our object of study. Thus, this work aimed to characterize the scientific production with the endangered species of the Xenarthra group that occurs in the Brazilian Cerrado, to identify possible areas of knowledge lacking in publications with these species.

MATERIAL AND METHODS

For this study, data were obtained from the Scopus database (http://www.scopus.com). We also collect data from IUCN (International Union for Conservation of Nature) Red List database (ANACLETO et al., 2014; MIRANDA, BERTASSONI, ABBA, 2014; MIRANDA et al., 2014; MORAES-BARROS, CHIARELLO, PLESE, 2014) and Ministry of the Environment (BRASIL, 2016) to obtain information on endemism and extinction risk. All documents published between 1976 and 2017 were included.

The search strategy was based on a similar or different combination of keywords, established with the name of the Xenarthra group or species belonging to this group that occurs in Cerrado biome, regardless of the published area of knowledge. From this survey process, the data field was based on the article title, abstract or keywords, articles or review documents, in all available periods and areas of knowledge.

Finally, the evaluation was based on the following parameters: year, language, senior author, number of citations, institution, country, research location, type of production, main areas of knowledge, types of journals, impact factor / related.

The data were analyzed using descriptive statistics. We used Spearman's correlation test to investigate a possible correlation between the variables analyzed, using a significance level of 0.05. Statistical analysis was performed by the BioEstat software 5.0.

RESULTS AND DISCUSSION

Figure 1 provides information related to the total number of published articles (205) on *Myrmecophaga tridactyla*, *Bradypus variegatus*, *Priodontes maximus*, and *Tolypeutes tricinctus*, between 1976 and 2017. It can be observed that the giant anteater stands out with the highest amount of publications 48% (99), followed by brown-throated sloth 36% (73), giant armadillo 13% (27) and Brazilian three-banded armadillo 3% (6).

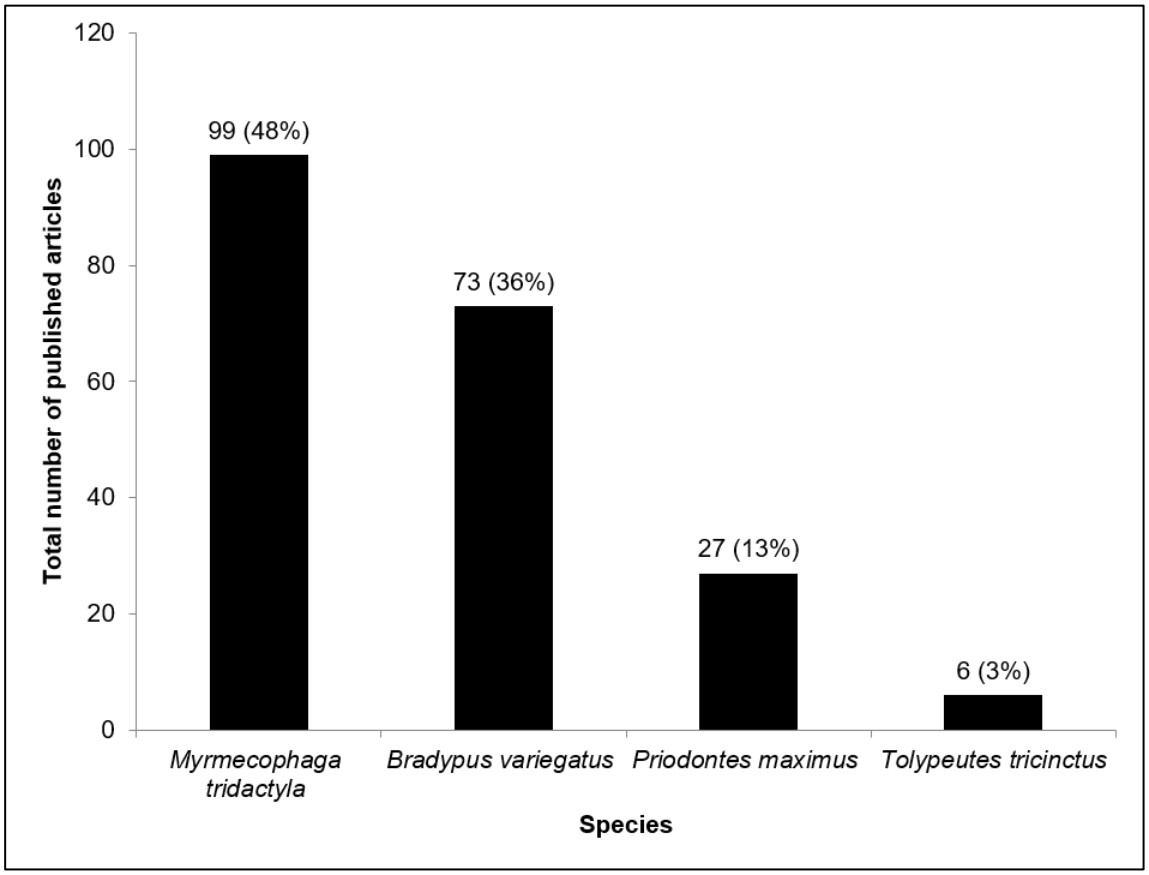

Figure 1. Total number of published articles on *Myrmecophaga tridactyla*, *Bradypus variegatus*, *Priodontes maximus*, and *Tolypeutes tricinctus*, between 1976 and 2017.

The publications on *Myrmecophaga tridactyla*, *Bradypus variegatus*, *Priodontes maximus*, and *Tolypeutes tricinctus* were relatively scarce, probably because these species are difficult to study in the wild (LOUGHRY, MCDONOUGH, 2013). The preponderance of papers published from the *M. tridactyla* and *B. variegatus* in this paper is probably related to factors, such as wide distribution on the environment. Nevertheless, *M. tridactyla*

and *B. variegatus* are vulnerable to extinction due to habitat loss, slow movement, solitary habit, and a long gestation (MIRANDA, BERTASSONI, ABBA, 2014; MORAES-BARROS, CHIARELLO, PLESE, 2014).

The number of publications about armadillos was substantially lower, probably because of the many problems associated with studying armadillos in the wild, such as their semi-fossorial and solitary habits. Also, habitat degradation, hunting, and low population densities may explain the low number of studies on armadillos (SUPERINA, PAGNUTTI, ABBA, 2014).

The analysis of citations reveals that brown-throated sloth led with 75 citations, followed by giant armadillo that received an average of 19 citations, Brazilian three-banded armadillo (7 citations), and giant anteater (6 citations). The low number of citations for giant anteater it's probably due to the most studies with the species were carried out in Brazil, in the Cerrado, and biomes of the wetlands of the Pantanal. However, studies carried out in other countries, and all Brazilian biomes are more encouraged and would probably have a higher number of citations (BERTASSONI; RIBEIRO, 2019). Citation data are extremely important and provides the elements for calculating of a journal's impact factor (IF) (SPINAK, 2015). The IF of a journal reveals the quality of the same journal since the journals with large impact factors reveal their greatest importance, and also the author's productivity (RUIZ et al., 2009).

The results of the association among the number of publications and year are shown in Figure 2. We found no significant association between the mentioned parameters and the *Tolypeutes tricinctus* ($r = 0{,}2000$, $p = 0{,}3272$), there was no increase in the number of studies over the years. In the other species, over the years, there is a significant increase in the number of publications ($p < 0.0001$): *Myrmecophaga tridactyla* ($r = 0{,}8732$), *Bradypus variegatus* ($r = 0{,}7342$), *Priodontes maximus* ($r = 0{,}6119$). These results may occur due to the little knowledge about armadillo species habits, alteration and loss of habitats and hunting (GUIMARÃES, 1997).

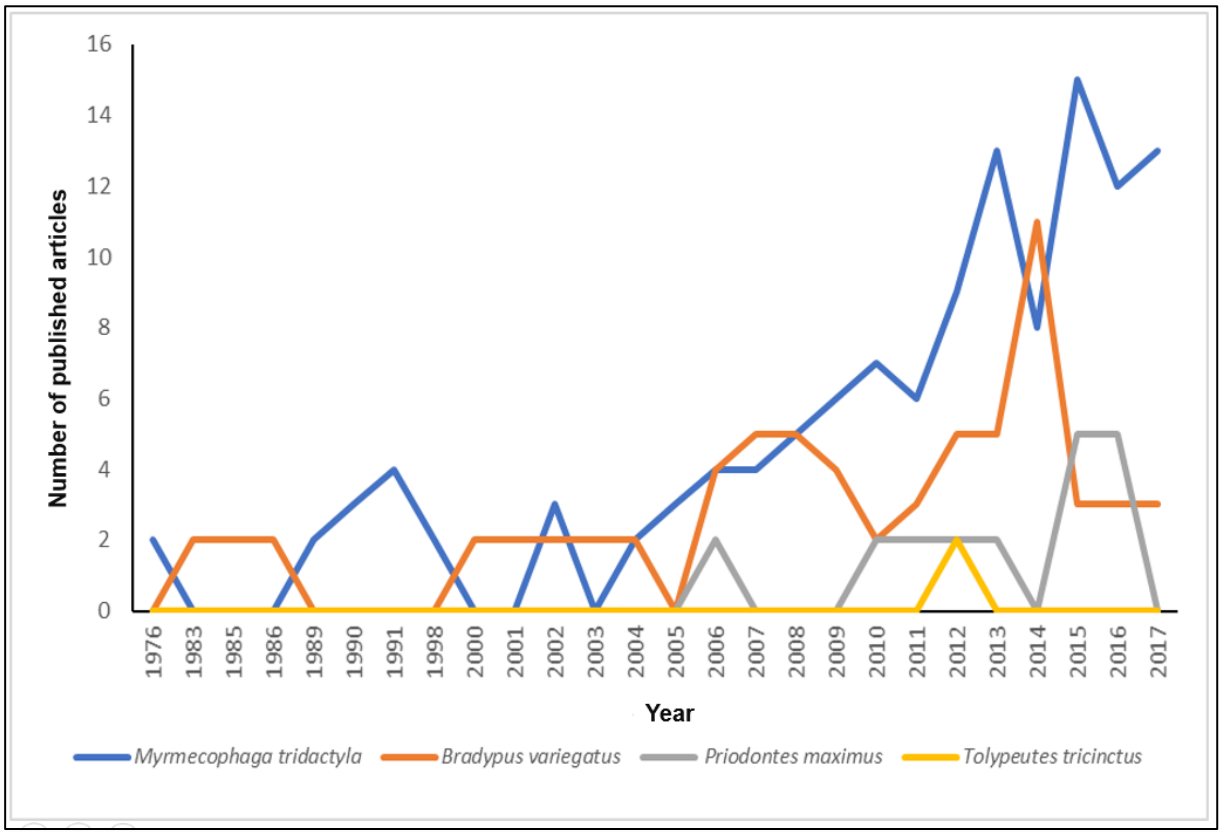

Figure 2. Total number of published articles on *Myrmecophaga tridactyla*, *Bradypus variegatus*, *Priodontes maximus*, and *Tolypeutes tricinctus*, between 1976 and 2017.

As Figure 3 indicates, the major contribution of published articles came from eight areas (agricultural sciences, microbiology/immunology, physiology, genetics/biochemistry, parasitology, morphology, ecology, and zoology). It should be noted that 64% of the scientific production of species analyzed in this study was published in the zoology, ecology, and morphology areas.

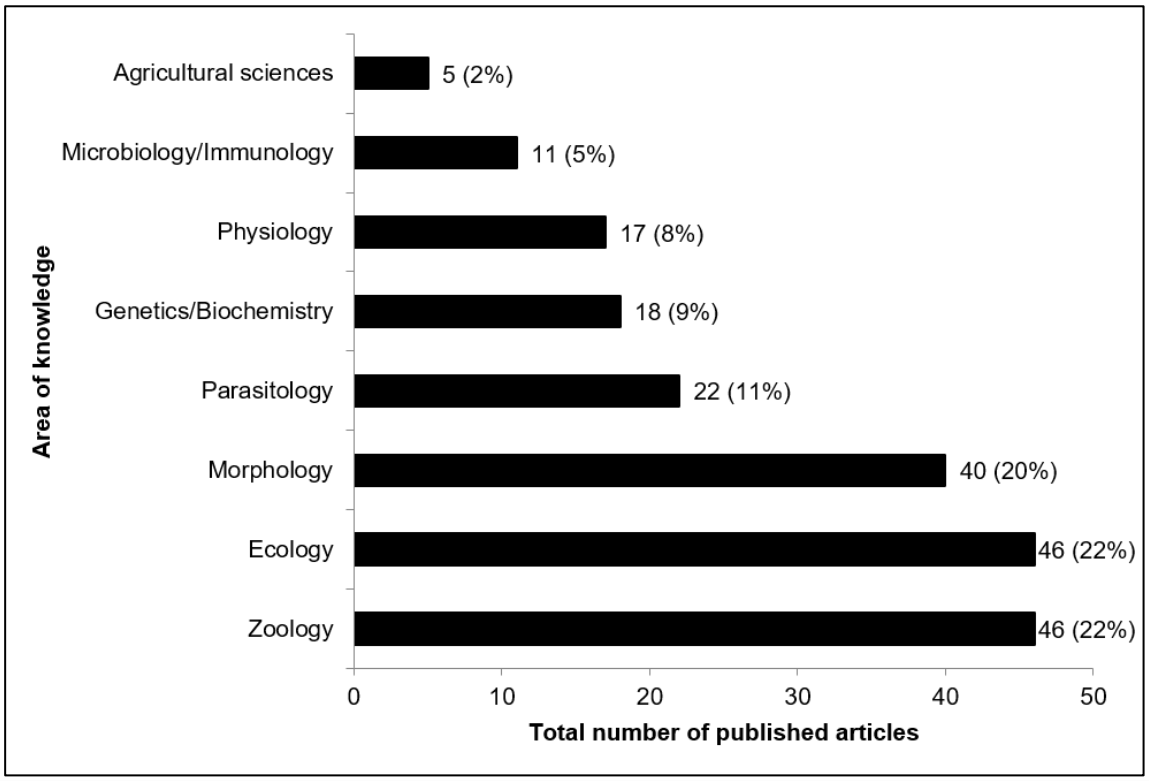

Figure 3. Total number of published articles by area of knowledge on *Myrmecophaga tridactyla*, *Bradypus variegatus*, *Priodontes maximus*, and *Tolypeutes tricinctus*, between 1976 and 2017.

Zoology, ecology, and morphology studies had significant science highlights because they encompass basic information about biological traits and the potential to cope with important threats to species studied conservation. Besides, certain types of studies, for example in physiology, require funding availability and the use of captive animals in the lab (LOUGHRY, MCDONOUGH, 2013; SUPERINA, PAGNUTTI, ABBA, 2014).

It can be observed in Figure 4, that articles on *Bradypus variegatus* and *Myrmecophaga tridactyla* were found in all areas of knowledge. Nonetheless, the absolute number of articles in each area of knowledge is still low in the face of the conservation status of the giant anteater and brown-throated sloth. Besides that, the current knowledge is not necessarily representative of the species as a whole since it covers only a small number of sites/populations (DINIZ; BRITO, 2012).

Armadillo species (*Tolypeutes tricinctus* and *Priodontes maximus*), there are several knowledge gaps. The Brazilian three-banded armadillo, *Tolypeutes tricinctus*, presented only studies in the zoology, ecology, and morphology areas. It is interesting to observe that were no publications found for the two armadillo species in important areas for conservation studies, such as genetics.

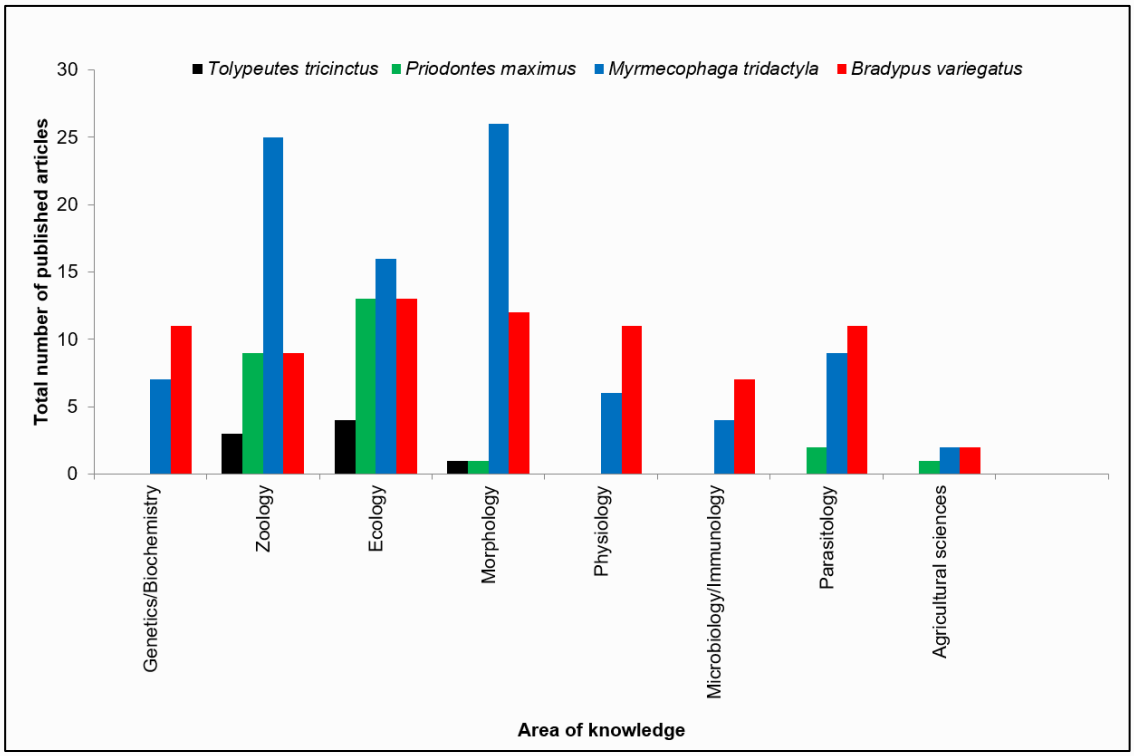

Figure 4. Total number of published articles by area of knowledge for *Myrmecophaga tridactyla*, *Bradypus variegatus*, *Priodontes maximus*, and *Tolypeutes tricinctus*, between 1976 and 2017.

Despite the existence of conservation programs, the giant armadillo and the Brazilian three-banded armadillo suffer major impacts and consequent risks of extinction (COSTA et al., 2005); thus, the lack of genetic studies for this species affects the conservation of genetic resources, which is essential for the preservation of threatened species (COSTA; MARTINS, 2008). The recent loss of species is inconvertible, so needs further research and study genetics, with focus on giant armadillo and Brazilian three-banded armadillo which have no studies in this field.

As it is illustrated in Figure 5, Brazil was the country with highest contributions on species of Xenarthra group (54%), followed by the United States (19%) and Argentina (6%).

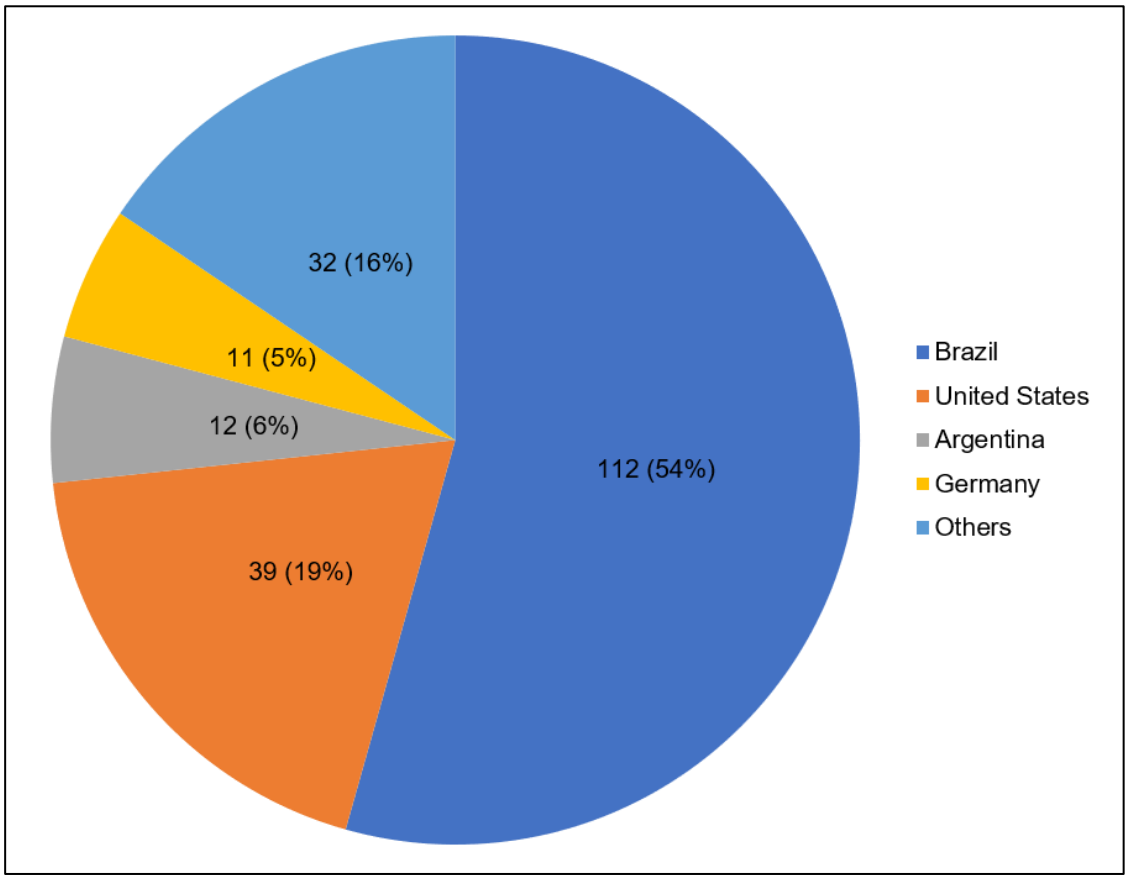

Figure 5. Countries that most published articles on *Myrmecophaga tridactyla*, *Bradypus variegatus*, *Priodontes maximus*, and *Tolypeutes tricinctus*, between 1976 and 2017.

Over the past years, Brazil underwent a significant increase in scientific production and currently ranked 13th among all countries worldwide in the publication of citable documents across all areas of science. Several factors have contributed to the current positive cycle of Brazilian scientific production, including the expansion of universities and research institutions, training of new doctors, and federal government investments. However, there is still the need to increase the impact of Brazilian research and the insertion of Brazil within the international scenario, considering that Brazil's innovation rate remains low, despite the increase in production (CROSS, THOMSON, SINCLAIR, 2017).

Table 1 shows the publications based on institutional distribution during 1976 to 2017. Findings revealed that four Brazilian universities are the most productive institutions: University of São Paulo (USP), Federal University of Goiás (UFG), State University Paulista (UNESP), University of Brasilia (UnB) and Federal University of Pernambuco (UFPE).

Table 1. Institutions that published the most articles on *Myrmecophaga tridactyla*, *Bradypus variegatus*, *Priodontes maximus*, and *Tolypeutes tricinctus*, between 1976 and 2017.

Institution	**Position per species (n)**				**n**
	Myrmecophaga tridactyla	*Bradypus variegatus*	*Priodontes maximus*	*Tolypeutes tricinctus*	
University of São Paulo (USP)	1º (10)	1º (9)	5º (1)	----	**20**
Federal University of Goiás (UFG)	2º (11)	----	5º (1)	----	**12**
State University of São Paulo (UNESP)	3º (8)	8º (1)	----	----	**9**
University of Brasilia (UnB)	4º (5)	----	1º (3)	1º (1)	**9**
Federal University of Pernambuco (UFPE)	----	2º (8)	----	----	**8**
Total	**34**	**18**	**5**	**1**	**58**

Two universities from the southeastern region, USP and UNESP, have the largest scientific production in the country, and were related to the unequal distribution of scientific and technological resources (CROSS, THOMSON, SINCLAIR, 2017). Some institutions in region of Brazil have more investments due to implemented policies by funding agencies, such as Fapesp, CNPq, Capes, and Finep.

According to General Index of Courses (IGC), the main indicator of the quality of the Ministry of Education (MEC), released on December 2018, twelve South and Southeast Brazilian universities have found a place among the 14 Brazilian universities that reached the maximum grade in IGC. The State University of Campinas (Unicamp) is the first-ranked in the IGC. The Federal University of Goiás (UFG) has a good assessment score – 4 – for the General Index of Courses, which corresponds to the maximum grade 5.

As expected, national institutions published more articles (56%) with the four species of Xenarthrans than international institutions (44%) (Figure 6).

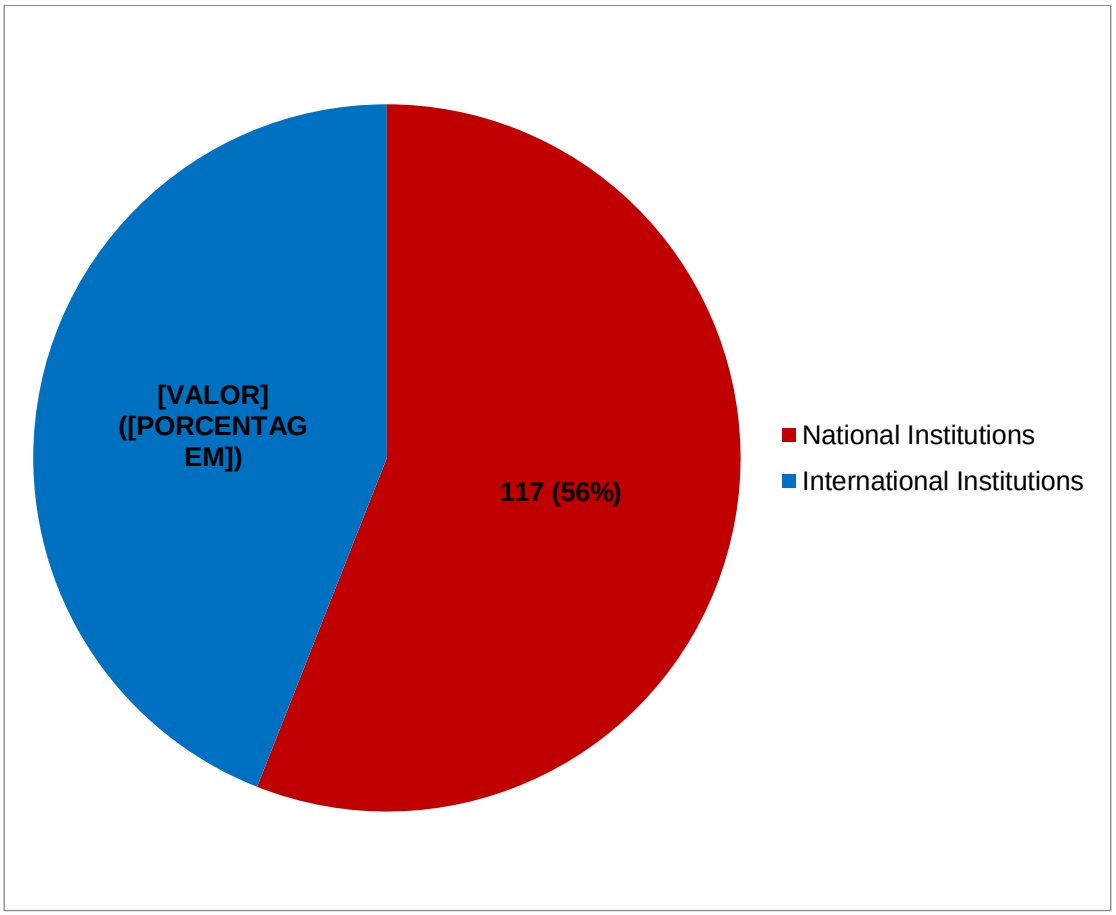

Figure 6. Proportion of national and international institutions that published articles on *Myrmecophaga tridactyla*, *Bradypus variegatus*, *Priodontes maximus*, and *Tolypeutes tricinctus*, between 1976 and 2017.

Evaluation of scientific production brings important information about scientific advances in several areas, and Brazil reached the 13th position in the world ranking of scientific paper production (CROSS, THOMSON, SINCLAIR, 2017) in other words, over the years there has been a significant increase in Brazilian scientific production. This increase is associated with the growth of postgraduate studies and also the increase of investment by the Brazilian government in science and technology (HILU; GISI, 2011).

CONCLUSIONS

The evaluation of scientific production on Xenarthra species threatened with extinction in the Cerrado biome, between 1976 and 2017, demonstrated a lack of research. It was also found that the number of articles on the species *Myrmecophaga tridactyla* (giant anteater) and *Bradypus variegatus* (brown-throated sloth) is more abundant than articles on the species *Priodontes maximus* (giant armadillo) and *Tolypeutes tricinctus* (Brazilian three-

banded armadillo). Also, there is an absence of studies for the armadillo species discussed in this study in the areas of physiology, genetics/biochemistry, and microbiology/immunology.

Our results also show the importance of investments for the knowledge production about the studied species, since the national institutions that have greater financial support in the development of research obtained a greater number of published articles and that are crucial for the development of conservationist public policies.

Finally, we emphasize that despite the vulnerability of the species mentioned in this study, there is a lack of research and data on biological knowledge that is essential for conservation programs. In this context, the identification of gaps in specific knowledge for each species classified as threatened with extinction associated with the causes of population decline are important tools in the development of strategies and targeting resources and efforts for the implementation of conservation initiatives for the species discussed in this article, mainly because they are suffering from hunting and constant habitat fragmentation.

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COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHOR'S CONTRIBUTIONS

L.F.A., E.L.M.D.N., P.A.C.D.A., and R.R.D.C. designed research, collected the data, and wrote the paper. P.O.P. reviewed the final English version, performed the taxonomic characterization, and gave useful technical comments. J.S.A.R. contributed to the writing of the final English version of the manuscript and edited the manuscript. F.M.R. performed the statistical analysis, supervised the project and gave useful technical comments. All authors actively participated in the results discussion, reviewed and approved the final version of the paper.

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