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REVIEW

Space use by the giant anteater (*Myrmecophaga tridactyla*): a review and key directions for future research

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Abstract

Understanding the use of space is essential to promote effective conservation actions, particularly to xenarthran species that are threatened by habitat loss, poaching, and other environment degradation. Information regarding the use of space by the giant anteater (*Myrmecophaga tridactyla*), a large and vulnerable Neotropical mammal, is sparse and sometimes inconsistent in the scientific literature. Our aims are (1) to present an updated overview of giant anteater use of space; (2) to identify knowledge gaps; and (3) to recommend the next steps to advance this knowledge. We compiled information from 53 publications regarding the key aspects of space use: movement patterns, home range size and overlap, and habitat use. We identified the following research priorities: (a) the need of studies on different populations throughout the species' range, including continuous native forest areas, and different spatial scales; (b) to develop research on dispersal by the individuals; (c) to understand movement patterns based on trajectory-related methods; (d) to comprehend home range overlap and territoriality ecological meaning; and (e) habitat selection and movement patterns on human-modified landscapes.

Keywords Ecology · Home range · Movement · Neotropical vertebrate · Pilosa · Xenarthra

Introduction

We are witnessing a global wave of habitat fragmentation and degradation, mostly driven by intensive human activities (Fahrig 2003; Allen and Singh 2016; Abrahms et al. 2017; McGowan et al. 2017). This scenario contributes to increasing the risk of species extinction (Butchart et al. 2010; Young et al. 2016). Among terrestrial vertebrates, more than 300 species have become extinct since 1500, and many of the remaining species are experiencing a decline in abundance (Dirzo et al. 2014) and are also losing suitable habitats (De Marco et al. 2018). For instance, 173 mammal species have already lost over 50% of their original range (Ceballos and Ehrlich 2002). For giant anteaters (*Myrmecophaga tridactyla*, Mammalia, Pilosa), the population loss is estimated at 30% in the past 26 years, mostly due to the decline in their range (Miranda et al. 2014; Miranda et al. 2015).

The giant anteaters' original distribution was broad, ranging from Belize to the south of South America, excluding the Andes. However, the species is considered locally uncommon to rare, and the populations from the northern and extreme southern reaches of this distribution are considered extinct (Miranda et al. 2014). Most populations are facing one or more threats, including habitat loss, wildfires, poaching, conflicts with dogs, and roadkills (Miranda et al. 2015). These threats, coupled with life history traits such as a low reproductive rate and a long period of parental care (Rodrigues et al. 2008), increase their vulnerability.

The species is listed as Vulnerable in the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (Miranda et al. 2014), and currently the giant anteater is the target species of research and conservation

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programs such as Instituto de Pesquisa e Conservação de Tamanduás do Brasil - Projeto Tamanduá (http://www.tamandua.org/), Brazil; Anteaters & Highways (www.tamanduabandeira.org), Brazil; Proyecto Iberá – Oso Hormiguero (http://www.proyectoibera.org), Argentina; and Proyecto Hormigueros (https://www.cunaguaro.co/proyecto-hormigueros), Colombia. However, there is still a shortage of information about the giant anteater in regard to space use patterns, such as home range size and the extent of home range overlap between individuals, habitat selection, and movement patterns in different localities (Rodrigues et al. 2008; Diniz and Brito 2012). These aspects of space use are fundamental for the definition of strategic conservation plans and actions, particularly to ensure their long-term conservation in the Anthropocene.

Giant anteaters have been recently studied in some localities within their area of distribution. Most of these data are available as gray literature or book chapters, but are sparse in peer-reviewed literature. Therefore, here we ask, what do we already know about the space use and movement patterns of this species? We aim with this review to provide an updated overview of what we know about the use of space by the giant anteater, point out new avenues to fill knowledge gaps, and recommend the next steps to advance this knowledge.

Methods

To collect the references related to space use patterns of the giant anteater, a search was conducted using all databases of Thomson Reuters™ Web of Science™ (available at http://apps.webofknowledge.com), *Edentata*, the annual publication of the IUCN/SSC Anteater, Sloth and Armadillo Specialist Group (http://xenarthrans.org/newsletter), complemented by a search in Google Scholar (www.scholar.google.com) and A.B. personal bibliographic list until 2019 September, which include theses and dissertations, books, and book chapters. We did not delineate a specific year so that the search would return all possible indexed articles. We used the scientific name (*Myrmecophaga tridactyla*) and the English, Portuguese, and Spanish common names ("giant anteater", "tamanduá-bandeira", "oso hormiguero") respectively. Then we filtered the result of the search using the keywords: movement, home range, and habitat. We applied following combination of keywords in Google Scholar: "Myrmecophaga tridactyla AND giant anteater AND* OR oso hormiguero AND* OR tamanduá-bandeira AND XXXX". XXXX was replaced by each one of the three keywords. Our dataset was organized, regarding the main contents of the literature compiled, into the following groups: (a) movement patterns, (b) home range size and overlap, (c) habitat use, and (d) the proximity to human-modified landscapes.

To provide an overview of the most recurrent words that appeared on our review, all titles of the literature on giant anteater were plotted in a word cloud (http://www.wordclouds.com). The program transforms the frequency of the words appearance in different sizes. To be more informative, we eliminated all the prepositions, scientific, and popular names.

For each study included in our dataset, where available, we noted the home range size estimation method used (Minimum Convex Polygon [MCP], Kernel, or Brownian Bridge [BB]) and separate home range size (km^2) estimates for males and females, the distance individuals moved per day (m/day), and the speed of movement (km/h; Table 1). In addition, we provide a brief history of monitoring methods of giant anteaters (Online Resource 1).

Results

Our bibliographic search retrieved 192 references in Web of Science™ and 51 in *Edentata*. After the filtering process, we retained 19 and 10 references from these sources, respectively. Additionally, we included 24 references from Google Scholar and A.B. personal bibliographic list. Our review is based on 53 publications (Table 2).

The word cloud highlighted the most common words registered on the titles of the publications retrieved in our review (Fig. 1). "Brazil", "Pantanal", "Cerrado", "Habitat", "Mammal", "Colombia", "Area", "Use", "Selection" and "Conservation" were among the most frequent words in the titles.

One of the remarkable features of most of these references is that they provide data related to a few anteaters restricted to regional areas, and occasionally the studies were from the same study site (for example, Nhumirim Ranch in Brazilian Pantanal; Table 1).

Movement patterns

The average daily distance moved is around 3700 m/day. The shortest distance reported is 1326 m/day and the longest is 11,000 m/day at an average speed of less than 1 km/h (Table 1). No recent study has recorded the movement's step-turned angles and their associations with habitat types.

Home range size and overlap

The first home range size estimate for the giant anteater was based on the species' bio-ecological traits (body mass, terrestrial habit, feeding specialist, low densities) and predicted a size of 9 km^2 (Silveira 1969). However, the first field study carried out estimated a home range size three times as large as this (Montgomery and Lubin 1977, Table 1). With the exception of a study that involved reintroduced individuals, subsequent

Table 1 Features of space use by giant anteaters (*Myrmecophaga tridactyla*) in different studies, organized in chronological order

Site	VHF or GPS / Method	HR (sex); n	Dist; m/day	Speed; km/h
–[1]	Theoretical	9	None	None
VEN [2]	VHF (following individuals on horseback)	25; 5	11,000	0.8
PNSC [3]	VHF MCP	3.6 ± 1.8 (F); 4 2.7 ± 1.2 (M); 4	2500-6000	–
PAN [4]	VHF MCP	> 9.3; 10	–	0.5 ± 0.3
PNE [5]	VHF MCP	6.9 ± 2.6 (F); 4 10.8 ± 6.9 (M); 10	–	–
	VHF Kernel	14.9 ± 3.92 (F); 4 18 ± 12 (M); 10	–	–
	GPS MCP	2.7 (F); 2 0.8 (M); 4	1764	0.6 ± 0.8
PAN [6]	VHF MCP	11.9 (F); 1 5.7 ± 1.7 (M); 4	5800	–
	VHF Kernel	18.7 (F); 1 8.2 ± 2 (M); 4	–	–
	GPS MCP	9.5 (F); 1 7.3 (M); 1	–	–
PR [7]	VHF MCP	1.6 (F); 1 8.8 (M); 1	–	–
	VHF Kernel	11.2 (F); 1 16.6 (M); 1	–	–
RR [8]	VHF MCP	4.9 ± 2.9 (F); 5 3.8 ± 3.2 (M); 5	–	–
	VHF Kernel	1.1 ± 0.4 (F); 5 6 ± 8.4 (M); 5	–	–
	GPS MCP	2.7 ± 0.6; 4	2687 ± 9,3	0.3 ± 0.1
PAN [9]	GPS MCP	3.9 (F); 2 3 (M); 2	3060	–
PNSC [9]	GPS MCP	2.5 (F); 1 4.4 (M); 1	5915	–
ARG [10]	VHF MCP	8.5 ± 10.7 (F);10 13.5 ± 10.7 (M); 11	–	–
	VHF Kernel	18.4 ± 27.8 (F); 10 22.6 ± 21.2 (M); 11	–	–
COL [11]	VHF Kernel	0.77 (F); 1 2 (M); 1	2720	–
EESB [12]	GPS MCP GPS Kernel GPS BB	1.44 (F); 1 2.46 (F); 1 0.92 (F); 1	1326 ± 451	–
ARG [13]	VHF Kernel	9.75 ± 1.74 (F); 5 32.5 ± 7.64 (M); 4	–	–
PAN [13]	GPS Kernel	9.62 ± 2 (F); 7 14.07 ± 1.97 (M); 3	–	–

Sources: [1] Silveira 1969; [2] Montgomery and Lubin 1977, Montgomery 1985; [3] Shaw et al. 1985, 1987; [4] Camilo-Alves 2003; [5] Miranda 2004; [6] Medri and Mourão 2005; [7] Braga 2010; [8] Macedo et al. 2010; [9] Bertassoni 2010; [10] Di Blanco 2015; [11] Rojano et al. 2015; [12] Bertassoni et al. 2017; [13] Di Blanco et al. 2017.

Study site: VEN = Venezuela; PAN = Brazilian Pantanal wetland; SCNP = Serra da Canastra National Park, Brazil; ENP = Emas National Park, Brazil; PR = Paraná State, Brazil; RR = Roraima State, Brazil; ARG = Iberá Natural Reserve, Argentina; COL = Casanare, Colombia; SBES = Santa Bárbara Ecological Station, São Paulo State, Brazil. Type of device (VHF or GPS) and the home range estimator (Minimum Convex Polygon - MCP; Kernel; Brownian Bridge - BB; Method), home range size (HR, km^2) related to sex and number of sampled individuals (n), average daily distance traveled (Dist; m/day) and average speed (Speed; km/h) are given.

studies in the wild have reported less variation in home range size information (Table 1).

Several studies have confirmed that the home ranges of giant anteaters overlap. The pair-to-pair analysis showed up to 90% overlap at a 1318 km^2 reserve in central Brazil (Miranda 2004), a 100% overlap in a 25.9 km^2 ranch in an urban/rural area of northern Brazil (Macedo et al. 2010), and 55% at a Brazilian Pantanal ranch of 104 km^2 (Medri and Mourão 2005). Overlap can occur within and between sexes, as well as with different ages (Miranda 2004; Medri and Mourão 2005; Macedo et al. 2010), and females can be more tolerant than males with their same-sex neighbors (Shaw et al. 1987).

Table 2 Giant anteater's (*Myrmecophaga tridactyla*) space use literature accessed until 2019 September. Keywords content is related to the following topics; habitat (H), home range (HR), and movement (M) which are retrieved by Google Scholar search, and * is in regards to literature not retrieved by the same platform.

	Year	Authors	Title	Source	Type	Keywords
Web of Science	2002	Mourão & Medri	A new way of using inexpensive large-scale assembled GPS to monitor giant anteaters in short time intervals	Wildlife Society Bulletin	Article	M
	2005	Medri & Mourão	Home range of giant anteaters (*Myrmecophaga tridactyla*) in the Pantanal wetland, Brazil	Journal of Zoology	Article	H HR M
	2006	Camilo-Alves & Mourão	Responses of a specialized insectivorous mammal (*Myrmecophaga tridactyla*) to variation in ambient temperature	Biotropica	Article	H
	2007	Mourão & Medri	Activity of a specialized insectivorous mammal (*Myrmecophaga tridactyla*) in the Pantanal of Brazil	Journal of Zoology	Article	H
	2010	Braga et al.	Marking behavior of the giant anteater *Myrmecophaga tridactyla* (Mammalia: Myrmecophagidae) in Southern Brazil	Zoologia	Article	HR
	2011	Vynne et al.	Resource Selection and Its Implications for Wide-Ranging Mammals of the Brazilian Cerrado	Plos One	Article	H HR
	2012	Zimbres et al.	Range shifts under climate change and the role of protected areas for armadillos and anteaters	Biological Conservation	Article	H
	2012	Kreutz et al.	Timber plantations as favourite habitat for giant anteaters	Mammalia	Article	H
	2013	Diniz & Brito	Threats to and viability of the giant anteater, *Myrmecophaga tridactyla* (Pilosa: Myrmecophagidae), in a protected Cerrado remnant encroached by urban expansion in central Brazil	Zoologia	Article	H
	2015	Di Blanco et al.	Habitat selection in reintroduced giant anteaters: the critical role of conservation areas	Journal of Mammalogy	Article	H
	2016	Quiroga et al.	Local and continental determinants of giant anteater (*Myrmecophaga tridactyla*) abundance: Biome, human and jaguar roles in population regulation	Mammalian Biology	Article	H
	2016	Paolino et al.	Buffer zone use by mammals in a Cerrado protected area	Biota Neotropica	Article	H
	2017	Di Blanco et al.	Habitat selection and home-range use by resident and reintroduced giant anteaters in 2 South American wetlands	Journal of Mammalogy	Article	H HR
	2017	Bertassoni et al.	Movement patterns and space use of the first giant anteater (*Myrmecophaga tridactyla*) monitored in São Paulo State, Brazil	Studies on Neotropical Fauna and Environment	Article	H HR M
	2017	Ascensao et al.	Spatial patterns of road mortality of medium-large mammals in Mato Grosso do Sul, Brazil	Wildlife Research	Article	H
	2018	Pardo et al.	Terrestrial mammal responses to oil palm dominated landscapes in Colombia	Plos One	Article	HR
	2018	Pinto et al.	Giant anteater (*Myrmecophaga tridactyla*) conservation in Brazil: Analysing the relative effects of fragmentation and mortality due to roads	Biological Conservation	Article	H
	2019	Meyer et al.	Effectiveness of Panama as an intercontinental land bridge for large mammals	Conservation Biology	Article	H HR
	2019	Bertassoni et al.	Land-use changes and the expansion of biofuel crops threaten the giant anteater in southeastern Brazil	Journal of Mammalogy	Article	H
Edentata	1995	Brooks	Distribution and limiting factors of edentates in the Paraguayan Chaco	Edentata	Article	*
	2003	Rodrigues et al.	Fitting radio transmitters to giant anteaters (*Myrmecophaga tridactyla*)	Edentata	Article	*
	2006	Oliveira et al.	Edentates of the Saracá-Taquera National Forest, Pará, Brazil	Edentata	Article	*
	2010	Desbiez & Medri	Density and habitat use by giant anteaters (*Myrmecophaga tridactyla*) and southern tamanduas (Tamandua tetradactyla) in the Pantanal wetland, Brazil.	Edentata	Article	*
	2012	Di Blanco et al.	Cinco Años de Radiomarcaje de Osos Hormigueros (*Myrmecophaga tridactyla*): Mejoras Implementadas y Lecciones Aprendidas	Edentata	Article	*
	2012	Diniz & Brito	The charismatic giant anteater (*Myrmecophaga tridactyla*): a famous John Doe?	Edentata	Article	*
	2015	Rojano-Bolaño et al.	Área de vida y uso de hábitats de dos individuos de oso palmero (*Myrmecophaga tridactyla*) en Pore, Casanare, Colombia	Edentata	Article	*

Table 2 (continued)

	Year	Authors	Title	Source	Type	Keywords
	2015	Rojano et al.	Registro de presencia del oso palmero (*Myrmecophaga tridactyla*) en plantaciones forestales comerciales en Colombia	Edentata	Article	*
	2018	Mamalis et al.	Stepping stones facilitate river crossings by *Myrmecophaga tridactyla* in the north-eastern Brazilian Amazon	Edentata	Article	*
	2018	Bertrand & Soares	First reports of giant anteater (*Myrmecophaga tridactyla*) and greater naked-tailed armadillo (Cabassous tatouay) for the Iguaçu National Park, Paraná, Brazil, with notes on all xenarthran occurrences	Edentata	Article	*
Google Scholar + personal bibliographic lists	1969	Silveira	História natural do tamanduá-bandeira *Myrmecophaga tridactyla* Linn. 1758, Myrmecophagidae	Vellozia	Article	*
	1977	Montgomery & Lubin	Prey influences on movements of Neotropical anteaters	Proceedings of The 1975 Predator Symposium	Book chapter	*
	1985	Shaw et al.	Ecology of the giant anteater *Myrmecophaga tridactyla* in Serra da Canastra, Minas Gerais, Brazil: a pilot study	The Evolution and Ecology of Armadillos, Sloths and Vermilinguas	Book chapter	*
	1985	Montgomery	Movements, Foraging and food habitats of four extant species of neotropical Vermilinguas	The Evolution and Ecology of Armadillos, Sloths and Vermilinguas	Book chapter	*
	1987	Shaw et al.	Behavior of free-living giant anteaters (*Myrmecophaga tridactyla*)	Biotropica	Article	H HR
	1992	Drumond	Padrões de forrageamento do tamanduá-bandeira (*Myrmecophaga tridactyla*) no Parque Nacional da Serra da Canastra: dieta, comportamento alimentar e efeito de queimadas	Minas Gerais Federal University	PhD thesis	*
	2003	Genoways & Timm	The xenarthrans of Nicaragua	Journal of Neotropical Mammalogy	Article	H
	2003	Camilo-Alves	Adaptações dos tamanduás-bandeira (*Myrmecophaga tridactyla* Linnaeus, 1758) à variação da temperatura ambiente no Pantanal da Nhecolândia, MS	Mato Grosso do Sul Federal University	PhD thesis	H
	2004	Miranda	Ecologia e conservação do tamanduá-bandeira (*Myrmecophaga tridactyla*, Linnaeus, 1789) no Parque Nacional das Emas	Brasília University	PhD thesis	HR
	2008	Polisar et al.	Patterns of vertebrate abundance in a tropical mosaic landscape	Studies on Neotropical Fauna and Environment	Article	H
	2008	Rodrigues et al.	Anteater behavior and ecology	The Biology of The Xenarthra	Book chapter	*
	2009	Timm et al.	Mammals of Cabo Blanco: History, diversity, and conservation after 45 years of regrowth of a Costa Rican dry forest	Forest Ecology And Management	Article	H HR
	2010	Macedo et al.	Área de vida, uso do habitat e padrão de atividade do tamanduá-bandeira na savana de Boa Vista, Roraima	Roraima: Homem, Ambiente e Ecologia	Book chapter	*
	2010	Bertassoni	Avaliação da relação entre área de vida, distância média diária percorrida e disponibilidade de energia de tamanduás-bandeira (*Myrmecophaga tridactyla*) em savanas neotropicais	Mato Grosso do Sul Federal University	MsC disserta-tion	HR
	2010	Braga	Ecologia e Comportamento de Tamanduá-bandeira *Myrmecophaga tridactyla* Linnaeus, 1758 no município de Jaguariaíva, Paraná.	Paraná Federal University	PhD thesis	H HR
Google Scholar + personal bibliographic lists	2014	Freitas et al.	Road-kills of the giant anteater in south-eastern Brazil: 10 years monitoring spatial and temporal determinants	Wildlife Research	Article	H
Google Scholar + personal bibliographic lists	2015	Timo et al.	Effect of the plantation age on the use of Eucalyptus stands by medium to large-sized wild mammals in south-eastern Brazil.	Iforest	Article	H
	2015	Rojano et al.			Article	H

Table 2 (continued)

	Year	Authors	Title	Source	Type	Keywords
			Population density and biomass of the giant anteater (*Myrmecophaga tridactyla*) in Pore, Casanare, Colombia	Revista Biodiversidad Neotropical		
	2015	Di Blanco et al.	Habitat selection in reintroduced giant anteaters: the critical role of conservation areas.	Journal of Mammalogy	Article	H
	2015	Di Blanco	Patrones de actividad y de uso de hábitat de Osos Hormigueros (*Myrmecophaga tridactyla*) reintroducidos en Iberá, Corrientes, Argentina	Universidad Nacional de Córdoba	PhD thesis	H
	2016	Passos et al.	The vulnerable giant anteater *Myrmecophaga tridactyla*: new records from the Atlantic Forest highlands and an overview of its occurrence in protected areas in Brazil	Oryx	Article	H
	2016	Versiani	O tamanduá-bandeira (*Myrmecophaga tridactyla*) em áreas protegidas e seus entornos no Cerrado do nordeste do estado de São Paulo	University of São Paulo	PhD thesis	H HR
	2017	Roberto	Distribuição potencial e atual do tamanduá-bandeira (*Myrmecophaga tridactyla*) e indicação de áreas prioritárias para sua conservação	University of São Paulo	MsC dissertation	H HR
Google Scholar + personal bibliographic lists	2018	Gaudin et al.	*Myrmecophaga tridactyla* (Pilosa: Myrmecophagidae)	Mammalian Species	Article	M

Habitat use

Habitat use patterns of the giant anteater depend on whether the giant anteater is active or inactive, on the temperature of the environment, and on seasonality (Medri and Mourão 2005; Camilo-Alves and Mourão 2006; Di Blanco et al. 2015; Di Blanco et al. 2016). The species uses vegetation-covered habitats during inactive periods and more open habitats when active (Camilo-Alves and Mourão 2006; Mourão and Medri 2007; Macedo et al. 2010; Di Blanco et al. 2016). It is known that vegetation-covered habitats (e.g., forest, shrublands, and timberlands) act as thermal refuges due to their more stable and milder core temperature (Mourão and Medri 2007), as was also suggested for other xenarthrans (Attias et al. 2018). Giant anteaters used shrub savanna to sleep in the Llanos of Venezuela (Montgomery and Lubin 1977; Montgomery 1985). The same pattern was also reported in central Brazil, even with grassland being the most abundant habitat type (Serra da Canastra National Park; Shaw et al. 1987).

In the Brazilian Pantanal wetland, giant anteater individuals used the available habitats in different proportions depending on whether they were active or sleeping (Medri and Mourão 2005), and forests were positively selected by individuals when inactive (Di Blanco et al. 2017). However, this behavior of preference on different types of habitats in dependency on the type of activity is highly associated with the temperature of the environment (Camilo-Alves and Mourão 2006; Attias et al. 2018). Giant anteaters monitored showed that in the hottest hours of the day, they prefer to be in sheltered habitats, such as forest patches, avoiding body' overheating and reducing their exposure to the sun's rays. Nonetheless, as the days became colder, the giant anteaters began and ended their activity progressively earlier and preferred resting in more open areas (Rodrigues et al. 2008).

Giant anteaters have also used anthropogenic areas such as agricultural fields and timber plantations of *Pinus* sp., *Acacia* sp., and *Eucalyptus* sp. (Miranda 2004; Braga 2010; Vynne et al. 2011; Kreutz et al. 2012; Timo et al. 2015). Nevertheless, the species tends to prefer natural habitat composition (Vynne et al. 2011), underutilizing the available plantations and timberlands (Braga 2010; Bertassoni et al. 2017). Other studies have reported that giant anteaters use or cross roads (Macedo et al. 2010; Vynne et al. 2011; Freitas et al. 2014; Versiani 2016; Ciocheti et al. 2017). The use of roads facilitates the individual's movement due to its free of vegetation space, making ants and termite nests easy targets, especially at the edges (Freitas et al. 2014). A positive relationship between the occupancy of the giant anteater and the dirt roads was observed in a study site in the south-central region of Brazil (Versiani 2016).

In regard to seasonality, only one study conducted in Argentina with a reintroduced population lasted long enough to collect seasonality data. The results showed a shorter activity period in the winter (Di Blanco et al. 2016).

Discussion

The awareness and concern for the maintenance and survival of giant anteater populations were drivers fostering research reflected by words in the cloud such as "Protected", "Conservation", "Mortality", and "Population". "Brazil" was one of the most frequent words on the cloud showing that most of the research has been done in the country, mainly on "Cerrado" and "Pantanal" biomes (Fig. 1).

Movement patterns

A model developed by Montgomery and Lubin (1977) showed that the general motion pattern of giant anteaters can be characterized as a long series of short stops interspersed with relatively faster movement in a straight line. They also include in the model the tortuosity of the trajectory. The trajectory is a term used in the movement ecology discipline and it is characterized as the curve described by the animal when it moves, taking into account number of discrete "steps" connecting successive relocations of the animal (Calenge et al. 2009). To the species, the rate and angles of the trajectory seem to depend on preys' characteristics, likely the distribution and abundance of ant and termite nests, foraging time, energy expended in each feeding event, etc. (Montgomery and Lubin 1977; Drumond 1992).

Fig. 1 Most common words registered on the titles of the publications the word cloud highlighted

The Montgomery and Lubin model can be improved with research based on movement trajectory, which may better elucidate in detail the speed and step-turned angle of the movement. There is a hypothesis which elucidate that animals will show low movement speed and large turning angles to stay in favorable habitats and the conversely to avoid unprofitable habitats (Turchin 1991); and this idea has been widely tested (Barraquand and Benhamou 2008; Duffy et al. 2011; Da Silveira et al. 2016; Grotta-Neto et al. 2019). Therefore, an important avenue for new research will certainly be studies comparing the trajectory of giant anteaters between well-preserved and human-modified landscapes. Additionally, studies on giant anteater roadkills can use the speed of movement to understand why the species is often a victim of vehicle collisions (Ribeiro et al. 2017; Ascensão et al. 2017; Sistema Urubu - http://cbee.ufla.br/portal/sistema_urubu/urubu-info.php).

Regarding the daily distance traveled, the largest reported value was 11,000 m/day (Montgomery and Lubin 1977, Table 1), which indicates that biologically, the species is able to move long distances. However, the authors attempted to follow individuals on horseback and reported difficulty in tracking the individuals due to their rapid movement. This is unlikely for the species; thus, we assume that the giant anteaters were trying to escape from this approximation, as occurs when the distance is too close and noisy (A.B. comm. pers.). Thereby, we assume an overestimation on this distance traveled per day. The largest known distance traveled is therefore about half of the above value (6000 m/day; Shaw et al. 1987, Table 1). However, since these data about the movement of giant anteaters were obtained in short-term studies (few months or less), some questions arise.

As distance moved influences home range size, and home range and dispersal distance of mammals are related (Bowman et al. 2002; Whitmee and Orme 2013), we ask: Do giant anteaters exhibit natal dispersal—here defined as the movement that an individual makes to establish its own home range? If so, does this dispersal behavior occur equally for both males and females? To date, no study has addressed the dispersal capacity of the individuals and there is a need for studies focusing on the different aspects of it. This can be particularly important for a better understanding of the animal's resilience to anthropogenic changes. Furthermore, if most giant anteater populations are restricted to small vegetation remnants (Diniz and Brito 2015; Bertassoni et al 2019), the following question emerges: Is it possible that a connected landscape for the species is on the 6000-m spatial scale? One promising avenue for obtaining those answers is real-time animal tracking technology applied in long-term studies (Jønsson et al. 2016).

In addition, based on the fact that a giant anteater cub remains with its mother for about a year (Jerez and Halloy 2003) and that home ranges can overlap, we ask: Do cubs disperse as soon as they gain their independence? Do female cubs remain in areas adjacent to their mothers' areas? Addressing these questions is challenging since it requires capturing and setting up telemetry devices for both the mother and the cub throughout the cub's independence, dispersion, and finally, the establishment of its own home range. Thus, studies using noninvasive molecular techniques may represent an alternative to explore those aspects (Smith et al. 2006; Miotto et al. 2012). Clozato et al. (2017) made a first step on this direction studying on the population structure and genetic diversity of giant anteaters.

Home range size

Most studies of home range provide size estimates obtained by the Minimum Convex Polygon (MCP, Mohr 1947) method. Other studies present data obtained from the Kernel estimator (Worton 1989), but the specific method used varied among them (i.e., 95% adaptive Kernel, 90% fixed Kernel, 95% fixed Kernel). However, as the use of GPS technology increases, the new trend is to use estimators that consider the trajectory instead of the MPC and/or Kernel (Benhamou and Riotte-Lambert 2012).

Home range sizes of the giant anteater vary greatly among studies. This variation results from several aspects, such as different monitoring protocols, which home range estimator was used, characteristics of study sites, seasonality, or anthropogenic impact (Rodrigues et al. 2008). Comparisons among different studies have little biological value because it is not possible to exclude the influence of these factors in the biological definition of the individual's home range. Moreover, home range sizes most likely differ between males and females, and between adults and juveniles. We need more long-term studies in several study sites and regions, using a large number of individuals and a systematic data collection protocol, in order to reach a biological understanding of these differences.

Despite the presence of a few large populations in Brazil (e.g., in Emas and Serra da Canastra National Parks), most of giant anteaters are restricted to small fragments in protected or non-protected areas (Miranda et al. 2014; Diniz and Brito 2015; Bertassoni et al. 2017; 2019). Carrying out studies in different regions, including areas of different sizes, should also examine anthropogenic impacts on the study site. For instance, jaguars present larger home ranges in regions with higher anthropogenic impacts, which may also be true for other large-sized animals, as giant anteaters (Morato et al. 2016; Tucker et al. 2018).

Home range overlap

Giant anteaters seem to be quite tolerant of their intraspecific neighbors, as evidenced by a great deal of home range overlap described in the scientific literature. However, they display a marking behavior that could have a role in territoriality (Braga et al. 2010; Allard et al. 2014), and several studies have reported intraspecific aggression (Shaw et al. 1987; Rocha and Mourão 2006; Kreutz et al. 2009; Miranda Júnior and Bertassoni 2014). More research is needed to resolve this seeming paradox so that we can better understand if territoriality occurs in giant anteaters and, if so, what ecological conditions favor its expression.

Habitat selection

No study has been published to date that focuses on examining giant anteaters in native continuous forest; consequently, the giant anteater is generally considered an open-habitat species that prefer grasslands and areas near swamps. Throughout its distribution, it is also found within forested biomes, such as the Amazonian and Atlantic Forests (Oliveira et al. 2006; Passos et al. 2016; Bertrand and Soares 2018; Santos et al. 2019). Habitat selection studies have highlighted the importance of covered and forested (non-open) habitats within the individual's core area, which is probably related to the availability of the mosaic of environmental temperatures. For example, the species uses gallery forests for foraging more often than open areas (Shaw et al. 1987); and even when forest habitats are less available, forest habitats can show a high positive selection (Di Blanco et al. 2015). The presence of forested areas that act as a temperature refuge seems to be one of the key factors in determining habitat use of giant anteaters (Camilo-Alves and Mourão 2006; Di Blanco et al. 2015). Timberlands can also be selected instead of native areas if they provide a suitable thermic refuge, as in the *Acacia* sp. plantations in northern Brazil (Kreutz et al. 2012).

Giant anteaters can tolerate altered habitats to a certain degree, but they depend on the proximity of natural areas (Vynne et al. 2011). In general, the persistence of the species seems to be related to habitat heterogeneity, which may offer a variety of resources, such as food, forest patches for thermic refuge, and corridor areas between habitats and matrix (the non-habitat portion of the landscape), such as sugarcane plantations (Bertassoni et al. 2019). Moreover, giant anteaters' use of modified areas needs to be addressed in more detail regarding different anthropogenic levels (e.g., rural and urban areas; sugarcane, soy, coffee plantations). Some studies have recorded the occurrence of giant anteaters in exotic pastures (Vynne et al. 2011; Rojano-Bolaño et al. 2015). Contrarily, a study of habitat selection using two different spatial scales showed that giant anteaters, in fact, avoid pasture with cattle high densities (1.3–5.5 livestock/ha) (Di Blanco et al. 2015). The authors pointed out that this avoidance may be due to the "open" characteristics of the pasture that exposes the species to dangerous conditions such as poaching, wildfires, and conflicts with domestic dogs.

The species tends to select natural habitats distant from roads (Vynne et al. 2011). However, in instances when habitat conditions are altered, and then heavily influenced by agricultural areas, individuals prefer to move using roads (Vynne et al. 2011). Overall, roads can act as a passage connector between habitat patches (Vynne et al. 2011; Versiani 2016).

The proximity to human-modified landscapes

The species can change its period of activity depending on the region and the degree of human impact. For example, giant anteaters visited urban areas from 18:00h to 21:00h, synchronizing with the off-peak times of a human population in northern Brazil (Macedo et al. 2010). A similar pattern was found in an intensely modified landscape (41% of sugarcane) in southeast Brazil (Versiani 2016; Paolino et al. 2016). These examples show the versatility of the giant anteater in managing its time and activity in or near human-dominated landscapes.

There is currently a collection of descriptive reports regarding the occurrence of the species in anthropogenic areas (Miranda 2004; Braga 2010; Vynne et al. 2011; Kreutz et al. 2012; Timo et al. 2015). Although descriptive characteristics are a first step toward new knowledge, research emphasizing ecological hypotheses related to the use of anthropogenic areas is essential, such as plastic-foraging strategies (Gilmour et al. 2018) and the effect of the anthropogenic footprint on animal movements (Tucker et al. 2018), especially in this historical moment of great anthropogenic changes (Johnson et al. 2017).

Conclusion

We present updated information about space use by the giant anteater. This information could be used to guide new research and help develop conservation practices. In summary, we highlighted:

- There is a need for further knowledge about the giant anteater throughout its geographical range. Most studies have been conducted in Brazil, in the Cerrado and Pantanal wetland biomes;
- Studies carried out in other countries and in all existing Brazilian biomes are encouraged and essential to move knowledge forward;
- There are no studies focusing on giant anteaters in continuous native forest. Research in these areas will be important to better understand the patterns of landscape use, and how patterns of space use in native forests mimic or differ from those reported from timberlands;
- The lack of ecological studies in human-dominated landscapes is also of great concern, and this is a knowledge gap that requires great attention;
- The decline of giant anteater populations is predominantly linked to human impacts, but there is evidence of adaptation to human-modified areas where natural resources are preserved. What are these resources? What is the extent of this behavioral plasticity/adaptation?

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