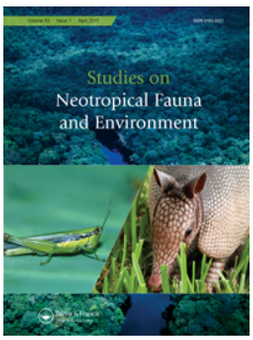

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SHORT COMMUNICATION

Movement patterns and space use of the first giant anteater (*Myrmecophaga tridactyla*) monitored in São Paulo State, Brazil

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ABSTRACT

This study analyzes a giant anteater's (*Myrmecophaga tridactyla*) movement patterns and space use in São Paulo, Brazil. It is the first study to track a giant anteater with Iridium-GPS. The anteater traveled an average distance of 1326 m day^{-1} with an average speed of 1.04 m min^{-1}. Home range by Kernel was 2.46 km^2 while the core area was 0.75 km^2, and estimates by Brownian bridge and minimum convex polygon were also provided. The anteater used shrub savanna, open savanna, and water habitats more than expected. Monitoring ended just after 10 days when the female giant anteater's GPS was found on an illegal trail.

RESUMO

Este estudo analisa os padrões de movimento e o uso do espaço por um tamanduá-bandeira (*Myrmecophaga tridactyla*) em São Paulo, Brasil. É o primeiro estudo a monitorar um tamanduá-bandeira com GPS-Iridium. O tamanduá-bandeira percorreu uma distância média de 1.326 m/dia com uma velocidade média de 1,04 m min^{-1}. A área de vida estimada por Kernel foi de 2,46 km^2, enquanto a área núcleo foi de 0,75 km^2. Estimativas por Ponte Browniana e Mínimo Polígono Convexo também foram fornecidas. O tamanduá-bandeira utilizou os hábitats savana arbustiva e aberta, e àqueles relacionados à água mais do que o esperado. O monitoramento terminou depois de 10 dias quando o GPS do tamanduá-bandeira foi encontrado caído em uma trilha ilegal.

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Giant anteater; telemetry; traveled distance; home range; habitat use

Introduction

The world's ecosystems are facing an unprecedented reduction of biological diversity (Mendenhall et al. 2012), and this downtrend is primarily due to anthropogenic threats. Like many states in Brazil, São Paulo, the most populous and economically developed, suffers from a severe reduction in biodiversity. It is, therefore, not surprising that Bressan et al. (2009) listed 436 species of vertebrates living in the state as "threatened". Such a striking number calls for the need to preserve native areas and slow this rapid loss of biodiversity; however, despite these facts, São Paulo's native vegetation remains highly fragmented and altered, mainly in the Cerrado biome. The Cerrado is a Brazilian biome where savanna vegetation predominates with small portions of gallery and semideciduous forest. It is the second largest region in the Neotropics (Mittermeier et al. 2005) and severely threatened by anthropogenic activities (Klink & Machado 2005). Unfortunately, only 0.5% of the Cerrado is protected (Durigan et al. 2007). The remnants left in the Cerrado, both in and outside of the protected areas, are required to maintain local biodiversity (Diniz & Brito 2015; Françoso et al. 2015).

The giant anteater (*Myrmecophaga tridactyla*, Linnaeus 1758) lives in these areas. This mammal is found in South and Central America (Superina et al. 2010) and is endangered in São Paulo (Chiquito & Percequillo 2009), in all of Brazil (Medri & Mourão 2008), and even at an international level (Miranda et al. 2014). Today, the giant anteater's population is decreasing and has been affected mostly due to habitat loss and fragmentation, poaching, road kill, and wildfires (Silveira et al. 1999; Koster 2008; Superina et al. 2010; Diniz & Brito 2013; Freitas et al. 2014). These factors, combined with low reproductive rates, long parental care, and low densities have enhanced the species' vulnerability (Rodrigues et al. 2008). Current estimates of its densities in well-preserved areas of Central Brazil range from 0.15

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to 0.4 individuals km^{-2} (Miranda et al. 2006b; Desbiez & Medri 2010).

Even as a flagship species, the giant anteater is not well known in Latin America. Most studies with an ecological emphasis have been conducted in well-preserved areas of Brazil, such as the tropical wetland area known as Pantanal (Medri & Mourão 2005, 2007; Camilo-Alves & Mourão 2006; Desbiez & Medri 2010), Emas National Park – ENP (Miranda 2004; Miranda et al. 2006b; Vynne et al. 2011), Serra da Canastra National Park – SCNP (Shaw et al. 1985, 1987), and "Campos Lavrados" in the state of Roraima (Macedo et al. 2010). The greater part of the studies tracked giant anteaters using telemetry to find and show space use, such as resource selection, activity, and home range pattern. The methods typically applied were either VHF – very high frequency – or a combination of VHF and modified-GPS telemetry. Modified GPS is an adapted handheld GPS connected to an external power source consisting of two sets of two D-size alkaline batteries. This is put together to a VHF device, in a waterproof compartment (see Mourão & Medri 2002 to details). Because of its technological characteristics the modified GPS is able to monitor giant anteater only in short-term studies, and it has already been used (Miranda 2004; Medri & Mourão 2005; Camilo-Alves & Mourão 2006; Bertassoni 2010; Macedo et al. 2010).

In general, GPS devices provide quick and precise knowledge of the animal's exact location, allowing researchers to relate its position with the habitat. This information furthers an understanding of why the animal is occupying this space and provides data to assess the consequences of its presence (Cagnacci et al. 2010; Kays et al. 2015).

To the best of our knowledge, no studies have tracked giant anteaters in the state of São Paulo, Brazil. To fill this gap, this study aims to characterize the movement patterns and space use of the first giant anteater monitored by Iridium-GPS in an isolated and protected Cerrado remnant in São Paulo, Brazil.

Materials and methods

Study area

Santa Bárbara Ecological Station (SBES, 22°48′59″ S, 49°14′12″ W; 600–680 m elevation) is located in the Águas de Santa Bárbara municipality in the state of São Paulo in southeastern Brazil. It has a total area of 27 km^2, and the climate is *Cwa* Köppen (Melo & Durigan 2011). The vegetation is a mosaic of "lato sensu cerrado", gallery forest, patches of semideciduous forest, and remnant portions of *Pinus* and *Eucalyptus* species. SBES is considered highly relevant because it is one of the few protected areas in São Paulo to have open physiognomies (Durigan & Ratter 2006; Melo & Durigan 2011). The difference between SBES and the majority of protected areas of the Cerrado biome in the state is the presence of open habitats. However, over the past few decades, the government has included the presence of exotic species such as *Pinus* spp., *Eucalyptus* spp., and *Brachiaria* spp., resulting in a mischaracterization of the protected area's environment (Melo & Durigan 2011).

The Santa Bárbara State Forest (17 km^2) lies in the vicinity of the SBES, with *Pinus* and *Eucalyptus* species that are owned by the São Paulo government as well as private harvesting and cattle ranching properties. The SBES is divided into four blocks by the SP-280 highway, an important unpaved road named the SP-261, and a dirt road providing access to the properties. There is also an urban area at the southern boundary (Melo & Durigan 2011).

Data collection and analysis

In October of 2014 and January of 2015, we carried out two capture campaigns, each lasting around 30 days. Our intent was to place harnesses (Rodrigues et al. 2003; Di Blanco et al. 2012), with the Iridium-GPS attached, on giant anteater specimens (collection permits COTEC 429/2014 D23/2013 PGH and SISBIO 38326-5).

We searched for the anteaters in a low-speed vehicle (with a maximum of 20 km h^{-1}) and used a blowpipe, Ketch All pole, and net pole to aid in the capture. Active searching followed by the specimen's capture has traditionally been the most common method for capturing giant anteaters (Shaw et al. 1987; Medri & Mourão 2005; Rojano-Bolaño et al. 2015). After successfully capturing one giant anteater, we sedated it with a combination of ketamine and midazolam (Miranda et al. 2006a). This protocol provides ample time to take biometric measures, weigh the animal, attach the Iridium-GPS harness, and collect biological samples. The handling was conducted in accordance with the Guidelines of the American Society of Mammalogists for the use of wild mammals in research (Sikes & Gannon 2011).

We programmed the GPS unit to take 21 fixes per day, one every 69 minutes, and analyzed the space use according to the GPS-fix, date, and hour transmitted via the Iridium system. We estimated traveled distances as the sum of the Euclidean distances between consecutive fixes using the Universal

Transverse Mercator coordinate system. We estimated the speed by dividing the covered distance between consecutive fixes by the time lag (69 min) and used the adehabitatHR package in R software (Calenge 2006) to estimate the home range size by Kernel density estimation and Brownian bridges, both in the 95% and 50% probabilities. For Kernel, we used the reference method to estimate the smoothing parameter "h". For Brownian bridge, we used the sig 1 as 1.2513, estimated by the function "liker" of the adehabitatHR package, and sig 2 as 15, referring to the precision error of the GPS measure in the field. To allow comparisons with previous studies, we also supplied estimates of 100% minimum convex polygon (MCP).

We applied chi-square at 99% significance level to outline habitat selection and used the SBES's official management document (Melo & Durigan 2011) to define the habitat categories present in the area. However, Melo and Durigan's (2011) detailed definition of vegetation types was too narrow for our purposes, so we merged the categories as follows: (a) Shrub savanna: "Cerrado *sensu stricto*" and dense cerrado; (b) Forest savanna ("Cerradão"): "Cerradão" and ecotone ("cerradão"/semideciduous forest); (c) Open savanna: open canopy cover and short–medium grass understory, humid or not; (d) Water-related areas: gallery forest and water; (e) Timber areas: *Pinus* spp. and *Eucalyptus* spp.; and (f) Dwellings and roads: roads and constructed sites. Detailed descriptions of Cerrado physiognomies can be found in Durigan and Ratter (2006).

We identified the proportion of each habitat category in the home range as available and every GPS-fix within its respective habitat category as used, and we calculated the available area with the ArcGIS 10.1 software (ESRI 2010). The percentage of habitat used was related with the category's percentage using the 95% Kernel home range.

Results

On 27 January 2015 at 00:32, we captured a female giant anteater in a gallery forest. The anteater weighed 32 kg. On 5 February, its Iridium-GPS was found on the ground, detached from the harness, 150 m from the SP-280 highway and near an illegal trail. Just three days earlier, on February 2, we had spotted the female with a healthy appearance and with the GPS harness attached. The results presented here were related only to this female anteater.

Data downloaded from the fallen Iridium-GPS included 135 valid GPS-fixes taken during 10 days of monitoring. Most fixes (n = 101) were within the SBES's limits, and 34 were in native vegetation of an adjacent private property. The mean distance traveled per day was 1326 ± 451 m, ranging from 678 to 1956 m day^{-1}. The average travel speed per day was 1.04 ± 0.33 m min^{-1} with the lowest speed at 0.68 and greatest at 1.7 m min^{-1} (Table 1). The estimated home range size using Kernel was 2.46 km^2 and 0.75 km^2 at 95% and 50% levels, and was 0.92 km^2 and 0.13 km^2 using Brownian bridge at 95% and 50% levels, respectively. The resulting MCP was 1.44 km^2, and the average MPC size per day was 0.13 km^2 (Table 1, Figure 1).

Table 1. GPS-fixes, mean distance traveled in meters (dist), average travel speed per day in meters per minute (speed) and giant anteater's daily home range by minimum convex polygon (MCP) method (km^2) at Santa Bárbara Ecological Station.

Date	GPS-fix	Dist (m)	Speed (m min^{-1})	Daily MCP (km^2)
28 January 2015	20	1852	1.33	0.28
29 January 2015	13	678	0.68	0.02
30 January 2015	21	1063	0.8	0.11
31 January 2015	20	1676	1	0.24
1 February 2015	18	1010	0.79	0.04
2 February 2015	16	1956	1.7	0.25
3 February 2015	14	1214	1	0.10
4 February 2015	13	1163	1.05	0.08
Total	**16.8 ± 1.2**	**1326.5 ± 159.5**	**1.04 ± 0.1**	**0.13 ± 0.03**

This female giant anteater used shrub savanna, open savanna, and water-related habitats within 95% Kernel home range in a proportion different than that which was predicted by chance (χ^2 = 51,44; df = 5; p < 0,01; Table 2). In the end, the timber areas were not used.

Discussion

Giant anteater short time monitoring

We emphasize that the space use results presented in this study specifically refer to the short-time monitoring of one female giant anteater. Nevertheless, Rodrigues et al. (2008) showed how GPS devices made home range estimates in about seven days while conventional VHF telemetry made similar estimates in anywhere from six to 12 months. Because this is the first study on giant anteaters to use Iridium-GPS technology, we consider our results highly informative. This use of space data is the first step in understanding how the giant anteater is capable of surviving in the Cerrado remnants of São Paulo. The remnants, both protected and not, are isolated among a multiple-use matrix (Durigan et al. 2007), and understanding the giant anteater's space use could clarify important

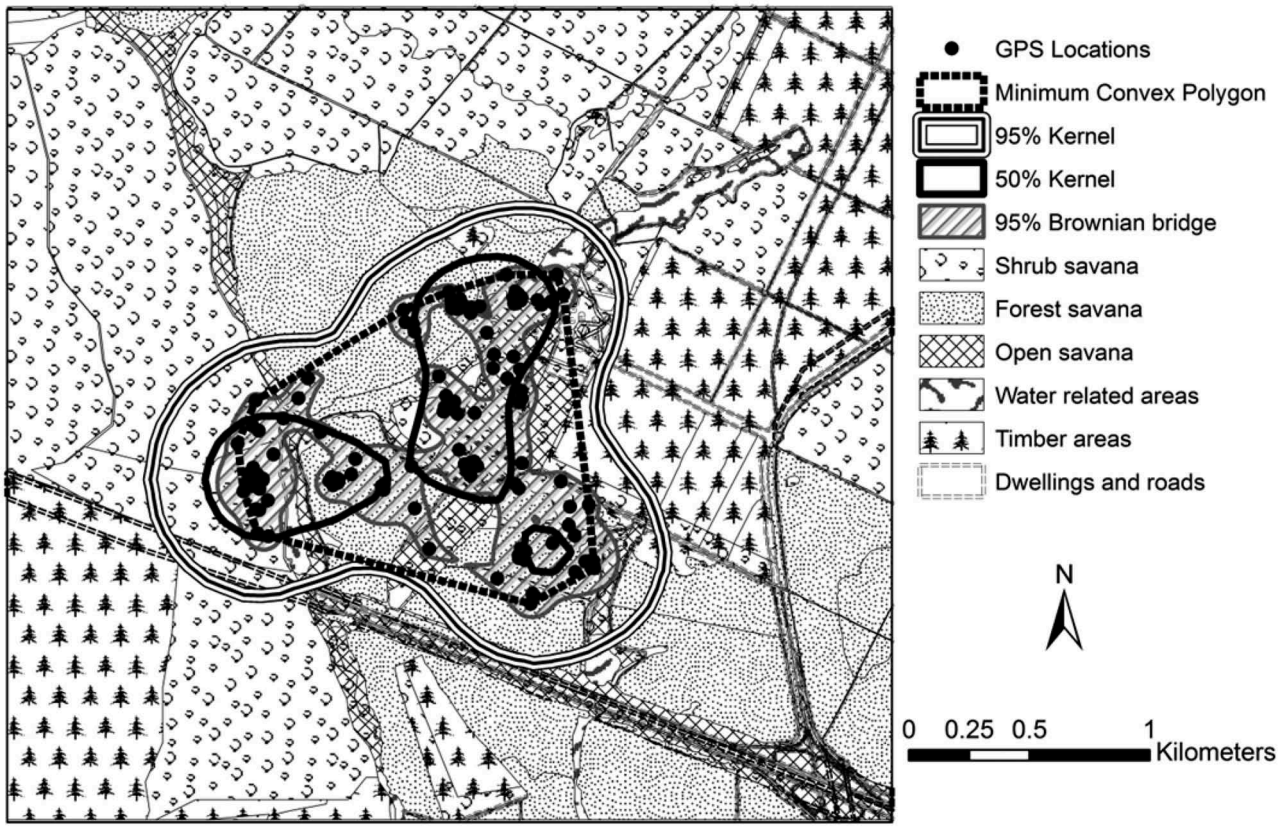

Figure 1. Female giant anteater's (*Myrmecophaga tridactyla*) home range estimated by Kernel and Brownian bridge, at 95% and 50% levels, at Santa Bárbara Ecological Station on the habitat map. The limits of 100% minimum convex polygon area is also shown (thick dotted line).

Table 2. Summary of habitat categories, giant anteater (*Myrmecophaga tridactyla*) GPS-fixes, its percentage (%), time expended in hours (time), available area inside 95% Kernel home range in km^2 (area), and percentage at the Santa Bárbara Ecological Station.

Habitat	GPS-fix	%	Time	Area (km^2)	%
Shrub savanna	48	35.6	55h12	0.56	22.58
Forest savanna	43	31.9	49h27	1.1	45.01
Open savanna	31	23	35h39	0.48	19.29
Water related areas	12	8.9	13h48	0.06	2.39
Timber areas	1	0.7	1h09	0.12	5.01
Dwellings and roads	0	0	0	0.14	5.81
Total	**135**	**100**	**155h15**	**2.47**	**100**

patterns, such as the giant anteater's use of adjacent private property and areas near highways and roads.

Unfortunately, monitoring was abruptly stopped when we discovered that our female giant anteater's GPS, but not the harness, had fallen on the ground. Since we found the fallen GPS on an unauthorized trail connected to highway SP-280 and had spotted the female only three days before, healthy and with the harness attached, we suspect a possibility of poaching. This hypothesis is based on the fact that it is highly unlikely the anteater was able to take off only the GPS device without also removing her harness. Additionally, we had ten permanent camera traps (Bushnell Trophy Cam), and, while not one of these cameras took a picture of an anteater with only a harness, they did register more than once a bird hunter with bird cages, a pack of hunting-type dogs, and the presence of people illegally on the premises of the SBES.

Other studies have also found intentional killing of giant anteaters. For example, Shaw and Carter (1980) stated that hunters often use giant anteaters for target practice, or simply because they regard the species as worthless or dangerous. More recently, Koster (2008) reported the killing of four giant anteaters because they posed a threat to hunting dogs. Despite these facts, the cause of the missing giant anteater still remains unconfirmed.

Home range and space use

Our home range size estimates proved consistent with some studies (Table 3), such as those that had similar sample size in number of individuals and fixes, as well as type of habitats. For example, the study in Paraná State, Brazil (Braga 2010) and Colombia (Rojano-

Table 3. Comparison of giant anteaters' (*Myrmecophaga tridactyla*) home ranges in different studies estimated by minimum convex polygon (MCP) and by Kernel (km^2). Time = average monitoring time in days; Method = VHF or GPS (modified GPS or Iridium); N_Sex = number of individuals and gender; N = number of fixes; Interval = consecutive time between fixes.

Reference	Area	Time	Method	N_Sex	N	Interval	MCP	Kernel
Shaw et al. (1987)	SCNP	240	VHF	4 M	27	1 week	2.74	–
				4 F	21		3.67	
Camilo-Alves (2003)	PAN	8	GPS	7 M	585	10 min	5.3	–
				3 F			3.6	
Miranda (2004)	ENP	6	GPS	4 M	607	10 min	0.8	–
				2 F			2.7	–
		245	VHF	10 M	38	1 week	10.8	18.05*
				4 F	38		6.93	14.93*
Mourão and Medri (2002); Medri and Mourão (2005)	PAN	9	GPS	1 M	1372	10 min	7.3	–
		165	VHF	1 F	947	1 week	9.5	8.17*
				4 M	27		5.6	18.7*
				1 F	27		11.9	
Bertassoni (2010)	RR	17	GPS	1 M	1144	15 min	3.13	–
		17		3 F	900		2.57	
	PAN	4		2 M	753	5 min	3.02	–
		5		2 F	979		3.87	
	SCNP	7		1 M	1376	5 min	4.38	–
		1		1 F	351		>2.55	
Braga (2010)	PR	390	VHF	1 M	66	Uninformed	8.92	16.62**
		120		1 F	14		1.60	11.19**
Di Blanco et al.(2015)	ARG	Annual	VHF	11 M	–	Variable	13.5	22.6***
				10 F	–		8.5	18.4***
Rojano-Bolaño et al. (2015)	COL	23	VHF	1 M	70	1 week	–	0.77***
				1 F	69		–	2.04***
Present	SBES	10	Iridium	1 F	135	69 min	1.44	2.46***

SCNP = Serra da Canastra National Park, Brazil; PAN = Pantanal wetland, Brazil; ENP = Emas National Park, Brazil; RR = Santa Teresa Ranch, Brazil; PR = Jaguariaíva municipality, Brazil; ARG = Iberá Natural Reserve, Argentina; COL = Casanare, Colombia. Annual = Individuals were followed for varying periods (X ± SD = 18.94 ± 11.43 months). * 95% adaptive Kernel; ** 90% fixed Kernel; *** 95% fixed Kernel.

Bolaño et al. 2015) had similar mosaic landscapes, with patches of native vegetation surrounded by anthropogenic land use. Also, both authors had low number of fixes. However, while MPC home range estimates in those two studies took around two months using conventional VHF, our home range estimates of the same magnitude took only 10 days using Iridium-GPS technology.

Nevertheless, our home range result was also different from other studies (Table 3). Our 95% Kernel estimate is less than the female average MPC sizes estimated at Pantanal wetland (Camilo-Alves 2003, Table 3), an area with much less anthropogenic threat than SBES, for instance. Reasons for these discrepancies might be related to the monitoring methods and its period, the season, the sample size, as well as individual differences (Rodrigues et al. 2008). Habitat features could influence home range size because they may directly impact animals' movement patterns. The amount of human interference in sites where giant anteaters are found may also influence which areas anteaters choose to occupy (Rodrigues et al. 2008). Miranda (2004) and Mourão and Medri (2002) were the first studies with giant anteaters to use GPS, even though the technology was modified GPS, and have since demonstrated the powerful capability of the technology. Even so, giant anteaters' home range estimates calculated via GPS technology seem to be underestimated as a consequence of short periods of monitoring (Table 3).

The differential use of forested habitats, such as the shrub savanna at our study site, has also been reported elsewhere. In the Brazilian Pantanal wetland, anteaters used the forests to rest and open areas to forage (Camilo-Alves & Mourão 2006; Medri & Mourão 2007). Covered habitats are known as thermic refuge for giant anteaters as measured by Camilo-Alves and Mourão (2006). They recorded temperatures inside and outside the forest patches, and indicated that when it was very hot in the open habitat, the temperature inside the forest patches was cooler, and vice versa. Then, the use of covered habitats is actually related to a thermoregulatory behavior to avoid exposure during the hottest or coldest hours of the day (Camilo-Alves & Mourão 2006). In addition, adult giant anteaters in Argentina showed a habitat selection for riparian forest and avoided open areas, regardless of the season (Di Blanco et al. 2015). Thus, giant anteaters' differential use to shrub savanna probably depends on the covered habitat's ability to balance heat conditions. Those covered habitats, like forests and shrubs, decisively affect anteaters' space use (Di Blanco et al. 2015).

Furthermore, the female giant anteater in our study used water-related habitats more than expected by chance. Since January and February are warm months in our study site, with temperatures reaching around 40°C

at noon, we hypothesized that the female was using water-related habitats to balance body heat in a habitat that has a cooler temperature, or she was entering the water to cool off the body, as was observed in the Brazilian Pantanal wetland study (Camilo-Alves 2003). Marshes and hygrophilous forests have also been previously registered as selected habitats (Braga 2010; Di Blanco et al. 2015); thus, water-related habitats may play an important factor in determining space use. Habitat heterogeneity seems to be key for giant anteater occurrence. A habitat selection study was done in Argentina and demonstrated that the species does not use livestock areas or homogeneous landscapes, even analyzing in two different scales (Di Blanco et al. 2015). In addition, a study at the ENP surroundings also revealed the use of soy plantations was only enabled by the presence of woodland and forest vegetation remnants (Vynne et al. 2011). Likewise giant anteaters selected areas that were further from roads as well as a habitat from the natural mosaic of savanna and woodlands that characterized the study site (Vynne et al. 2011). Cerrado areas, such as the SBES, have many different vegetation types (Durigan & Ratter 2006) occurring also in a mosaic with grassland, shrub savanna, Cerradão, and semideciduous forest. This diversity provides a variety of resources like shelter from sunlight, water habitats to cool off, and open areas to warm up, all of which are important for a species with a low basal metabolic rate and body temperature (McNab 1985).

In this study, we used the SBES as a model to characterize the movement patterns of the first giant anteater in São Paulo, Brazil and the first tracked with Iridium-GPS. We believe this is an initial and fundamental stage in acquiring the knowledge to understand how this species moves and persists in remnants of the Cerrado.

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Disclosure statement

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