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PENSOFT

Ants in the diet of Collared Anteater, *Tamandua tetradactyla* (Linnaeus, 1758) (Pilosa, Myrmecophagidae), in the state of Rio de Janeiro, Brazil

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Abstract
The Collared Anteater, *Tamandua tetradactyla* (Linnaeus, 1758), is a small mammal predator of ants. There are few studies describing which species are in fact consumed by them. This study was aimed to investigate the diversity and abundance of local species of ants preyed by the *T. tetradactyla*. Eight samples of stomach contents collected in the period from 2009 to 2014 were analyzed and identified at the lowest possible taxonomic level. We found 5,906 ants distributed in 16 species. The most abundant samples were number 2 and 4 with almost 2,000 individuals and the highest richness and abundance was Myrmicinae subfamily with eight species and 3,721 individuals. The ant richness found in this research demonstrates that the anteaters are generalists and opportunistic about their diet, not having a preference for a particular species, but rather for those insects that are available in their habitat.

Keywords
Diet, Formicidae, insect, predation, Tamanduá.

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Introduction

The genus *Tamandua* Gray, 1825 occurs from Venezuela to the North of Uruguay and Argentina (Wetzel 1975; Hayssen 2011) and has two species: *T. tetradactyla* (Linnaeus, 1758) and *T. mexicana* (Saussure, 1860). These species are among the most specialized mammals for their nutrition, feeding almost exclusively on arthropods and mainly ants and termites (Lubin and Montgomery 1981; Montgomery 1985). However, they also prey on bees and show interest in honey from hives (Nowak 1999; Sandoval-Gómez et al. 2012), and each individual has different food preferences (Redford 1983). They localize their prey mainly by smell and move continuously for 8–10 h each day (Lubin and Montgomery 1981). They make use of a variety habitats and are predominantly active in the evening and morning (Lubin et al. 1977; Nowak 1999; Medri et al. 2006; Smith 2007; Hayssen 2011).

Tamandua tetradactyla is a common species in all Brazilian biomes (Desbiez and Medri 2010). It is one of the most frequently roadkilled animals in southeastern Brazil, and studies of the impacts caused by the road network and resident fauna have enabled access to previously unavailable data (Bernegossi et al. 2018), such parasites (Pinheiro et al. 2018), diseases (Muñoz-García et al. 2018), and food preferences (Gallo et al. 2017) . The analysis of contents in the digestive system of roadkilled animals shows how carcasses can be used to generate information on the biology and feeding habits of this species. We report on the species richness and abundance of ants found in the stomach contents of *T. tetradactyla* found dead on a federal highway in southeastern Brazil.

Methods

The stomach contents of eight roadkilled anteater specimens were examined. The carcasses came from a stretch highway (BR-040) between the Brazilian municipality of Rio de Janeiro, state of Rio de Janeiro and Juiz de Fora, state of Minas Gerais (Fig. 1, Table 1). Part of the highway is located in the important environmental protection area of Petrópolis (Station 2), Rio de Janeiro state, which has other fragments of Atlantic Forest near the highway along the sampled section in addition to this conservation unit (Bueno and Almeida 2010).

The highway BR-040 has been monitored since 2006 by the Projeto Caminhos da Fauna (Wildlife Pathways Project), mapping the roadkill of wild vertebrates (Tab. 1) with the objective of reduce this impact in points where that are most frequent. The roadkilled fauna on the BR-040 is monitored in partnership with the concessionaire that manages the highway (Companhia de Concessão Rodoviária Juiz de Fora - Rio de Janeiro; hereafter CONCER). The monitoring is done along the highway under the concession (Rio de Janeiro/Juiz de Fora), accounting for 180.4 km of road, in both directions, totaling 360 km. CONCER employees were trained to monitor roadkill, and monitoring was done daily, both day and night.

Carcasses were collected, and all stomach contents were removed and preserved in 70% alcohol. Contents were analyzed under a Zeiss Stemi SV6 stereomicroscope, and the arthropods were separated. Recognizable fragments were sorted, mounted on entomological pins, and identified to genus using the publication of Baccaro et al. (2015). For initial species determinations keys contained in the most recent taxonomic revisions were used (i.e. Hashmi 1973; Urbani 1999; Longino 2002; Mackay and Mackay 2004; Fernandes et al. 2014), Identifications were later checked by comparing our materials with identified specimens in the Ângelo Moreira da Costa Lima Entomological Collection of the Federal Rural

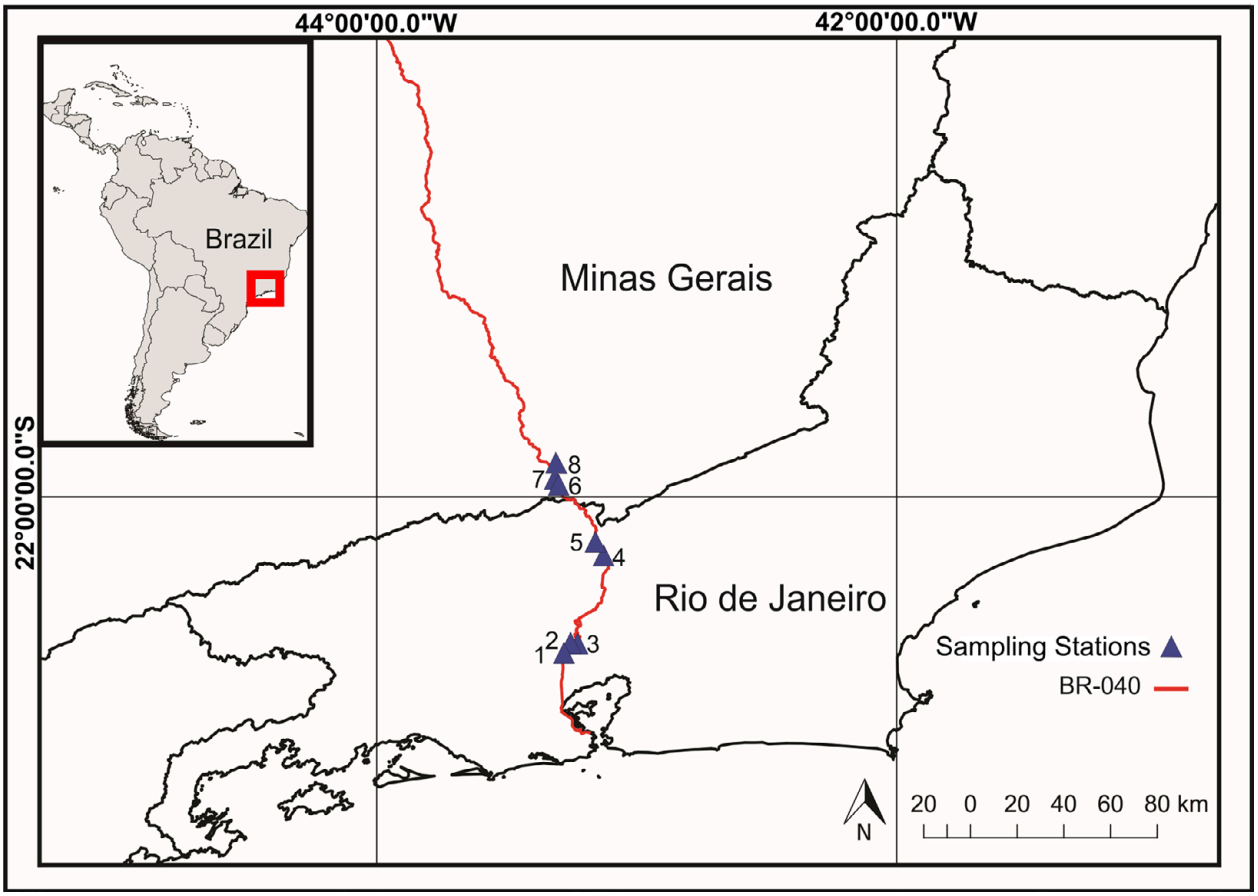

Figure 1. Stations along highway BR-040 (Rio de Janeiro–Juiz de Fora) between 2009 and 2014 where stomach contents of roadkilled *Tamandua tetradactyla* were sampled for ants; see Table 1.

Table 1. The samples stations coordinates along highway BR-040 (Rio de Janeiro–Juiz de Fora) between 2009 and 2014.

Sites of collision	Geographic coordinates	Date
1	22°35′33″S, 043°16′48″W	03/IX/2012
2	22°33′16″S, 043°15′16″W	11/II/2012
3	22°33′28″S, 043°13′38″W	22/XI/2009
4	22°13′20″S, 043°07′38″W	22/VIII/2009
5	22°10′13″S, 043°09′32″W	28/VIII/2013
6	21°55′53″S, 043°18′52″W	27/I/2011
7	21°57′15″S, 043°18′01″W	10/XI/2014
8	21°57′05″S, 043°18′04″W	02/XI/2014

University of Rio de Janeiro and with the images available on AntWeb (2018). All materials collected in this study were deposited in the Coleção Entomológica do Instituto Oswaldo Cruz (CEIOC; Rio de Janeiro, Brazil).

Results

Of the eight stomachs analyzed, 5,906 specimens of ant were found. These were found to belong to five subfamilies, 12 genera, and 16 species. The subfamily with the greatest abundance (Table 2) and species richness (Table 3) was Myrmicinae, with 3,721 specimens and eight species.

We determined that Stations 2 and 4, in the cities of Petrópolis and Areal, respectively, had the greatest abundance (nearly 2,000 insects). Station 5 had the least abundance. The most frequent species was *Camponotus rufipes* (Fabricius, 1775) (Fig. 2C, D), which was found in five of the eight samples. Two other species frequent in more than three samples were *Camponotus atriceps* (Smith, 1858) (Fig. 2A, B) and *Cephalotes pusillus* (Klug 1824) (Fig. 2E, F).

Camponotus atriceps (Smith, 1858)

Materials examined. BRAZIL: Rio de Janeiro: along highway BR-040 • 4 workers, Station 4 (22°13′20″S, 043°07′38″W), C. Bueno coll., 11-II-2012 (CEIOC 72734, 72735, 72736, 72737). • 3 workers, Station 8 (21°57′05″S, 043°18′04″W), C. Bueno coll., 02-XI-2014 (CEIOC 72738, 72739, 72740).

Identification. *Camponotus atriceps* (Fig. 2A, B) was identified through a combination of characters described by Hashmi (1973) and Longino (2002). Body thickly covered by hairs, from head to gaster; in mesosoma, indistinctly marked, without defined lateral and dorsal regions; head sub-square, with occipital region presenting higher density of hairs; clypeus with a well-developed longitudinal median carina; antennal scapes fully covered with hairs; gaster usually with more hairs in dorsal view. There is a great variation in coloration,

Table 2. The abundance of ant subfamilies found in the stomach contents of the of eight *Tamandua tetradactyla* specimens roadkilled on BR-040 (Rio de Janeiro–Juiz de Fora) between 2009 and 2014.

Subfamily	*N*	%
Dolichoderinae	470	8.51
Formicinae	1,636	29.62
Myrmicinae	3,721	67.36
Ponerinae	47	0.85
Pseudomyrmecinae	31	0.56

Table 3. Species found in the stomach contents of eight specimens of *Tamandua tetradactyla* roadkilled on the BR-040 (Rio de Janeiro–Juiz de Fora) between 2009 and 2014.

Order, family, species	Sites of collision							
	1	2	3	4	5	6	7	8
Hymenoptera	x							
Formicidae								
Dolichoderinae								
Dolichoderus lamellosus (Mayr, 1870)	x							
Linepithema micans (Forel, 1908)		x						
Linepithema neotropicum Wild, 2007		x						
Formicinae								
Camponotus atriceps (Smith, 1858)	x	x		x		x		x
Camponotus rufipes (Fabricius, 1775)				x	x	x	x	x
Myrmicinae								
Acromyrmex aspersus (Smith, 1858)			x					
Atta sexdens (Linnaeus, 1758)								x
Cephalotes pusillus (Klug, 1824)	x			x	x			x
Pheidole gibba Mayr, 1887			x					
Solenopsis geminata (Fabricius, 1804)		x	x					
Solenopsis invicta Buren, 1972			x					
Strumigenys cosmostela Kempf, 1975		x						
Wasmannia auropunctata (Roger, 1863)	x			x	x			
Ponerinae								
Neoponera crenata (Roger, 1861)			x					
Neoponera villosa (Fabricius, 1804)			x					
Pseudomyrmecinae								
Pseudomyrmex gracilis (Fabricius, 1804)		x						

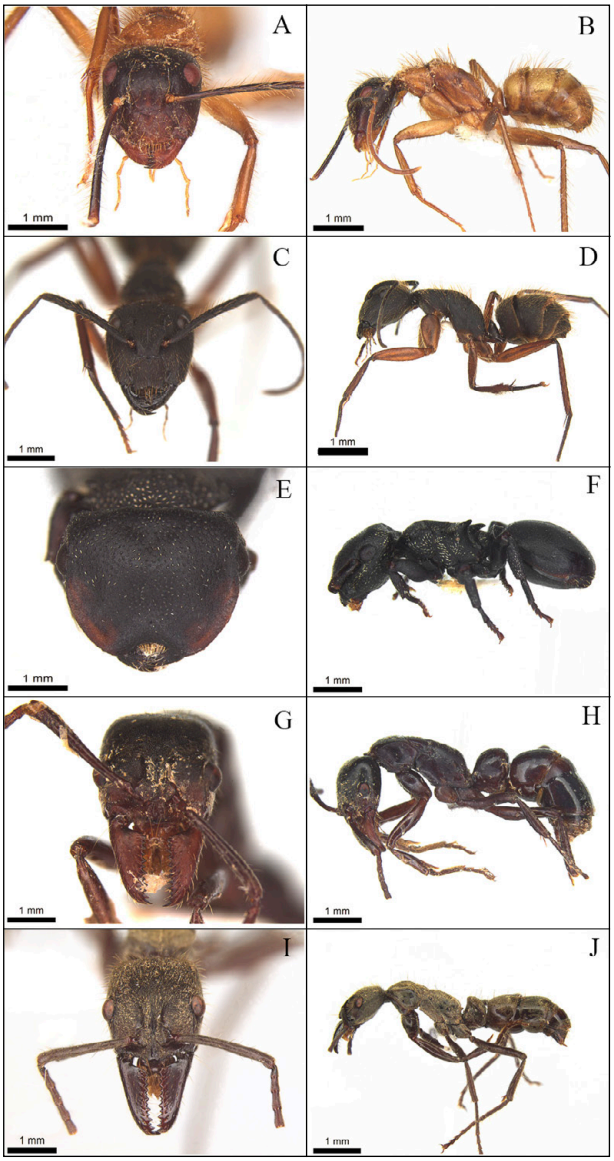

Figure 2. Species of ants found in the stomach contents of eight specimens of *Tamandua tetradactyla* roadkilled on the BR-040 (Rio de Janeiro–Juiz de Fora) between 2009 and 2014. **A–F.** Species more frequent in the samples: (**A, B**) *Camponotus atriceps*; (**C, D**) *C. rufipes*; (**E, F**) *Cephalotes pusillus*. **G–J.** Ant species avoided by ant-eaters due to their aggressive defenses: (**G, H**) *Neoponera crenata*; (**I–J**) *N. villosa*.

including bicolored with head dark brown and body yellow, or body entirely dark brown or entirely yellow.

Camponotus rufipes (Fabricius, 1775)

Materials examined. BRAZIL: Rio de Janeiro: along highway BR-040 • 3 workers, Station 1 (22°35′33″S, 043°16′48″W), C. Bueno coll., 22-XIII-2009 (CEIOC 72743, 72744, 72745) • 2 workers, Station 8 (21°57′05″S, 043°18′04″W), C. Bueno coll., 02-XI-2014 (72741, 72742).

Identification. *Camponotus rufipes* (Fig. 2C, D) was identified using the characters described by Hashmi (1973) and Mackay and Mackay (2004). Body covered by golden-yellow or reddish hairs which vary in length; anterior border of clypeus strongly concave, with angled sides and longitudinal median carina well developed; scapes dilated and flattened at apex, with hairs in their whole extension, from the base to apex; mesosoma with well-defined promesonotal suture and poorly defined mesometanotal suture; legs usually reddish-brown.

Cephalotes pusillus (Klug, 1824)

Material examined. BRAZIL: Rio de Janeiro: along highway BR-040 • 2 workers & 1 major worker, Station 8 (21°57′05″S, 043°18′04″W), C. Bueno coll., 02-XI-2014 (CEIOC 72746, 72747, 72748).

Identification. *Cephalotes pusillus* (Fig. 2E, F) was identified with the combination of characters described by Kempf (1951) and Andrade and Urbani (1999). Head sub-opaque, shorter than broad, with its upper border convex; occipital region with defined projections; thorax opaque, with anterior edge arched and humerus angulate. Mesosoma with pronotum laterally expanded backward into a narrow, denticulate crest, and with two short teeth on each side, posterior tooth markedly shorter than anterior. Posterior corner of pronotum rectangular and protruding; promesonotal suture well defined. Mesonotum on each side with a very small and sub-rectangular tooth. Basal surface of metanotum in same plane as mesonotum, with a short lateral tooth, larger than second pronotal tooth, and a very long subcylindrical posterior spine originating from posterior corner and diverging at about 45 degrees from longitudinal axis. Propodeum moderately convex. Entire thorax finely, quite densely, and strongly reticulate-punctuate, containing a brilliant silver scale. Petiole opaque, finely reticulated, and with an inconspicuous and slightly curved lateral denticle. Postpetiole opaque, as broad as petiole, apically truncated, with a wide basal projection, also finely reticulated with sparse and scaly hairs, and subdivided on each side at the apex, curving slightly forward. Gaster opaque, elliptical, and emarginate anterior medially; first gastral tergite with very narrow lateral border, not distinctly defined and without crest; tergites and sternites finely and rather reticulate-punctuate.

Neoponera crenata **(Roger, 1861)**

Material examined. BRAZIL: Rio de Janeiro: along highway BR-040 • 12 workers, Station 8 (21°57′05″S, 043°18′04″W), C. Bueno coll., 02-XI-2014 (CEIOC 72751 to 72762).

Identification. *Neoponera crenata* (Fig. 2G, H) was identified following the description of Mackay and Mackay (2010). Anterior medial region of clypeus with a strong protuberance; eyes relatively large; carina malar not defined; mesosoma with pronotum carina present but poorly defined; propodeal spiracle oval; petiole, in lateral view, as long as high, with anterior and posterior faces almost parallel and dorsal margin convex; head and back of mesosoma punctuate; side of pronotum weakly punctuate, smooth, and shiny; gaster with poorly developed

stridulatory organ on second tergite; the whole body usually reddish-brown.

***Neoponera villosa* (Fabricius, 1804)**

Material examined. BRAZIL: Rio de Janeiro: along highway BR-040 • 2 workers, Station 8 (21°57′05″S, 043°18′04″W), C. Bueno coll., 02-XI-2014 (CEIOC 72749, CEIOC 72750).

Identification. *Neoponera villosa* (Fig. 2I, J) was identified following descriptions by Mackay and Mackay (2010) and Fernandes et al. (2014) works where they highlighted several conspicuous features. Body large (about 15 mm), black, covered by long golden-yellow hairs. Legs reddish-brown. Petiole thick in profile, with anterior face slightly concave and posterior face rounded and convex. Anterior clypeal margin convex but concave medially with a median notch; malar carina well defined; stridulatory organ is well developed in second tergite on gaster.

Discussion

The Myrmicinae, present in six of our eight samples, stands out for its species richness, morphological variety, and trophic strategies (Bolton 2003; Baccaro et al. 2015). Myrmicines use a wide variety of nesting sites, depending on species, including deep in soil layers as well as in the forest canopy (Delabie et al. 2000). Because they are so abundant in tropical habitats, the ants of this subfamily are common prey for animals such as anteater, which has developed an ability to locate its prey by smell (Hayssen 2000).

The high abundance of ants in the stomach contents of anteaters from Stations 2 and 4 is due to the fragments of the Atlantic Forest at these places. At these stations heterogeneity of the landscape and species diversity are greater. Station 2 is bordered by the Tinguá Biological Reserve, which is characterized by dense ombrophilous forest and part of the Ecological Corridor of the Serra do Mar (a network of parks, reserves, and private areas of less intensive use and integrated planning; IBAMA 2006). Station 4 is near several fragments of the Atlantic Forest of approximately 1 km^2 each, which offers a variety of habitats for forage and shelter (Collinge 1996).

Camponotus rufipes, the species most frequently found, nests in soil and also fallen or hollowed logs, and colonies of this species are very common and populous (Ronque et al. 2018; Suguituru et al. 2015). Logs are used by anteaters for shelter, locomotion, and foraging, and provide an easy source of insect prey (Redford 1983; Hayssen 2011; Sandoval-Gómez et al. 2012). *Camponotus atriceps* is another species with similar nesting habits as *C. rufipes* (Longino 2002). Although *Cephalotes pusillus* is arboreal and dominates the tree canopy (Fagundes et al. 2017), it is still easily found by anteaters than other species in different habitats. These three species are synanthropic and, therefore, are more frequent in anthropic habitats such as urban centers or along highways (Suguituru 2015).

According to Lubin et al. (1977), there is some evidence that anteaters avoid some groups of ants that have aggressive defenses or impalpable body structures, such as thorns and strong jaws (e.g. leafcutter ants, Myrmicinae) or the ability to sting (e.g. army ants, Dorylinae and Ponerinae). Such ants, although abundant, are almost absent in studies of stomach contents (Hayssen 2011; Sandoval-Gómez et al. 2012). In our samples, eight species of Myrmicinae and two Ponerinae, *Neoponera crenata* (Fig. 2G, H) and *N. villosa* (Fig. 2I, J), were identified. When feeding on these ant species with aggressive defenses, anteaters tend to feed as quickly as possible, ingesting just a few individuals, and then move on to other nests to avoid wounds to their olfactory apparatus, the main sensory organ used in foraging (Reiss 2000; Smith 2007; Haysen 2011).

Also were identified 20 morphospecies of ants were also classified in the genus *Azteca* Forel, 1878, *Crematogaster* Lund, 1831, *Odontomachus* Latreille, 1804, *Sericomyrmex* Mayr, 1865 based on their morphological structures. Other orders were also possible to be identified the genus, like Termites (Blattodea, Isoptera), being they *Cornitermes* Wasmann, 1897, *Nasutitermes* Dudley, 1890, *Velocitermes* Mathews, 1977 and also beetles (Coleoptera) where they were possible to be identified only the order.

Termites and ants compose about 2% of the planet's species (Korb 2008), however, they are the most abundant animals on Earth, accounting more than half of the planet's biomass, making them one of the main food sources for many small mammals species and other animals (Wilson and Hölldobler 2005).

The importance of these eusocial insects in trophic webs is such significant that mammals end up in 2nd place after the ants as the most important termite predators, small arthropods and even other ant species (Wilson 1971, Cerdá and Dejean 2011). Although the anteaters are toothless, they ingest the food and detritus of the colonies of their prey, pressing them against their palate and swallow in this process, can occur body fragmentation of the ingested insects and with this, increase the difficulty of the process of this material (Reiss 2000).

The anteaters have a low metabolic rate because they have a diet based on a low-calorie energy source, which leads to long digestion, which, retain the insects in their stomach for a long period of time (Mcnab 2009, Reiss 2000). Several species of insects found in the samples are common species in regions with anthropic disturbances, such as roads and proximity to urban centers in regions of Atlantic Forest (Suguituru et al. 2015, Baccaro et al. 2015).

In *T. tetradactyla* diet studies, few of them are about the richness of species, in fact, that anteaters feed. It has been observed in the literature that rare species are found in the diet, possibly due to the fact that it is difficult to obtain samples in a suitable conservation state

(Hayssen 2011, Sandoval-Gómez et al. 2012, Vaz et al., 2012, Ferreira et al., 2015, Cunha et al., 2015). Approximately 9,000 ants can be consumed per day by an anteater (Macdonald 2007), depending on their habitat and also their state of preservation (Leal et al. 1993, Lopes et al. 2010, Suguituru et al. 2013). Despite this large amount, in many studies only 10% of the stomach contents available for analysis are used, leaving other food items, such as ants and other arthropods (Reis-Filho et al. 2007, Gallo et al. 2017). In this present study, we used all available content in the eight samples, where we found 16 species and 26 morphospecies of ants identified in genus and 17 other morphospecies belonging to other orders.

The arthropod richness found in this research demonstrates that the anteaters are generalized and opportunistic about their diet, not having a preference for a particular species, but rather for those insects that are available in their habitat, including those ant species who is avoided by their aggressive defenses. The most frequent species found are common of environments with anthropic impacts and showed a little about the degree of conservation of the environment in which the anteaters are inserted, as is the trophic relationship between the anteater population and the social insect community. The use of carcasses of animals can provide us with relevant information in the field of ecology, mainly for the conservation of species. Data from these roadkilled animals show that there are different data on the natural populations of mammals and other vertebrates, such as disease outbreaks, endoparasites, genetic problems, and especially the trophic relationships in the region.

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Authors' Contributions

MMS identified specimens and wrote the manuscript. CELE revised the manuscript. CB collected the specimens and revised the manuscript. AJMN identified specimens and revised the manuscript.

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