Oecologia Australis
24(1):141-153, 2020
https://doi.org/10.4257/oeco.2020.2401.11

NEW PARASITE OCCURRENCES IN *Tamandua tetradactyla* (PILOSA: MYRMECOPHAGIDAE) IN THE NORTHEAST OF BRAZIL: A PALEOPARASITOLOGICAL STUDY

*Mônica Vieira de Souza[1,2], Marcia Chame[1,2], Sheila Maria Ferraz Mendonça de Souza[1], Gisele Daltrini Felice[3], Niéde Guidon[3] & Luciana Sianto[1,2]**

[1] Fundação Oswaldo Cruz (Fiocruz), Escola Nacional de Saúde Pública Sérgio Arouca (ENSP), Laboratório de Paleoparasitologia e Ecologia, Rua Leopoldo Bulhões 1480 Manguinhos, CEP: 21041-210., Rio de Janeiro, RJ, Brazil.

[2] Instituto Nacional de Ciência e Tecnologia de Arqueologia, Paleontologia e Ambiente do Semiárido do Nordeste do Brasil (INAPAS). Centro Cultural Sérgio Motta, s/n – Campestre, CEP: 64770-000, São Raimundo Nonato, PI, Brazil.

[3] Fundação Museu do Homem Americano (Fumdham), Centro Cultural Sérgio Motta, s/n, CEP: 64770-000, São Raimundo Nonato, PI, Brasil.

E-mails: mvieira26@gmail.com; chame.marcia@gmail.com; sferraz@ensp.fiocruz.br; gdfelice@yahoo.com.br; guidon@fumdham.org.br; lucianasianto@gmail.com (*corresponding author)

Abstract: Paleoparasitological studies have revealed parasite eggs in coprolites from humans and other animals, obtained in archaeological sites in the New and Old World. However, to date, the only parasite found in anteaters coprolites is *Gigantorhynchus echinodiscus* (Acanthocephala: Gigantorhynchidae). Here we present the results of paleoparasitological analysis of nine *Tamandua tetradactyla* coprolites, of layers dated from 8,870 and 3,190 years BP, collected in three archaeological sites: Toca dos Coqueiros, Toca da Passagem and Toca do Enoque, rock shelters located in the southeast of the Piauí state, Brazil. Each coprolite was rehydrated in 0.5% trisodium phosphate solution, homogenized with a glass rod for spontaneous sedimentation. A minimum of 20 slides of each sample was examined using light microscopy. Acanthocephalan eggs of three morphotypes were found: *G. echinodiscus, Macracanthorhynchus hirudinaceus* and *Oligacanthorhynchus* sp.. Three morphotypes of Nematoda eggs and oocysts of cf. Entamoeba sp. were also found. The finding of *G. echinodiscus*, a species commonly reported in anteaters, reinforces the previous data and highlights the specificity and antiquity of this host-parasite interaction. This is the first finding of Oligacanthorhynchidae and Aspidoderidae parasites in T. tetradactyla. These findings evidence the need for more studies of the parasitic fauna of T. tetradactyla from both ancient and current times aiming to broaden the knowledge about the parasite diversity of this host and the evolutionary processes that led to these interactions.

Keywords: Acanthocephala; anteater; endoparasites; Paleoparasitology; semiarid.

INTRODUCTION

Tamandua tetradactyla (Linnaeus, 1758), popularly known as collared anteater or *mixila*, belongs, together with other anteaters, to the Family Myrmecophagidae Gray, 1825, restricted to the Americas. It is found from the east of the Andes to the north of Argentina and Uruguay, and occurs in all Brazilian biomes (Oliveira & Vilella 2003). It has medium size, a semi-prehensile tail, and short hair. This species is arboreal and feeds mainly on ants and termites (Nowak 1999). Anteaters have a large foraging area, due to the need for daily consumption of a large number of insects, dedicating part of their day to exploration activities (Montgomery 1985). Currently, the species is classified in the category of “least concern” according to the IUCN Red List (2014), threatened by the transformation of the natural landscapes to agropastoral fields (Oliveira & Vilella 2003).

Studies investigating the parasitic fauna of living anteaters are frequent, carried out with captive and free-living animals (Lainson & Shaw 1990, 1991, Diniz *et al.* 1995, Freitas *et al.* 2006). However, *Gigantorhynchus echinodiscus* (Diesing, 1851) Hamann, 1892 (Acanthocephala: Gigantorhynchidae) is the only Acanthocephala described so far for these animals, with dates of up to 32,000 years (Ferreira *et al.* 1989).

The identification of parasites in ancient remains helps to understand the evolution and ecology of parasitic infections. It also provides information about the paleoenvironment and the paleoclimate, by studying their biological cycles, since parasites are influenced by biotic and abiotic factors (Hugot *et al.* 1999, Arriaza *et al.* 2010, Beltrame *et al.* 2015). The interest in parasitism in nonhuman animals from prehistory has intensified. Nowadays, similar studies are conducted in several countries, providing data that prove the antiquity of host-parasite relations (*e.g.* Reinhard 1990, Gonçalves *et al.* 2003, Sianto *et al.* 2017).

Animal coprolites are often studied in Paleoparasitology, and the first study in Brazil was conducted by Araújo and colaborators (1980), who found eggs of *Parapharyngodon sceleratus* (Nematoda: Pharyngodonidae) in lizard coprolites dating from 9,000 years BP. Other studies conducted later, in Brazilian samples, helped to identify new parasite species, occurrences in new hosts and regions, or to establish the antiquity of these relations. As examples, we may cite the finding of eggs of the species *Strongyloides ferreirai* n. sp. (Nematoda: Strongyloididae), *Trichuris* sp. (Nematoda: Trichuridae) and *Syphacia* sp. (Nematoda: Oxyuridae) in coprolites of *Kerodon rupestris* (Rodentia: Caviidae) (Araújo *et al.* 1980, 1989, Souza *et al.* 2012); and *Echinopardalis* sp. (Acanthocephala: Oligacanthorhynchidae) (Noronha *et al.* 1994); *Spirometra* sp. (Cestoda: Diphyllobothriidae) , *Toxocara cati*, (Nematoda: Toxocaridae), *Calodium* cf. *hepaticum* (Nematoda: Capillaridae), *Trichuris* cf. *muris*, *Oncicola* sp. (Acanthocephala: Oligacanthorhynchidae) and *Echinostoma* sp. (Trematoda: Echinostomatidae) in feline coprolites (Sianto *et al.* 2014). However, the knowledge about anteater’s parasites in the past is still scarce. Here we report the finding of eggs of three morphospecies of Acanthocephala, Nematoda eggs and larvae, and protozoan oocysts in anteaters’ coprolites from the region known as “The Cradle of American Man”, in the Brazilian semiarid.

MATERIALS AND METHODS

Study area

Two archaeological sites are located in the Serra da Capivara National Park: Toca dos Coqueiros (768076 UTM E, 9022106 UTM N) and Toca da Passagem (750514 UTM E, 9049988 UTM N), and one in the Serra das Confusões National Park: Toca do Enoque (658743 UTM E, 8988649 UTM N), both in the state of Piauí, Northeast Brazil (Figure 1). The Toca dos Coqueiros site is a rock shelter, located in Serra Talhada, municipality of Coronel José Dias, state of Piauí. In this site, the skeleton of a man dating back 11,000 years BP was found associated with lice-infested hair (Lessa & Guidon 2002). One coprolite collected from a layer dated 8,870 ± 60 years BP was analyzed. Toca da Passagem is also a rock shelter located in the northwestern part of Serra da Capivara, in the Serra Branca region, also in the municipality of Brejo do Piauí. Cave paintings and lithic pieces were the only vestiges of human occupation found until now (Fumdham 2007). From this site, one coprolite of the family Myrmecophagidae was recovered from an archaeological layer dated of approximately 3,190 ± 70 years BP. The third site, Toca do Enoque, is a rock shelter located inside the Serra das Confusões National Park, in the Serra das Andorinhas, municipality of Guaribas (Guidon & Da Luz 2009). A set of well-preserved human graves was found associated to a great amount of ornaments made with animal matter (Guidon & Da Luz 2009, Faure *et al.* 2011). The occupancy dates for the site are between 8,270 ± 40 and 3,430 ± 40 years old AP (Guidon & Da Luz 2009). From this site, seven samples of anteater coprolites were recovered.

Archaeological excavations in these sites were carried out by the team of archaeologists of the American Man Museum Foundation (Fumdham), who recovered and sent the coprolites to the

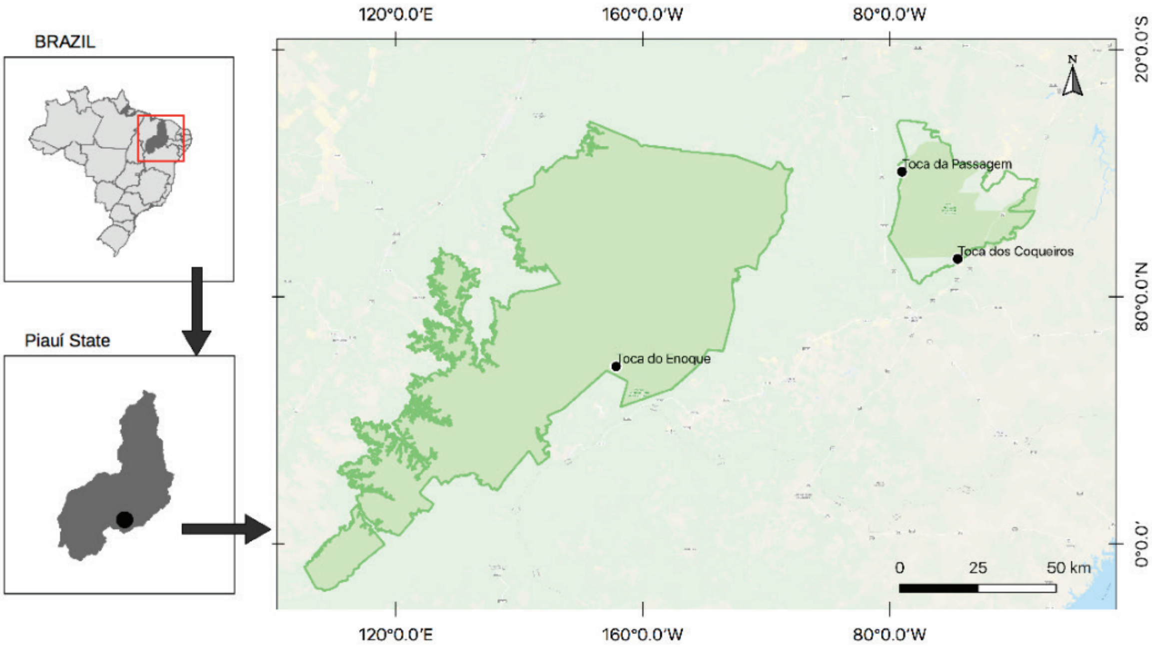

Figure 1. Location of Serra da Capivara National Park, Serra das Confusões National Park, and the archaeological sites of Toca do Coqueiro, Toca da Passagem and Toca do Enoque, in the southeast of the state of Piauí, Brazil.

Laboratory of Paleoparasitology of the Oswaldo Cruz Foundation, Rio de Janeiro, for analysis. All archaeological sites were occupied by human groups in the prehistory.

Paleoparasitological analysis

The identification of the zoological origin of the coprolites (Figure 2) was made in the laboratory considering morphometric and food content analyses (which is mostly composed of Hymenoptera (ants) and Isoptera (termites) for the family Myrmecophagidae, as proposed by Chame (2003)). Small fragments (between 0,5 and 1g) of each coprolite were immersed separately in 0.5% aqueous solution of trisodium phosphate for a period of 72 hours (Callen & Cameron 1960), followed by homogenization, and spontaneous sedimentation technique. A minimum of 20 slides of each sample were analyzed under an optical microscope Nikon® E200, in increments of 100x and 400x. The eggs found were photographed and measured using Image Pro Express® software and their dimensions and morphology were compared with the data described in the literature as according to Amin (2003), Bowman (2009), Petrochenko (1971), and Yamaguti (1963). Identifications at specific level were made not only based on egg morphology and morphometry but also based on previous occurrence records in hosts, according to the current literature.

RESULTS

All nine coprolites were identified as belonging to *T. tetradactyla* because of the morphological characteristics of the material: long, cylindrical and continuous, and compatible morphometry for this species, ranging from 3.00 to 6.50 cm x 1.50 to 2.50 cm, according to those described by Chame (2003). In the analysis of the macroscopic remains, fragments of Hymenoptera (ants) and Isoptera (termites) were identified, which are items usually found in dietary studies of this anteater species (Chame 2003), confirming the zoological identification of the coprolites. All the coprolites analyzed had one or more parasite morphotypes. Considering helminths, six morphotypes were found, three of the phylum Acantocephala and three of the phylum Nematoda. A protozoan morphotype was also observed.

Acanthocephalans

Three morphotypes of Acanthocephala eggs were identified. The smallest morphotype (Table 1), identified as *Gigantorhynchus echinodiscus* (Gigantorynchidae) (Figure 3A), was fusiform,

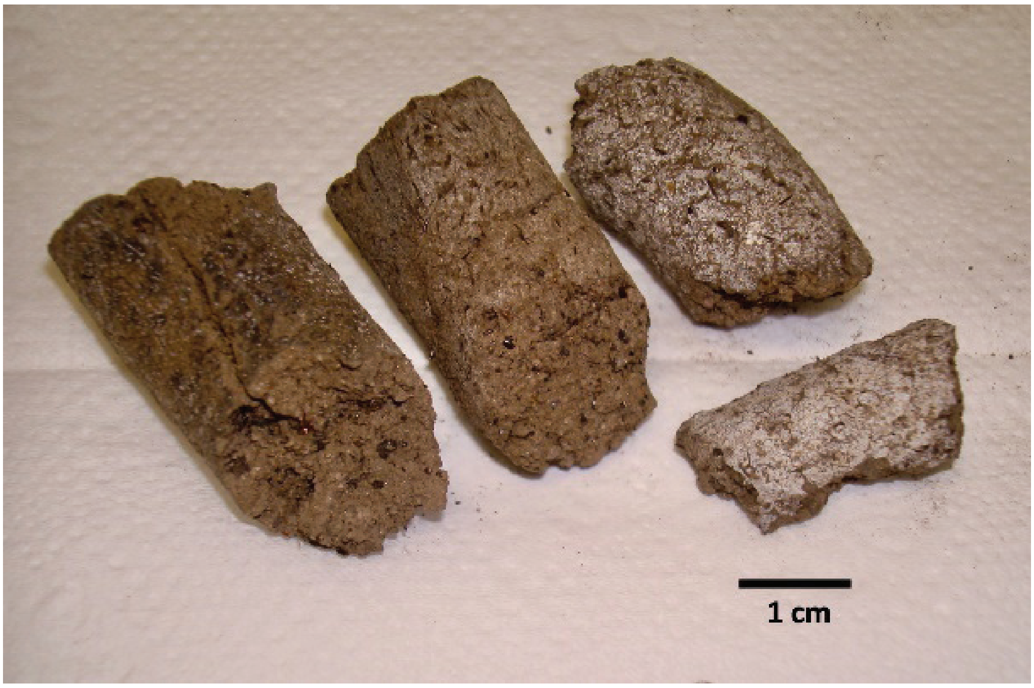

Figure 2. *Tamandua tetradactyla* coprolites found at Serra da Capivara National Park, Serra das Confusões National Park, and the archaeological sites of Toca do Coqueiro, Toca da Passagem and Toca do Enoque, in the southeast of the state of Piauí, Brazil.

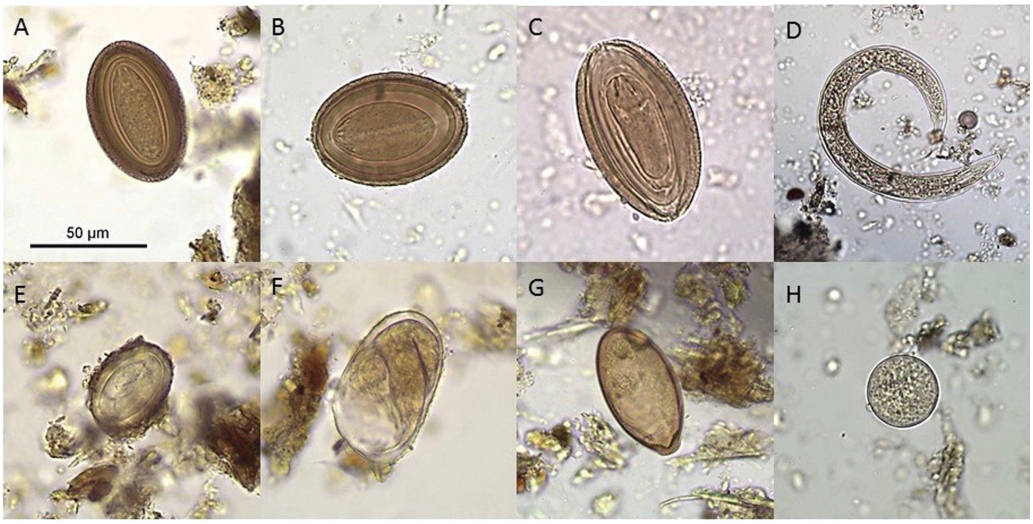

Figure 3. (A) *Gigantorhynchus echinodiscus*, (B) *Oligacanthorhynchus* sp., (C) *Macracanthorhynchus hirudinaceus*, (D) Nematoda larva, (E) Aspidoderidae, (F) Strongylida, (G) Nematoda gen. sp., (H) cf. *Entamoeba* sp. found in the *Tamandua tetradactyla* coprolites from Serra da Capivara National Park and Serra das Confusões National Park, southeast of Piauí state, Brazil.

brown, and with three wraps, the outermost with a compact granular coating. We recovered 151 eggs of this acanthocephalan (149 in four coprolites from Toca do Enoque and two in one coprolite from Toca do Coqueiros).

The second morphotype was found in two samples from Toca do Enoque, identified as *Olygacanthorhynchus* sp. (Oligacanthorhynchidae) (Figure 3B). The eggs found were rounded, elliptical, with three membranes being the outermost thick and granular, with acanthor visible, coloration ranging from yellow to brown. Measurements are described in table 1.

The third morphotype of Acanthocephala, was compatible with the species *Macracanthorhynchus hirudinaceus* (Oligacanthorhynchidae) (Figure 3C), and was found in the only coprolite from Toca dos Passagem and in three samples from Toca do

Table 1: Sample size, mean and range size of helminths eggs and protozoa cysts found in *Tamandua tetradactyla* coprolites from the Brazilian semiarid. Measurements are in micrometers (µm).

Location	Parasites found / samples	Eggs found	Eggs measured	Measures range per sample		Mean per species (Standard Deviation)	
				Lenght	Width	Lenght	Width
Toca dos Coqueiros -Serra da Capivara National Park (n=1)	Acanthocephala						
	Gigantorhynchus echinodiscus	2	2	67.40-69.00	43.40-46.00	68.20 (1.13)	44.70 (1.84)
Toca da Passagem - Serra da Capivara National Park (n=1)	Acanthocephala						
	Macracanthorhynchus hirudinaceus	25	25	81.00-96.80	47.00-60.00	88.90 (3.95)	54.50 (3.21)
Toca do Enoque - Serra das Confusões National Park (n=7)	Acanthocephala						
	Gigantorhynchus echinodiscus	149	82	59.88-71.78	36.60-55.90	65.79 (3.15)	44.02 (2.51)
	Macracanthorhynchus hirudinaceus	90	81	70.09-87.76	45.09-59.77	76.72 (4.75)	50.62 (4.28)
	Oligacanthorhynchus sp.	15	15	62.18-77.48	43.08-55.54	70.60 (5.30)	49.96 (3.66)
	Nematoda						
	Aspidoderidae	8	8	43.89-47.94	27.26-34.62	46.48 (1.24)	31.33 (2.20)
	Strongylida	3	3	56.89-68.48	38.78-42.83	61.42 (6.19)	41.15 (2.11)
	Nematoda gen. sp.	1	1	60.57	32.21	0	0
	Rhizopoda						
	cf. *Entamoeba* sp.	4	4	28.07-32.33	27.03-32.33	30.41 (2.24)	29.92 (2.82)

Enoque. A total of 115 almond-shaped eggs were recovered, with three well-defined membranes, striations in the outer shell and thickening at the extremities. Egg size was the largest among the acanthocephalans recovered (Table 1).

Nematodes

Eggs of three morphotypes of Nematoda were identified (Table 1). Eight eggs of Aspidoderidae (Figure 3E), were elliptic, with thick bark and granular surface and were found in four samples from Toca do Enoque site. Three eggs of the order Strongylida (Figure 3F) were found in one sample (14%) from Toca do Enoque. The eggs were elliptical, light in color with smooth and thin shell, and embryonated. One elliptical Nematode egg (Figure 3G), brown in color, with operculum at one end, measuring 60.57 μm x 32.21 μm was found in one sample (14%) from Toca do Enoque, but could not be identified. In addition, 25 nematode larvae were recorded in three samples (Figure 3D) of the Toca do Enoque site, but few internal structures were preserved, which made the diagnosis impossible. A sheath could be observed, but it was not possible to observe the oral cavity, esophagus or cuticle, structures essential to identification (Taylor 2010).

Protozoan

Four (N = 4) protozoan cysts were found in two (29%) of the seven samples from Toca do Enoque. The morphology (spherical mature cysts, slightly ovoid, without the presence of vacuoles of glycogen and chromatoid bodies, and at least four nuclei) and measurements observed are compatible with *Entamoeba* sp. (Entamoebidae) (Figure 3H, Table 1).

Polyparasitism was observed in 56% (5/9) of the coprolites, with monoparasitism in 44% (4/9). *G. echinodiscus* was the most frequent helminth. There was a predominance of monoparasitism by *M. hirudinaceus*. For polyparasitism, the most frequent association was between *G. echinodiscus* and Aspidoderidae (4/9).

DISCUSSION

Acanthocephalans are endoparasites (many with cosmopolitan distribution) that infect a wide variety of vertebrates and have an indirect life cycle involving an arthropod as intermediate host (Petrochenko 1971, Kennedy 2006). In most acanthocephalan eggs, the acanthor is visible; however, it is not always possible to visualize the embryo's hooks. Acanthocephalan eggs were found in human and non-human coprolites from archaeological sites in the New World (*e.g.* Moore *et al.* 1969, Ferreira *et al.* 1989, Beltrame *et al.* 2015) and less often in the Old World (Bouchet *et al.* 1989, 2000, Mowlavi *et al.* 2015). One of the most revealing paleoparasitological data on acanthocephalans comes from archaeological sites where ancient people habitually consumed insects to supplement their nutritional deficiency caused by the scarcity of food, thus exposing themselves to this zoonotic parasite (Fry 1977, Reinhard & Bryant 2008). However, in animal coprolites, the finding of acanthocephalan eggs are still occasional. In addition to the finding of *G. echinodiscus* in Myrmecophagidae (Ferreira *et al.* 1989, Sianto 2009), four other genera were found: *Echinopardalis* (Noronha *et al.* 1994), *Oncicola* (Sianto *et al.* 2014) and *Prosthenorchis* (Beltrame *et al.* 2016) in carnivore coprolites from Brazil and Argentina, and *Macracanthorhynchus* in ancient raptor pellets from Argentina (Beltrame *et al.* 2015), and in canid coprolites from Iran (*Macracanthorhynchus hirudinaceus*) (Mowlavi *et al.* 2015).

Seven species of *Gigantorhynchus* are considered valid by Yamaguti (1963), Petrochenko (1971), and Amin (2003), with three species described for the family Myrmecophagidae: *G. echinodiscus, G. ungriai* and *G. lopezneyrai*. The most frequent acanthocephalan species found in feces of all species of this family is *G. echinodiscus*, with eggs measuring between 64-70 μm x 42-45 μm. *G. ungriai* Antonio, 1958, is described in *T. tetradactyla* only from Venezuela and their eggs measure 60 x 40 μm (Yamaguti 1963). *Gigantorhynchus lopezneyrai* was only reported once in Venezuela by Diaz-Ungria (1958), but only males of the parasite were found, therefore, there is no egg description. Besides the species of the genus *Gigantorhynchus*, *Moniliformis monechinus* Linstow, 1902 (Moniliformidae) was also described for *T. tetradactyla* in South America (Yamaguti 1963, Petrochenko 1971), and the eggs of this acanthocephalan are the largest described for anteaters (104 μm x 57 μm) and morphologically distinct from those of *G. echinodiscus*. This is the only species of *Giganthorhynchus* reported in Brazilian anteaters to date, with records on coprolites (Ferreira et al. 1989) and modern material (Yamaguti 1963, Travassos 1917, Petrochenko 1971, Amin 2013). *Giganthorhynchus ungriai* Antonio, 1958 and *G. lopezneyrai* Diaz-Ungria, 1958 were registered for Venezuelan anteaters; however, they have egg measurements not compatible with those found in the present study (Yamaguti 1963, Amin 2013). *Giganthorhynchus lutzi* Machado Filho, 1941 is the other species found in Brazilian marsupials, but it has larger eggs (Yamaguti 1963, Petrochenko 1971, Amin 2013).

The genus *Oligacanthorhynchus* has 36 species described (Amin 2003), and has ants, termites and coleopteran larvae as intermediate hosts, all normally consumed by anteaters and armadillos. The morphology and morphometry of the eggs found have characteristics consistent with the descriptions of *O. carinii* (Travassos 1917, Meyer 1932, Smales 2007), so we suggest that this is the species found in the present study. *Oligacanthorhynchus carinii* is described infecting armadillos (Dasypodidae) as *Dasypus novemcinctus* from the midwest of Brazil, and from Peru (Travassos 1917, Martinez 1984); *Tolypeutes matacus* from Bolivia, Paraguay and Argentina (Martinez 1984, Smales 2007, Gomez-Puerta 2011); and *Chaetophractus vellerosus* from Argentina (Martinez 1984), whose order Cingulata (Xenarthras) is phylogenetically close to Pilosa (anteaters) and has the same feeding habit, with the consumption of termites and ants, intermediate hosts of parasites of the genus *Oligacanthorhynchus*. Other species reported in Brazil as *O. pardalis*, found in *Leopardus pardalis* (Travassos 1917); *O. major*, reported for *Pecari tajacu* and *Tayassu pecari* (Richardson *et al.* 2006); *O. microcephalus* in *Caluromys philander* (Richardson *et al.* 2014), i.e., has not been investigated due to phylogeny and geographical distribution. This is the first description of the genus *Oligacanthohynchus* in the region and of the *Tamandua* host.

Macracanthorhynchus hirudinaceus infects mainly domestic and wild swine (definitive hosts) but, as an opportunistic parasite, it can also infect other mammals such as canids, rodents, cattle and humans (Schmidt & Nickol 1985, Taylor *et al.* 2010). Eggs size vary between 70 and 110 μm and are very resistant to environmental factors as high temperatures, surviving in the soil for several years (Yamaguti 1963, Petrochenko 1971, Acha & Szyfres 2003). Although this species is normally registered for pigs, it is considered a species without host specificity, and is still found in dogs, rodents, and man, being considered a zoonosis (Pradatsundarasar & Pechranond 1965; Estrada 1997; Owen 2005). There is a single report of this species in anteaters, recovered from the intestinal content of run over anteaters in SC (Vieira *et al.* 2016), who found the adult female acanthocephalan with eggs, showing that infection is possible in this host, which supports our report in coprolites. Just like other parasites, the infection by *M. hirudinaceus* may vary according to the availability of the intermediate hosts during certain periods of the year, such as periods of high temperature. The intermediate hosts are larvae of coleopterans (Stumpf 1986) like those of the American genus *Phyllophaga*, which has dozens of species described in Brazil (Schmidt & Nickol 1985). Corrêa Vaz *et al.* (2012) reported that Coleoptera, Hymenoptera and Isoptera are also consumed by anteaters in Serra da Capivara National Park.

Macracanthorhynchosis is considered a zoonosis by the World Health Organization, with cases reported worldwide, linked to the accidental ingestion of coleopterans containing the Acanthor larva (*e.g.* Leng *et al.* 1983, Estrada 1997). Paleoparasitological studies in human samples in the region did not reveal the presence of *Macracanthorhynchus*, the presence of this parasite in anteaters indicates the availability of this parasite in the environment in remote times, which could expose the human groups to infection. In human coprolites *Macracanthorhynchus ingens*, endemic in North America, has been found in Ancestral Pueblo (Anasazi) associated with the consumption of cockroaches and crickets (Fugassa *et al.* 2011). In a Spanish Neolithic site, *Macracanthorhynchus* sp. was found and associated with the consumption of pork evidenced by the finding of pig bones (Maicher *et al.* 2017). Other sporadic findings of unidentified Acanthocephala species were made in the Old World (Bouchet *et al.* 1989, 2000).

The eggs of Aspidoderidae are compatible with those found by Beltrame *et al.* (2015) identified as *Paraspidodera uncinata* (Rudolphi 1819) Travassos, 1914. Ascarididae gen. sp. eggs were reported in feces of *T. tetradactyla* and *M. tridactyla* from captivity in São Paulo and in Minas Gerais state (Diniz *et al.* 1995, Marinho & Valdes 2012). *Paraspidodera* is one of the four genera of the family Aspidoderidae, which infects Neotropical mammals. They are monoxene parasites commonly found in the cecum and colon of the rodent belonging to the infraorder Hystricognathi (Taylor 2010). Three species of the genus *Paraspidodera* are currently known to infect *Cavia* spp., *Kerodon* spp., *Cuniculus* spp. and *Ctenomys* spp.: *P. uncinata*; *Paraspidodera americana* Khalil & Vogelsang, 1931; and *Paraspidodera uruguaya* Khalil & Vogelsang, 1931. However, only *P. uncinata* occurs in Brazil and has been found in *Kerodon rupestris* feces from Serra da Capivara National Park (Saldanha 2016). In coprolites, there are records of *P. uncinata* in rodents (Sardella & Fugassa 2009) and in raptor pellets from Patagonia, in which there were also found arthropod remains (Beltrame *et al.* 2015). This is the first report of the family Aspidoderidae in anteater's coprolites.

Parasites of the order Strongylida have cosmopolitan distribution, most commonly found in tropical and subtropical climate regions infecting a wide variety of mammals. Eggs of *Strongyloides* spp. were found in anteater feces (without measures) in *T. tetradactyla* and *Myrmecophaga tridactyla* from São Paulo Zoo, Brazil (Diniz *et al.* 1995), and *T. tetradactyla* feces from Serra da Capivara National Park (Brandão *et al.* 2009). This genus was found in rodent coprolites from Argentina (Beltrame *et al.* 2015), and in feces of *Allouatta caraya*, *Canis familiares*, *Sus scrofa* and *Pecari tajacu* by Brandão *et al.* (2009) from PNSC. It is possible that the eggs found in this study belong to the genus *Strongyloides* but we cannot confirm the identification. This is the first report of helminths of the order Strongylida in Myrmecophagidae coprolites.

The Nematoda egg with one operculum found in this study was morphologically and morphometrically similar to those identified as *Gnathostoma* sp. by Sianto (2009) (57.7 – 58.0 μm x 38.0 - 40.9 μm, N = 18) in human, rocky cavy and non-human primate coprolites. *Gnathostoma* spp. infects several vertebrates, including carnivores and lacertids (Bowman 2009), but no references were found citing eggs with these characteristics infecting anteaters. Because only one egg was found, we cannot rule out the possibility of false parasitism.

The species *Entamoeba coli* (Grassi 1879) has up to eight nuclei, whereas *Entamoeba histolytica* Schaudinn, 1903 has up to four nuclei (Bowman 2009). However, there are currently more than 51 species defined for the genus, and the size of the cysts varies greatly, even when they come from the same host (Hooshyar *et al.* 2015). *Entamoeba* spp. are currently associated with dysentery in captive anteaters, along with other parasites such as helminths and bacteria (Diniz *et al.* 1995, Marinho & Valdes 2012). Protozoan cysts are not easily found in archaeological material due to the fragility of the outer membrane (Ferreira *et al.* 1992), and most findings are obtained through the application of immunological techniques (Gonçalves *et al.* 2003, Frias *et al.* 2013, Le Bailly *et al.* 2014). Nevertheless, in archaeological material, *Entamoeba* cysts are reported since the 1970s, when it was observed in coprolites of an Inca child found in Chile dating to 1,500 AD by Pizzi & Schenone (1974); by Fouant and collaborators (1982) in pre-Columbian Chilean and Peruvian mummies, and more recently by Le Bailly and collaborators (2014) in two Cemeteries of the Caribbean Colonial Period (Guadeloupe). In non-human samples, *Entamoeba* sp. cyst was found in extinct Caprinae from Mallorca (Nunes *et al.* 2017). In the studied region, only *Eimeria* sp. oocysts were found in Cervidae coprolites from 9,000 years BP (Ferreira *et al.* 1992) and 3,800 BP (Sianto 2009). Humans are the reservoirs, (sometimes non-pathogenic) of *Entamoeba* spp. and little is known about the potential transmission between wild animals and man, and vice versa (Acha & Szyfres 2003). To date, there is no evidence of transmission from one animal to another. Infection is acquired by ingestion of food and water contaminated with fecal material. However, vectors such as dipterans are also potential mechanic sources of transmission (Acha & Szyfres 2003).

Few studies report the parasitic biodiversity found in anteaters today, and rarer are the studies with ancient material (Ferreira *et al.* 1989, Sianto 2009, Souza 2013). Thus, it is important to know the parasites that infect or infected this host, aiming at its proper management and future scenarios for conservation, since parasites constitute an important part of biodiversity, having a fundamental role in the control of populations and evolution (Petrochenko 1971, Ostfeld & Holt 2004).

The finding of *G. echinodiscus* reinforces previous data that the relationship between this parasite and anteaters is ancient (Ferreira *et al.* 1989). This study showed that Oligacanthorhynchidae parasites were present in tamanduas from the Brazilian semiarid 8,870 ± 70 years ago. This is the first report of eggs of the family Aspidoderidae, of the order Strongylida and cysts of cf. *Entamoeba* sp. in *T. tetradactyla* coprolites. These findings evidenced the need for further studies on feces and coprolites of the local fauna in order to find out which hosts harbored these parasites in the past and which have kept them until now. These kinds of paleoparasitological studies are essential to increase the knowledge about the evolution of parasitic infections in animal populations, and ecological relationships between these animals.

ACKNOWLEDGEMENTS

Instituto Nacional de Arqueologia, Paleontologia e Ambiente do Semi-Árido do Nordeste do Brasil (INAPAS- 465428/2014-2), INCT - MCTI/CNPq/CAPES/FAPs nº 16/2014, and PNPD/CAPES 88887.137834/2017-00.

REFERENCES

Acha, P. N., & Szyfres, B. 2003. Acanthocephaliases and Nematodiases. In: P. N. Acha & Szyfres, B (Eds.), Zoonoses and communicable diseases common to man and animals. 3th ed. Vol. III. pp. 1-395. Washington, D.C.: Pan American Health Organization (PAHO): Parasitoses.

Amin, O. M. 2003. Classification of the Acanthocephala. Folia Parasitologica, 60, 273–305. DOI: 10.14411/fp.2013.031

Araújo, A. J., Confalonieri, U. E., & Ferreira, L. F. 1980. Oxyurid infestations in small animals from 9,000 B.P. in Brazil. Paleopathology newsletter, 31, 13–14.

Araújo, A., Ferreira, L. F., Confalonieri, U., Chame, M. & Ribeiro, B. 1989. *Strongyloides ferreirai* Rodrigues, Vicente & Gomes, 1985 (Nematoda, Rhabdiasoidea) in rodent coprolites (8.000 - 2.000 years BP), from archaelogical sites from Piauí, Brazil. Memórias do Instituto Oswaldo Cruz, 84, 493–496. DOI: http://dx.doi.org/10.1590/S0074-02761989000400006

Arriaza, B. T., Reinhard, K. J., Araújo, A. G., Orellana, N. C., & Standen, V. G. 2010. Possible influence of the ENSO phenomenon on the pathoecology of diphyllobothriasis and anisakiasis in ancient Chinchorro populations. Memórias do Instituto Oswaldo Cruz, 105, 66–72. DOI: http://dx.doi.org/10.1590/S0074-02762010000100010.

Brandão, M. L., Chame, M., Cordeiro, J. L. P., & Chaves, S. A. M. 2009. Diversidade de helmintos intestinais em mamíferos silvestres e domésticos na Caatinga do Parque Nacional Serra da Capivara, Sudeste do Piauí, Brasil. Revista Brasileira de Parasitologia Veterinária, 18, 19–28. DOI: 10.4322/rbpv.018e1004

Beltrame, M. O., Fernández, F. J., & Sardella, N. H. 2015. First paleoparasitological record of acanthocephalan eggs from Northwestern Patagonia (Late Holocene, Argentina). Acta Tropica, 146, 33–35. DOI: 10.1016/j.actatropica.2015.02.019

Beltrame, M. O., Fernández, F. J., & Sardella, N. H. 2015. Reptile and rodent parasites in raptor pellets in an archaeological context: the case of Epullan Chica (northwestern Patagonia, Argentina). Quaternary Science Reviews 119, 1–10. DOI: http://dx.doi.org/10.1016/j.quascirev.2015.04.014

Beltrame, M. O., De Porras, M. E, Barberena, R., Llano, C. L., & Sardella, N. H. 2016. First study of fossil rodent middens as source of paleoparasitological evidences (northwestern Patagonia, Argentina). Parasitology International, 65, 352–356. DOI: https://doi.org/10.1016/j.parint.2016.04.007.

Bouchet, F., Audoin, F., Leger, N., Marchais, R., Baucheron, F., & Munoz la Casta, J. 1989. Etude parasitologique des coprolithes et des sediments de trois ensembles clos medievaux de la Rue de Lutece (Ile de la Cité) a Paris. Revue d'Aschéométrie, 13, 13–21. DOI: 10.3406/arsci.1989.867

Bouchet, F., Lavazec, C., Nattier, V., Dommelier, S., Bentrad, S. & Paicheler, J. C., 2000. Étude de la parasitofaune du site medieval de Charavines (Lac de Padru, Isere, France). Bulletin de la Société Zoologique de France, 125, 205–215.

Bowman, D. D. 2009. Parasitologia Veterinária de Georgis. 8 ed. Barueri, São Paulo, Manole. p. 422.

Callen, E. O. & Cameron, T. W. M. 1960. A prehistoric diet as revealed in coprolites. New Scientist, 8, 3540.

Chame, M. 1988. Estudo comparativo das fezes e coprólitos não humanos da região arqueológica de São Raimundo Nonato, Sudeste do Piauí. Master thesis. Museu Nacional, Universidade Federal do Rio de Janeiro. p. 134.

Chame, M. 2003. Terrestrial Mammal Feces: a Morphometric Summary and Description. Memórias do Instituto Oswaldo Cruz, 98, 71–94. DOI: http://dx.doi.org/10.1590/S0074-02762003000900014.

Corrêa Vaz, V., Santori, R. T., Jansen, A. M., Delciellos. A. C., & D'Andrea. P. S. 2012. Notes on Food Habits of Armadillos (Cingulata, Dasypodidae) and Anteaters (Pilosa, Myrmecophagidae) at Serra da Capivara National park (Piauí State, Brazil). Edentata, 13, 84–89. DOI: https://doi.org/10.5537/020.013.0107

Diniz, L. S. M., Costa, E. O., & Oliveira, P. M. A. 1995. Clinical disorders observed in Anteaters (Myrmecophagidae, Edentata) in captivity. Veterinary Research Communications, 19, 409–415. DOI: 10.1007/BF01839320

Estrada, M. B. F. 1997. Presentación del primer caso humano de parasitismo por *Macracanthorhynchus hirudinaceus* en el Perú y breve revisión. Revista Peruana de Medicina Experimental y Salud Publica, 14, 2.

Faure, M., Guérin, C., & Da Luz, M. F. 2011. Les parures des sépultures préhistoriques de l'abri-sous-roche d'Enoque (Parc National Serra das Confusões, Piauí, Brésil). Anthropozoologica, 46, 27–45. DOI: 10.5252/az2011n1a2

Ferreira, L. F., Araújo, A., Confalonieri, U., & Chame, M. 1989. Acanthocefalan eggs in animal coprolites from archaeological sites from Brazil. Memórias do Instituto Oswaldo Cruz 84, 201–203. DOI: http://dx.doi.org/10.1590/S0074-02761989000200007

Ferreira, L. F., Araújo, A., Confalonieri, U., Chame, M., & Ribeiro, B. 1992. *Eimeria* Oocysts in Deer Coprolites Dated from 9,000 Years BP. Memórias do Instituto Oswaldo Cruz, 87, 105–106. DOI: http://dx.doi.org/10.1590/S0074-02761992000500021

Fouant, M. M., Allison, M., Gerszten, E., & Focacci, G. 1982. Parasitos intestinales entre los indigenas Precolombinos. Chungara 9, 285–299.

Freitas, F. L. C., Almeida, K. S, Zanetti, A. S, Nascimento, A. A, Machado, C. R., & Machado, R. Z. 2006. Espécies do gênero *Eimeria* (Apicomplexa: Eimeriidae) em tamanduás bandeira (*Myrmecophaga Tridactyla* Linnaeus, 1758) em cativeiro Revista Brasileira de Parasitologia Veterinária, 15(1), 29 –32.

Frias, L., Leles, D., & Araújo, A. 2013. Studies on protozoa in ancient remains - A Review. Memórias do Instituto Oswaldo Cruz, 108, 1–12. DOI: http://dx.doi.org/10.1590/S0074-02762013000100001.

Fugassa, M. H., Reinhard, K.J., Johnson, K. L., Gardner, S. L., Vieira, M., & Araújo, A. 2011. Parasitism of prehistoric humans and companion animals from Antelope Cave, Mojave County, Northwest Arizona. Journal of Parasitology, 97, 862–867. DOI: 10.1645/GE-2459.1.

Fry, G. F. 1977. Analysis of prehistoric coprolites from Utah. University of Utah, Anthropological Papers, Salt Lake City, n. 97, p. 45.

FUMDHAM. 2007. Proteção, manutenção e pesquisa na região do Parque Nacional Serra da Capivara in Relatório Anual. Fundação Museu do Homem Americano, Fumdham: p. 35.

Guidon, N., & Da Luz, M. F. 2009. Sepultamentos na Toca do Enoque (Serra das Confusões-Piauí) – Nota Prévia. Fumdhamentos VIII, 115–123.

Gomez-Puerta, L. A. 2011. Algunos acantocéfalos de la Familia Oligacanthorhynchidae del Perú. Revista Peruana de Biología, 18, 383–385. DOI: http://dx.doi.org/10.15381/rpb.v18i3.458

Gonçalves, M. L. C., Araújo, A., & Ferreira, L. F. 2003. Human intestinal parasites in the past: New findings and a review. Memórias do Instituto Oswaldo Cruz, 98, 103–118. DOI: http://dx.doi.org/10.1590/S0074-02762003000900016.

Hall, H. J. 1972, *Apud* Reinhard KJ. Archaeoparasitology in North America. American Journal of Physical Anthropology

1990, 82, 145–163. DOI: 10.1002/ajpa.1330820204

Hooshyar, H., Rostamkhani, P., & Rezaeian, M. 2015. An annotated Checklist of the human and animal Entamoeba (Amoebida: Endamoebidae) species – A review article. Iranian Journal of Parasitology, 10(2), 146–156.

Hugot, J. P., Reinhard, K. J., Gardner, S. L., & Morand, S. 1999. Human enterobiasis in evolution: origin, specificity e transmission. Parasite, 6, 201–208. DOI: 10.1051/parasite/1999063201.

Kennedy, C. R. 2006. Ecology of the Acanthocephala. Cambridge University Press, Cambridge. p. 249. DOI: https://doi.org/10.1017/CBO9780511541902

Lafferty, K. D., Allesina, S., Arim, M., Briggs, C. J., De Leo, G., Dobson, A. P. *et al.* 2008. Parasites in food webs: the ultimate missing link. Ecology Letters, 11, 533–546. DOI: 10.1111/j.1461-0248.2008.01174.x.

Lainson, R., & Shaw, J. J. 1990. Coccidia of Brazilian Mammals: *Eimeria corticulata* n. sp. (Apicomplexa: Eimeriidae) from the Anteater *Tamandua tetradactyla* (Xenarthra: Myrmecophagidae) and *Eimeria zygodontomyis* n. sp. from the Cane Mouse *Zygodontomys lasiurus* (Rodentia: Cricetidae). Journal of Protozoology, 37, 51–54. DOI: 10.1111/j.1550-7408.1990.tb01115.x

Lainson, R., & Shaw, J. J. 1991. Coccidia of Brazilian Mammals: *Eimeria marajoensis* n. sp. (Apicomplexa: Eimeriidae) from the Anteater, *Tamandua tetradactyla* (Xenarthra: Myrmecophagidae). Journal of Protozoology, 38, 28–30. DOI: https://doi.org/10.1111/j.1550-7408.1991.tb04792.x

Le Bailly, M., Romon, T., & Kacki, S. 2014. New Evidence of *Entamoeba histolytica* Infections in Pre-Columbian and Colonial Cemeteries in the Caribbean. Journal of Parasitology, 100, 684–686. DOI: 10.1645/13-476.1.

Leng, Y., Huang, W., & Liang, P. 1983. Human infection with *Macracanthorhynchus hirudinaceus* Travassos, 1916 in Guangdong Province, with notes on its prevalence in China. Annals of Tropical Medicine and Parasitology. 77, 107. DOI: 10.1080/00034983.1983.11811681.

Lessa, A., & Guidon, N. 2002. Osteobiographic Analysis of Skeleton I, Sítio Toca dos Coqueiros, Serra da Capivara National Park, Brazil, 11,060 BP: First Results. American Journal of Physical Anthropology, 118, 99–110. DOI: 10.1002/ajpa.10084

Maicher, C., Hoffman, A., Còte, N. M. L., Pérez, A. P., Segui, M. S., & Le Bailly, M. 2017. Paleoparasitological investigations on the Neolithic lakeside settlement of La Draga (Lake Banyoles, Spain). The Holocene, 1–10. DOI: 10.1177/0959683617702236.

Marinho, A. V., & Valdes, S. A. C. 2012. Diagnóstico de parasitas gastrintestinais de tamanduás-bandeira (*Myrmecophaga tridactyla*, Linnaeus, 1758) mantidos em cativeiro e terapia farmacológica – relato de caso. Clínica Veterinária, 17(96), 96–102.

Martin, G. 2008. Pré-história do Nordeste do Brasil. 4ed. Recife: Editora Universitária UFPE.

Martinez, F. A. 1984. *Hamanniella carinii* Travassos, 1916 (Acanthocephaloµ Gigantorhynchidae) em dasipodideos de Argentina. Boletin Chileno de Parasitologia, 39, 37–38.

Meyer, A. 1932. Acanthocephala. Dr. H.G. Bronn's Klassen und Ordnungen des TierReichs. Akad. Verlag, Leipzig, 4: 1–332.

Mitchell, P. D., Stern, E. & Tepper, Y. 2008. Dysentery in the crusader kingdom of Jerusalem: an ELISA analysis of two medieval latrines in the City of Acre (Israel). Journal of Archaeological Science, 35(7), 1849–1853. DOI: https://doi.org/10.1016/j.jas.2007.11.017

Mowlavi, G., Makki, M., Heidari, Z., Rezaeian, M., Mohebali, M., Araujo, A. *et al.* 2015. *Macracanthorhynchus hirudinaceus* eggs in canine coprolite from the Sasanian Era in Iran (4th/5th Century CE). Iranian Journal of Parasitology, 10(2), 245–249.

Montgomery, G. G. 1985. Movements, Foraging and Food Habits of the four extant species of Neotropical Vermilinguas (Mammalia; Myrmecophagidae). In: G. G. Montgomery (Ed.), The Evolution and Ecology of Armadillos, Sloths, and Vermilinguas. pp. 365–387. Washington, D.C.: Smithsonian Institution Press.

Moore, J. G., Fry, G. F., & Englert, Jr. E. 1969. Thorny-headed worm infection in North American prehistoric man. Science, 163, 1324–1325. DOI: 10.1126/science.163.3873.1324

Noronha, D., Ferreira, L. F., Rangel, A., Araújo, A., & Gomes, D. C. 1994. *Echinopardalis* sp. (Acanthocephala, Oligacanthorhynchidae) eggs in felid coprolites dated from 9,000 years before present, found in the Brazilian northeast. Memórias do Instituto Oswaldo Cruz, 89(1), 119-120. DOI: http://dx.doi.org/10.1590/S0074-02761994000100022.

Nowak, R. M. 1999. Walker's Mammals of the World. v. 1. 6. ed. Baltimore and London: The Johns Hopkins University Press: p. 836.

Nunes, V. H. B., Alcover, J. A., Silva, V. L., Cruz, P. B., Machado-Silva, J. R. & Araújo, A. J. G. 2017. Paleoparasitological analysis of the extinct *Myotragus balearicus* Bate 1909 (Artiodactyla, Caprinae) from Mallorca (Balearic Islands, Western Mediterranean). Parasitology International, 66(2), 7–11. DOI: https://doi.org/10.1016/j.parint.2016.11.009.

Ostfeld, R. S., & Holt, R. D. 2004. Are predators good for your health? Evaluating evidence for top-down regulation of zoonotic disease reservoirs. Front Ecology Enviroment, 2(1), 13–20. DOI: https://doi.org/10.1890/1540-9295(2004)002[0013:APGFYH]2.0.CO;2.

Oliveira, E. V., & Vilella, F. S. 2003. Xenarthros p. 487-492. In: Livro Vermelho da fauna ameaçada de extinção no Rio Grande do Sul. EDIPUCRS, Porto Alegre, Brasil. p. 632.

Oliveira-Santos, J. D. 2013. Diversidade de helmintos intestinais em cães domésticos (*Canis familiaris* Linnaeus, 1758) e de raposas (*Cerdocyon thous* Linnaeus, 1766) no semiárido do Nordeste do Brasil e implicações para a saúde. Master thesis. Escola Nacional de Saúde Pública Sérgio Arouca, Fundação Oswaldo Cruz. p. 204. https://www.arca.fiocruz.br/xmlui/handle/icict/24530

Petrochenko VI. 1971. Acanthocephala of Domestic and Wild Animals. Israel Program for Scientific Translations. p. 272.

Pizzi, T., & Schenone, H. 1954. Hallazgo de huevos de *Trichuris trichiura* en contenido intestinal de um cuerpo arqueologico incaico. Boletín Chileno de Parasitologia, 9, 73–75.

Reinhard, K. J. & Bryant, V. M. 2008. Pathoecology and the Future of Coprolite Studies in Bioarchaeology. In: A. W. M. Stodder (Ed.), Reanalysis and Reinterpretation in Southwestern Bioarcheology. pp. 205-224. Arizona State University Press.

Reinhard, K. J. 1990. Archaeoparasitology in North America. American Journal of Physical Anthropology. 82(2), 145–63.

Saldanha, B. M. 2016. Diversidade de helmintos intestinais em mocós *Kerodon rupestris* (Wied-Neuwied, 1820) no Parque Nacional Serra da Capivara, Piauí, Brasil: uma síntese em 30 anos de informação, Master thesis, Universidade Federal Fluminense. p. 148. https://app.uff.br/riuff/handle/1/6140

Sardella, N. H., & Fugassa. M, H. 2009. Paleoparasitological Analysis of Rodent Coprolites in Holocenic Samples from Patagonia, Argentina. Journal of Parasitology, 95(3), 646–651. DOI: 10.1645/GE-1809.1

Sianto, L. 2009. Parasitismo em populações Pré-Colombianas: helmintos de animais em coprólitos de origem humana do Parque Nacional Serra da Capivara, PI, Brasil, Doctoral thesis, Fundação Oswaldo Cruz, Escola Nacional de Saúde Pública. p. 189. https://www.arca.fiocruz.br/handle/icict/2547

Sianto, L., Souza, M. V., Chame, M., Da Luz, M. F., Guidon, N., Pessis, A. M., & Araújo, A. 2014. Helminths in feline coprolites up to 9000 years in the Brazilian Northeast. Parasitology International, 63, 851–857. DOI: 10.1016/j.parint.2014.08.002.

Sianto, L., Chaves, S. A. M., Antunes-Ferreira. N., & Silva, A. R. M. 2017. *Toxocara* eggs in an 18th century Franciscan from Portugal. The challenge of differentiating between parasitism and chance in Paleoparasitology. International Journal of Paleopathology, 18, 47–51. DOI: 10.1016/j.ijpp.2017.05.004.

Smales, L. R. 2007. Oligacanthorhynchidae (Acanthocephala) from Mammals from Paraguay with the Description of a New Species of *Neoncicola*. Comparative Parasitology, 74(2), 237–243. DOI: https://doi.org/10.1654/4271.1.

Schmidt, G. D., & Nickol, B. B. 1985. Development and Life Cycles, Chapter 8. In: D. W. T. Crompton and B. B. Nickol (Eds.), Biology of the Acanthocephala. Cambridge University Press. p. 273–305.

Souza, M. V., Sianto, L., Chame, M., Ferreira, L. F., & Araújo, A. 2012. *Syphacia* sp. (Nematoda: Oxyuridae) in coprolites of *Kerodon rupestris* Wied-Niuwied, 1820 (Rodentia: Caviidae) from 5,300 years BP in northeastern Brazil. Memórias do Instituto Oswaldo Cruz, 107, 539–542. DOI: http://dx.doi.org/10.1590/S0074-02762012000400015.

Souza, M. V. 2013. Parasitos encontrados em coprólitos do Parque Nacional Serra das Confusões, Piauí, Brasil, Master thesis. Escola Nacional de Saúde Pública, Fundação Oswaldo Cruz. p. 101. https://www.arca.fiocruz.br/xmlui/handle/icict/24532

Stumpf, I. V. K. 1986. Hospedeiros intermediários de *Macracanthorhynchus hirudinaceus* (Pallas 1781) (Acanthocephala) em Mandirituba, Paraná, Brasil. Acta Biológica Paranaense, 15(1,2,3,4), 87-124. DOI: http://dx.doi.org/10.5380/abpr.v15i0.821.

Taylor, M. A., Coop, R. L., & Wall, R. L. 2010. Parasitologia Veterinária, 3rd ed., Guanabara Koogan, Rio de Janeiro: p. 742.

Travassos, L., 1917. Contribuição para o conhecimento da fauna helmintológica brasileira. VI. Revisão dos acantocéfalos brasileiros. Parte 1. Fam. Gigantorhynchidae Hamann, 1892. Memórias do Instituto Oswaldo Cruz, 9, 5–67.

Vieira, D. L., Vanhoni, M. S., Dias de Castro, L. L. & Milczewsk, V. 2016. *Macracanthorhynchus hirudinaceus* em tamanduá-mirim (*Tamandua tetradactyla*) do município de São Francisco do Sul/SC. Archives of Veterinary Science, 21, supl 2, 1346–1348. ISSN 1517-784X, 21(00).

Yamaguti, S. 1963. Acanthocephala. Systema Helminthum. Wiley Intersci., New York, London, 5: p. 423 .

Yeh, H. Y., Pluskowski, A., Kalejs, U., & Mitchell, P. D. 2014. Intestinal parasites in a mid-14th century latrine from Riga, Latvia: fish tapeworm and the consumption of uncooked fish in the medieval eastern Baltic region. Journal of Archaeological Science, 49, 83–89. DOI: https://doi.org/10.1016/j.jas.2014.05.001.

Yeh, H. Y., Prag, K., Clamer, C., Humbert, J. B., & Mitchell, P. D. 2015. Human intestinal parasites from a Mamluk Period cesspool in the Christian quarter of Jerusalem: Potential indicators of long distance travel in the 15th century AD. International Journal of Paleopathology, 9, 69-75. DOI: 10.1016/j.ijpp.2015.02.003.

Submitted: 25 February 2019
Accepted: 16 October 2019
Published online: 18 October 2019
Associate Editor: Rosana Gentile