



Three new species of *Eimeria* Schneider 1875 in the montane grass mouse, *Akodon montensis* (Rodentia: Cricetidae: Sigmodontinae), and redescription of *Eimeria zygodontomyis* Lainson and Shaw 1990 from southeastern Brazil

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Abstract

We describe three new coccidian species of the genus *Eimeria* Schneider 1875 (Apicomplexa: Eimeriidae) and redescribe and report *Eimeria zygodontomyis* Lainson and Shaw, 1990 in the montane grass mouse, *Akodon montensis* Thomas, 1913 from the Serra dos Órgãos National Park in southeastern Brazil. Sporulated oocysts of *Eimeria zygodontomyis* are ellipsoidal to cylindrical with a 0.6 (0.5–0.8) μm thick very delicate bi-layered wall; length \times width ($n = 49$) 18.3×12.5 (16–20 \times 11–13) μm ; length/width ratio of 1.4 (1.2–1.6); 1 polar granule occasionally present; micropyle, residuum both absent. Sporocysts are ellipsoidal; length \times width 8.5×5.2 (8–11 \times 5–6) μm ; length/width ratio of 1.5 (1.3–1.7) μm ; Stieda body is prominent; sub-Stieda body is absent; sporocyst residuum is compact. Sporulated oocysts of *Eimeria montensis* n. sp. are spheroidal to subspheroidal with a 1.2 (1.0–1.4) μm thick bi-layered wall; outer layer lightly pitted; length \times width ($n = 30$) 16.3×12.5 (15–17 \times 13–15) μm ; length/width ratio of 1.3 (1.0–1.4); 1 polar granule present; micropyle, residuum both absent. Sporocysts are ellipsoidal; length \times width 7.2×5.1 (6–8 \times 4–6) μm ; length/width ratio of 1.4 (1.2–1.6); Stieda body is present, sub-Stieda body is absent; sporocyst residuum consists of small, scattered granules. Sporulated oocysts of *Eimeria uricanensis* n. sp. are ovoidal to pyriform with a 1.4 (1.3–1.6) μm thick bi-layered wall; outer layer lightly pitted; length \times width ($n = 40$) 26.6×18.6 (23–30 \times 17–20) μm ; length/width ratio of 1.4 (1.3–1.6); 1 polar granule present; micropyle, residuum both absent. Sporocysts are ellipsoidal, length \times width 13.3×8.0 (10–16 \times 7–9) μm ; length/width ratio of 1.7 (1.5–1.9); Stieda body, sub-Stieda body both absent; sporocyst residuum consists of a cluster of granules, forming a spheroid mass. Sporulated oocysts of *Eimeria parnasiensis* n. sp. are subspheroidal to ellipsoidal with a 1.8 (1.3–2.4) μm thick bi-layered wall; outer layer lightly pitted; length \times width ($n = 54$) 28.2×21.9 (26–32 \times 19–28) μm ; length/width ratio of 1.3 (1.2–1.4); 1 polar granule present; micropyle is absent; oocyst residuum is present and consists of a cluster of granules of varying thickness. Sporocysts are ovoidal, tapering towards the Stieda body; length \times width 12.2×7.6 (10–13 \times 6–9) μm ; length/width ratio of 1.6 (1.4–1.9); Stieda body is present; sub-Stieda body is absent; sporocyst residuum is present and consists of an aggregate of thin granules.

Keywords Rodents · Coccidia · *Akodon montensis* · Atlantic Forest · Cricetidae

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Introduction

The Serra dos Órgãos National Park (PARNASO) is located centrally within the Serra do Mar Ecological Corridor (Aguiar et al. 2005). Four species of grass mouse, *Akodon* (Cricetidae: Sigmodontinae), are known to occur in the Brazilian state of Rio de Janeiro and three of these are found in the PARNASO: *Akodon cursor* Winger, 1887, *Akodon serrensis* Thomas, 1902, and *Akodon montensis* Thomas, 1913 (Oliifiers et al. 2007). These mice are terrestrial, have an insectivore-omnivore diet (Graipel et al. 2003), and are known to host a range of organisms, including viruses and helminths, in the Atlantic Forest biome (Da Silva and Casteleti 2003; Simões et al. 2014; Teixeira et al. 2014). We recently described *Eimeria akodonensis* from *A. montensis* in this biome (de Santana Miglionico et al. 2018) and part of its endogenous development. At the same time, Barreto et al. (2017) described the first coccidian species found in two spiny rats (Rodentia: Echimyidae) in the Pantanal of Mato Grosso state, Brazil.

More than 1300 species of protozoan parasites of the genus *Eimeria* Schneider, 1875 have been described to date (Duszynski et al. 2000) and are known to infect a number of different types of host, although few data are available on the cricetid rodent hosts of the Brazilian Atlantic Forest biome.

The present study describes the sporulated oocyst stage of four *Eimeria* species from the feces of the montane grass mouse, *Akodon montensis*, captured in the Atlantic Forest of southeastern Brazil. Three of the sporulated oocysts are new species and a redescription of *E. zygodontomyis* Lainson and Shaw 1990 from *A. montensis* are provided. *Eimeria zygodontomyis* was originally described from the hairy-tailed bolo mouse, *Necromys lasiurus*, in 1990 from Serra dos Carajás, in the northern Brazilian state of Pará (Lainson and Shaw 1990).

Material and methods

Study area

The study area was the PARNASO in Rio de Janeiro state, Brazil (22° 27' 49" S, 43° 05' 14.09" W). This national park is a continuous tract of well-preserved Brazilian Atlantic Forest and is one of the state's principal remnants of this forest biome (Aguiar et al. 2005). Specimen collection was authorized by the Chico Mendes Institute for Biodiversity Conservation and the Oswaldo Cruz Foundation Ethics Committee for the Use of Animals in Research. All animals not released back to the wild were humanely euthanized using methods approved by the ethics committee.

Trapping

Rodents were trapped in the PARNASO during 10 consecutive days in November 2014 and July 2015. Traps were set along 10 transects during each expedition. Tomahawk® (16 × 5 × 5 in.) and Sherman® traps were set on the ground along these transects, with a total of 90 traps being set each night. Pitfall traps, made of 100-l buckets buried in the ground, were placed along four transects, with 20 traps on each transect and a total of 80 pitfall traps per night. Traps were checked once in the morning and, when necessary, new baits were inserted in the traps. Rodents were captured in all models of traps used and the total catching effort was 5920 night-traps. Traps with rodents were removed from the capture transects and taken to the field laboratory. In the field laboratory, rodents were removed from their traps and transferred into cotton bags (60 × 35 cm); they were then measured, identified, and euthanized using ketamine and xylazine. Euthanasia and all field and laboratory procedures followed veterinary and Fiocruz guidelines. Skins were prepared as museum specimens and skeletons were cleaned by dermestid larvae before these voucher specimens and their parasites were deposited in the scientific collection of the National Museum (Museu Nacional) at Universidade Federal do Rio de Janeiro (UFRJ) and in Universidade Federal Rural do Rio de Janeiro (UFRRJ), respectively. Samples were collected during the Rede Bioma (Biome Network) project “Inventories: Patterns of Diversity, Biogeography, and Endemism of Mammals, Birds, Amphibians, Fruit Flies, and Parasites in the Atlantic Forest,” which is supported by a consortium of Brazilian research agencies and financed by Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq)—Programa de Pesquisa em Biodiversidade (PPBio) Rede Bioma.

Collection of oocysts and morphological analysis

Feces were collected directly from the last portion of the small intestine of euthanized animals and placed in 15-ml screw-capped tubes containing 5 ml of 2.5% (w/v) potassium dichromate. To promote sporulation of any oocysts present, tubes were kept at room temperature for 5 days, submitted daily to vigorous manual stirring (with screw caps on), followed by cap opening for 2 min for oxygenation. Fifteen days after sampling, 0.5 ml of the material was submitted to centrifugal floatation (Sheather 1923), transferred to slides, examined under a microscope at a magnification of × 400 (Duszynski and Wilber 1997) and kept at 4 °C after examination. Morphological descriptions were developed and measurements collected using a Carl Zeiss

Axio Scope.A1 binocular microscope with an apochromatic oil immersion objective lens and AxioVision imaging system (Wilber et al. 1998). The oocysts were examined with a Zeiss Imager.A2 light microscope equipped with Nomarski interference contrast microscopy and $\times 100$ objective lenses, with the images being captured with an AxioCam MRc. All measurements are given as mean values in micrometers, followed by the range of values in parentheses (Duszynski and Wilber 1997). In our descriptions, we used the standardized guidelines and abbreviations of Wilber et al. (1998) to describe various oocyst structures: mean length (L), width (W), their measurement ranges and length/width (L/W) ratios, micropyle (M), oocyst residuum (OR), polar granule (PG), sporocyst L and W and their measurement ranges and L/W ratios, Stieda body (SB), sub-Stieda body (SSB), para-Stieda body (PSB), and sporocyst residuum (SR).

Results

Six (11.4 %) of the 53 *A. montensis* specimens were examined infected with *Eimeria*; three of them with two species simultaneously. Oocysts of the three new *Eimeria* spp. are described below, and the oocysts of *E. zygodontomyis* observed in *A. montensis*, a new host for this parasite, are also described.

Redescription of *Eimeria zygodontomyis* Lainson and Shaw 1990 (Figs. 1, 2, and 3)

Type host: *Necromys lasiurus* (Lund, 1841).

Type locality: Serra dos Carajás, in the northern Brazilian state of Pará.

Other hosts: *Akodon montensis* (Rodentia: Sigmodontinae).

Geographic distribution: *A. montensis* is distributed from the state of Rio de Janeiro to Rio Grande do Sul and the eastern state of Minas Gerais, Brazil.

Description of sporulated oocyst: Oocysts ellipsoidal to cylindrical; wall very delicate, 0.6 (0.5–0.8) thick; number of layers, 2; (L \times W) ($n = 49$) 18.3 \times 12.5 (16–20 \times 11–13); (L/W ratio), 1.4 (1.2–1.6); 1 PG occasionally present; M, OR: both absent.

Description of sporocyst: Sporocysts ellipsoidal, 8.5 \times 5.2 (8–11 \times 5–6); L/W ratio, 1.5 (1.3–1.7); SB: present and prominent; SSB, PSB: both absent; SR: present; SR characteristics: compact.

Prevalence: 2 of 53 (3.8%).

Sporulation: Unknown, but within 5 days.

Site of infection: Unknown: oocysts from feces.

Endogenous stages: Unknown.

Cross-transmission: Not investigated.

Pathology: Unknown.

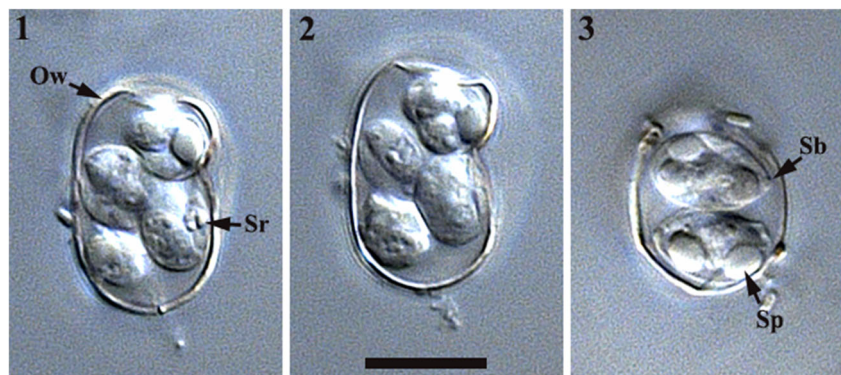
Materials deposited: Symbiotype hosts (Frey et al. 1992), skin and skeleton, are deposited in the National Museum in Rio de Janeiro (adult males, MNRJ # 83769 and 83771). Photovouchers and oocysts preserved in 2.5% potassium dichromate solution (Williams et al. 2010) are deposited in the Zoology Museum of Universidade Federal Rural do Rio de Janeiro (accession # MZURPTZ2018012). The phototypes and line drawings were deposited in the Parasitology Collection of Laboratório de Biologia de Coccídios (<http://r1.ufrj.br/labicoc/index.html>) of Universidade Federal Rural do Rio de Janeiro, Seropédica, RJ, Brazil (repository # P-83/2017).

Etymology: The specific name indicates the host genus from which the parasite was first isolated

Remarks:

Eimeria zygodontomyis was originally described in the hairy-tailed bolo mouse, *Necromys lasiurus* (= *Zygodontomyis lasiurus*), from Serra dos Carajás, in the northern Brazilian state of Pará. This locality is more than 2000 km north of the Serra dos Órgãos National Park. Due to Brazilian Atlantic Forest fragmentation (Olifiers et al. 2005; Rocha et al. 2007), *N. lasiurus*, a rodent that typically lives in open fields of the Caatinga, Cerrado, and Pantanal biomes, has

Fig. 1–3 Nomarski interference-contrast photomicrographs of *E. zygodontomyis* Lainson and Shaw 1990 from the rodent *A. montensis*. Stieda body (Sb), sporocyst residuum (Sr), oocyst wall (Ow), sporozoite (Sp). Scale bar = 10 μ m



expanded its geographic range into deforested areas of the Atlantic Forest biome in Rio de Janeiro state, Brazil where it has been captured in 16 localities of 10 municipalities (de Oliveira Santos et al. 2018). Morphologically, the oocysts found in *A. montensis* are identical to those described in *N. lasiurus*, with only minor differences in size. The oocysts from the two rodents share a number of characteristics, such as the thin wall, sporocyst residuum, curved sporozoite, prominent Stieda bodies, polar granules rare, and the cylindrical shape of the oocyst. The oocysts retrieved from *N. lasiurus* by Lainson and Shaw (1990) measured 16.5×12 ($14\text{--}19 \times 11\text{--}13$), in comparison with 18.3×12.5 ($16\text{--}20 \times 11\text{--}13$) recorded in the present study. The measurements of the sporocysts were even more similar, with those from *N. lasiurus* measuring 8.4×5.5 ($7\text{--}9 \times 5\text{--}6$), and those recorded in the present study, 8.5×5.2 ($8\text{--}11 \times 5\text{--}6$) Table 1. It is interesting to note that *Akodon* and *Necromys* are very closely related phylogenetically (D'elia et al. 2003, 2008).

***Eimeria montensis* n. sp.** (Figs. 4, 5, 6, and 13)

Type host: *Akodon montensis* (Rodentia: Sigmodontinae).

Type locality: Serra dos Órgãos National Park in Petrópolis, in the state of Rio de Janeiro, Brazil ($22^\circ 27' 49''$ S, $43^\circ 05' 14.09''$ W).

Other hosts: Unknown.

Geographic distribution: *A. montensis* is distributed from the state of Rio de Janeiro to Rio Grande do Sul and the eastern state of Minas Gerais, Brazil.

Description of sporulated oocyst: Oocysts spheroidal to subspheroidal; wall 1.2 (1.0–1.4) thick; number of layers, 2; outer wall is lightly pitted; $L \times W$ ($n = 30$) 16.3×12.5 ($15\text{--}17 \times 13\text{--}15$); L/W ratio, 1.3 (1.0–1.4); 1 PG present; M, OR: both absent.

Description of sporocyst: Sporocysts ellipsoidal, 7.2×5.1 ($6\text{--}8 \times 4\text{--}6$); L/W ratio, 1.4 (1.2–1.6); SB: present; SSB, PSB: both absent; SR: present; SR characteristics: consists of small, scattered granules.

Prevalence: 3 of 53 (5.7%).

Sporulation: within 15 days.

Site of infection: Unknown. Oocysts from feces.

Endogenous stages: Unknown.

Cross-transmission: Not investigated.

Pathology: Unknown.

Materials deposited: Symbiotype hosts (Frey et al. 1992), skin and skeleton, are deposited in the National Museum in Rio de Janeiro (adult males, MNRJ # 83769 and 837770; adult female, MNRJ # 83775). Photovouchers and oocysts preserved in 2.5% potassium dichromate solution (Williams et al. 2010) are deposited in the Zoology Museum of Universidade Federal Rural do Rio de Janeiro (accession # MZURPTZ2018011). The phototypes and line drawings were deposited in the Parasitology Collection of Laboratório de

Biologia de Coccídios (<http://r1.ufrj.br/labicoc/index.html>) of Universidade Federal Rural do Rio de Janeiro, Seropédica, RJ, Brazil (repository # P-82/2017).

Etymology: The specific epithet “*montensis*” we derived from the species name of the rodent.

Remarks:

The oocysts of *E. montensis* are similar in size to *E. zygodontomyis* but they are spheroidal to subspheroidal compared to ellipsoidal to cylindrical and possess a thicker, bi-layered vs. a thinner mono-layered wall (Table 1).

***Eimeria uricanensis* n. sp.** (Figs. 7, 8, 9, and 14)

Type host: *Akodon montensis* (Rodentia: Sigmodontinae).

Type locality: Serra dos Órgãos National Park in Petrópolis, Rio de Janeiro state, Brazil ($22^\circ 27' 49''$ S, $43^\circ 05' 14.09''$ W).

Other hosts: Unknown.

Geographic distribution: *A. montensis* is distributed from the state of Rio de Janeiro to Rio Grande do Sul and the eastern state of Minas Gerais, Brazil.

Description of sporulated oocyst: Oocysts ovoidal to pyriform; wall 1.4 (1.3–1.6) thick; number of layers, 2; outer wall is lightly pitted; $L \times W$ ($n = 40$) 26.6×18.6 ($23\text{--}30 \times 17\text{--}20$); L/W ratio, 1.4 (1.3–1.6); 1 PG present; M, OR: both absent.

Description of sporocyst: Sporocysts ellipsoidal, 13.3×8.0 ($10\text{--}16 \times 7\text{--}9$); L/W ratio, 1.7 (1.5–1.9); SB, SSB: both absent; SR: present; SR characteristics: consists of a cluster of granules, forming a spheroid mass.

Prevalence: 2 of 53 (3.8%)

Sporulation: Unknown.

Site of infection: Unknown. Oocysts from feces.

Endogenous stages: Unknown.

Cross-transmission: Not investigated.

Pathology: Unknown.

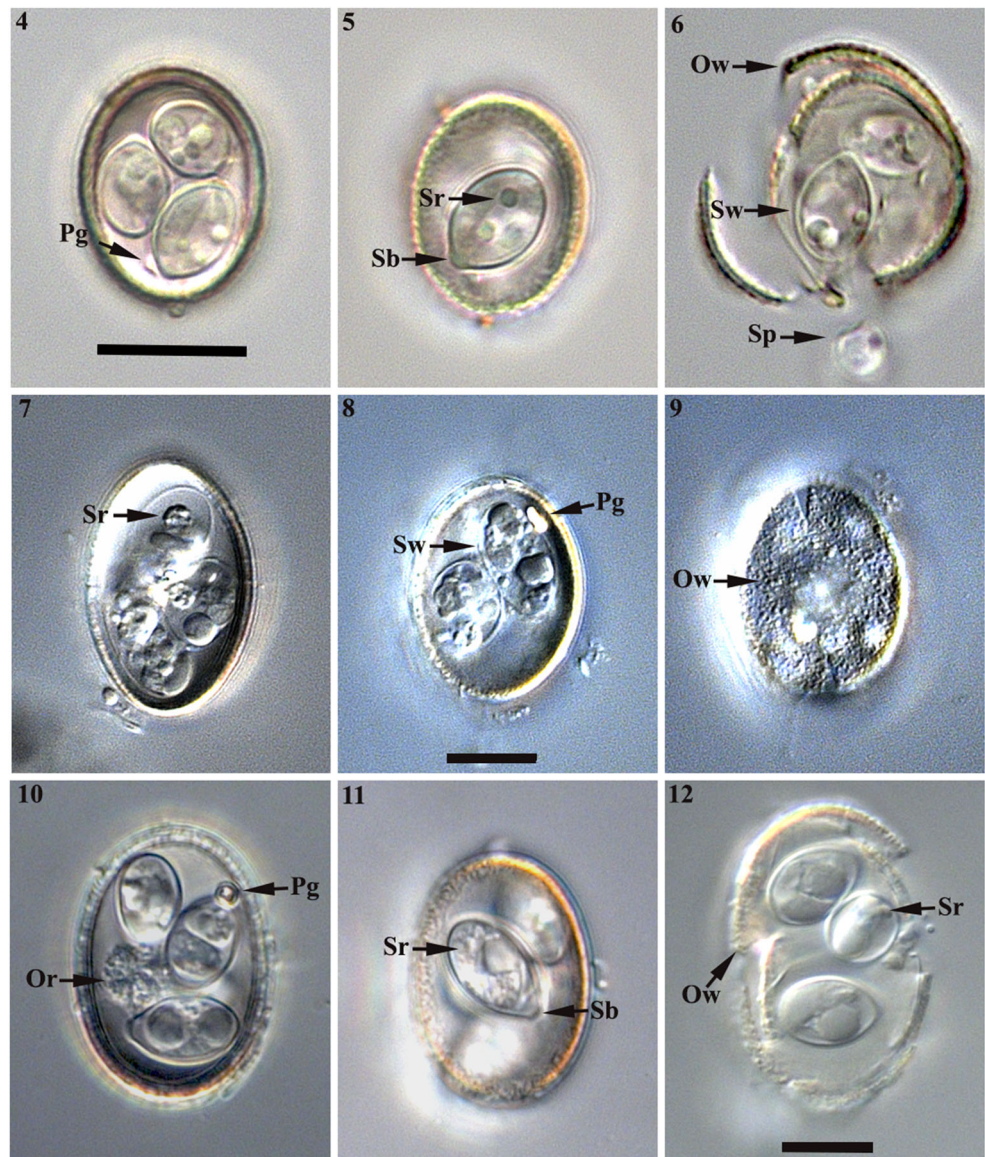
Materials deposited: Symbiotype hosts (Frey et al. 1992), skin and skeleton, are deposited in the National Museum in Rio de Janeiro (young male, MNRJ # 83771; adult female, MNRJ # 83775). Photovouchers and oocysts preserved in 2.5% potassium dichromate solution (Williams et al. 2010) are deposited in the Zoology Museum of Universidade Federal Rural do Rio de Janeiro (accession # MZURPTZ2018010). The phototypes and line drawings were deposited in the Parasitology Collection of Laboratório de Biologia de Coccídios (<http://r1.ufrj.br/labicoc/index.html>) of Universidade Federal Rural do Rio de Janeiro, Seropédica, RJ, Brazil (repository # P-81/2017).

Etymology: The specific epithet “*uricanensis*” is derived from Uricanal, which is the locality inside PARNASO where the host was captured.

Remarks:

The oocysts of *E. uricanensis* are ovoidal to pyriform, which is different from *E. akodoni*, *E. parnasiensis*, *E. akodonensis*, and *E. oryzomyi*. Its shape index is the largest, 1.4 (1.3–1.6), among the four species. However, the

Fig. 4–12 Nomarski interference-contrast photomicrographs of *E. montensis* (4–6), *E. uricanensis* (7–9), and *E. parnasiensis* (10–12). Note the highly refractile polar granule (Pg), oocyst wall (Ow), oocyst residuum (Or), sporocyst residuum (Sr), Stieda body (Sb), sporozoite (Sp), sporocyst wall (Sw). Scale bar = 10 μ m



sporocysts of *E. uricanensis* lack a Stieda body, which is present in the other four species. In addition, while the oocysts of *E. akodoni* have a tri-layered wall, those of *E. uricanensis* are bi-layered (Table 1).

***Eimeria parnasiensis* n. sp.** (Figs. 10, 11, 12, and 15)
 Type host: *Akodon montensis* (Rodentia: Sigmodontinae).
 Type locality: Serra dos Órgãos National Park in Petrópolis, Rio de Janeiro state, Brazil (22° 27' 49" S, 43° 05' 14.09" W).

Fig. 13–15 Composite line drawing of the sporulated oocysts of the new coccidian species described. *E. montensis* (13), *E. uricanensis* (14), and *E. parnasiensis* (15) Scale bar = 10 μ m

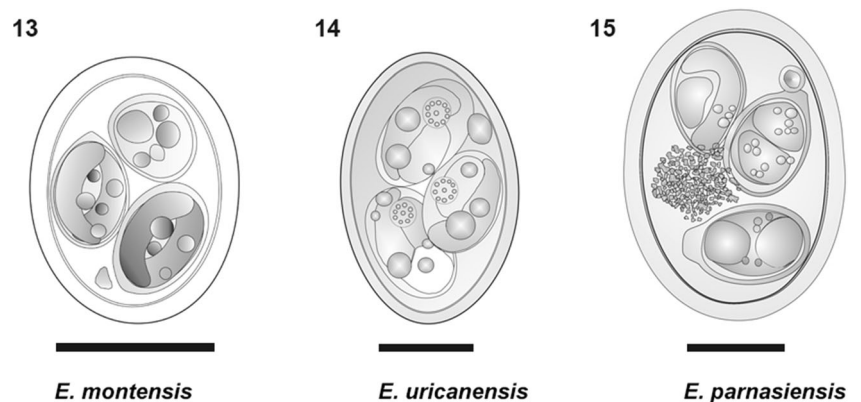


Table 1 Morphology descriptions of *Eimeria* spp. recorded in *Akodon montensis* and others Cricetidae rodents from Brazil and Venezuela. Metrical data given in micrometres as the mean followed by the range in parentheses, some publications do not provide adequate information on the measurements (not reported= NR).

Host	<i>Eimeria</i> species	Reference/ country	Oocyst shape	Oocyst size (L/W)	Oocyst wall thickness	Oocyst shape index	Polar granule	Sporocyst size (L/W)	Stieda body/ Sub-Stieda body
<i>Akodon montensis</i>	<i>E. montensis</i>	Present study/Brazil	Spheroidal to ellipsoidal	16.3 × 12.5 (14.9–17.4 × 13.3–15.4)	Bilayered 1.2 (1.0–1.4)	1.3 (1.0–1.4)	Present	7.2 × 5.1 (6.1–7.8 × 4.3–5.7)	Present/Absent
*	<i>E. uricanensis</i>	Present study/Brazil	Ovoidal to pyriform	26.6 × 18.6 (23–30 × 17–20)	Bilayered 1.4 (1.3–1.5)	1.4 (1.3–1.6)	Present	13.3 × 8.0 (10.0–15.5 × 7.4–9.2)	Absent/Absent
*	<i>E. parnasiensis</i>	Present study/Brazil	Subspheroidal to ellipsoidal	28.2 × 21.9 (25.5–31.5 × 19.0–28.1)	Bilayered 1.8 (1.3–2.4)	1.3 (1.2–1.4)	Present	12.2 × 7.6 (10.0–13.3 × 6.3–8.5)	Present/Absent
*	<i>E. akodonensis</i>	de Santana Miglionico et al. (2018)/Brazil	Subspheroidal to ellipsoidal	25.3 × 20.2 (21.0–28.0 × 17.0–22.0)	Bilayered 1.5 (1.3–1.6)	1.3 (1.2–1.4)	Present	11.8 × 7.9 (9.3–14.4 × 6.7–9.3)	Present/Absent
<i>Akodon urichi venezuelensis</i>	<i>E. akodoni</i>	Arcay (1981)/ Venezuela	Fusiform to Ellipsoidal	27 × 18 NR	Tri-layered (1.5)	NR	Present	14 × 7 NR	Present/Absent
<i>Necomys lasiurus</i>	<i>E. zygodontomyis</i>	Lainson and Shaw (1990)/Brazil	Ellipsoidal to cylindroidal	16.5 × 12 (13.7–18.7 × 11.2–12.5)	Single layer 0.6	1.4 (1.2–1.5)	Present	8.4 × 5.5 (7.4–8.7 × 5.0–6.2)	Present/Absent
<i>Akodon montensis</i>	<i>E. zygodontomyis</i>	Present study/Brazil	Ellipsoidal to cylindroidal	18.3 × 12.5 (15.8–20.0 × 10.8–13.1)	Bilayered 0.6 (0.5–0.8)	1.4 (1.2–1.6)	Present	8.5 × 5.2 (7.7–10.7 × 4.5–6.2)	Present/Absent

Other hosts: Unknown.

Geographic distribution: *A. montensis* is distributed from the state of Rio de Janeiro to Rio Grande do Sul and the eastern state of Minas Gerais, Brazil.

Description of sporulated oocyst: Oocysts subspheroidal to ellipsoidal; wall 1.8 (1.3–2.4) thick; number of layers, 2; outer wall is lightly pitted; L × W ($n = 54$) 28.2 × 21.9 (26–32 × 19–28); L/W ratio, 1.3 (1.2–1.4); 1 PG present; M, absent; OR: present; OR characteristics: consists of a cluster of granules of varying thickness.

Description of sporocyst: Sporocysts ovoidal, tapering towards the SB, 12.2 × 7.6 (10–13 × 6–9); L/W ratio, 1.6 (1.4–1.9); SB: present; SSB, PSB: both absent; SR: present; SR characteristics: consists of an aggregate of thin granules.

Prevalence: 1 of 53 (1.9%).

Sporulation: Unknown.

Site of infection: Unknown. Oocysts from feces.

Endogenous stages: Unknown.

Cross-transmission: Not investigated.

Pathology: Unknown.

Materials deposited: Symbiotype host (Frey et al. 1992), skin and skeleton, are deposited in the National Museum in Rio de Janeiro (adult male, MNRJ # 83773). Photovouchers and oocysts preserved in 2.5% potassium dichromate solution (Williams et al. 2010) are deposited at the Zoology Museum of Universidade Federal Rural do Rio de Janeiro (accession #

MZURPTZ2018009). The Phototypes and line drawings were deposited in the Parasitology Collection of Laboratório de Biologia de Coccídios (<http://r1.ufrj.br/labicoc/index.html>) of Universidade Federal Rural do Rio de Janeiro, Seropédica, RJ, Brazil. (repository # P-80/2017).

Etymology: The specific epithet is derived from the Portuguese acronym of the study area (PARNASO: Parque Nacional da Serra dos Órgãos).

Remarks:

The oocysts and sporocysts of *E. parnasiensis* are similar in size and morphology to those of *E. akodoni* and *E. akodonensis*. However, while the oocysts of *E. akodoni* have a tri-layered wall, the wall of the oocysts of *E. parnasiensis* is bi-layered. Of all the *Eimeria* species known to parasitize cricetid rodents, *E. akodonensis* is the most similar to *E. parnasiensis*, although it has a thicker wall (1.8 vs. 1.5 in the new species), a different-shaped sporocyst residuum, and much thicker spheroidal granules (Table 1). The oocyst residuum is a large spheroidal to subspheroidal globule in *E. akodonensis*, but *E. parnasiensis* is forming a bulky aggregate of fine granules.

Discussion

In Brazil, despite the 75 genera and about 243 species of rodents described, few studies have been done on the

taxonomy of their coccidia. Carini and Pinto made the first descriptions of coccidia (Pinto 1928; Carini 1932, 1935, 1937). After a long period of neglected study, coccidian species were described in Amazonia in *Necomys lasiurus* and *Sciurus* sp. (Lainson and Shaw 1990; Lainson et al. 2005). More recently, Barreto et al. (2017) described new species of *Eimeria* from the rodents *Thrichomys fosteri* and *Clyomys laticeps* in the Pantanal biome. In this work, we describe and name three new species of coccidia, *E. montensis*, *E. uricanensis*, and *E. parnasiensis*, and provide a redescription of *E. zygodontomyis*, in the montane grass mouse *A. montensis* from the Serra dos Órgãos National Park in Rio de Janeiro state, Brazil. Our descriptions of the new species and the finding of *E. zygodontomyis* more than 2000 km south of its type locality, along with the deposited phototypes in publicly accessible museums will help others advance our understanding of the parasite fauna of this group of rodents.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All trapping procedures followed the guidelines for the capture, handling, and care of animals established by the Ethics Committee on the Use of Animals in Research of the Oswaldo Cruz Institute/Fundação Oswaldo Cruz in Rio de Janeiro, and authorized under license numbers L-049/08 and LW81/12. The capture of wild animals was authorized by the Chico Mendes Institute for Biodiversity Conservation (ICMBio), through authorization number 45839-1, in accordance with the pertinent Brazilian legislation.

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