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EIMERIA SPECIES FROM *CRYPTOTIS* SHREWS (INSECTIVORA: SORICIDAE) WITH DESCRIPTION OF A NEW SPECIES

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ABSTRACT: Fresh fecal samples from 12 shrews, 10 *Cryptotis goodwini* Jackson, 1933, and 2 *Cryptotis merriami* Thomas, 1898, were collected between December 1994 and May 1998; 11 (92%) were positive for eimeriid coccidia, including 8 of 8 *C. goodwini* and 2 of 2 *C. merriami* from Honduras and 1 of 2 *C. goodwini* from Guatemala. Two *Eimeria* species were found: 1 is consistent with the description of *Eimeria whitakeri* Upton and McAllister, 1991, and 1 is described in this study as new. Sporulated oocysts of the new species are subspheroidal, 16.8×15.7 ($14\text{--}20 \times 15\text{--}19$) μm , with a length–width (L/W) ratio of 1.1 (1.0–1.2); they lack a micropyle and oocyst residuum, but 1–2 polar granules are always present. Sporocysts are elongate and ovoidal, 8.4×6.0 ($6\text{--}10 \times 4.5\text{--}7.5$) μm , with a L/W ratio of 1.4 (1.2–1.7) and have a Stieda body and sporocyst residuum. This is the 49th *Eimeria* species described from all Insectivora but only the third from *Cryptotis* species.

The Insectivora is a medium-sized order (7 families, 66 genera, ~428 species) of eutherian mammals that range from the size of a baby mouse to that of a small rabbit (Yates, 1984; Nowak, 1991; Hutterer, 1993). These animals are characterized by a long narrow snout, primitive rooted teeth, small ears, and tiny eyes that sometimes lack external openings. Many are fossorial or semifossorial, and invertebrates constitute the bulk of the diet of most species, although some are known to eat small vertebrates, eggs of ground-nesting birds, fruits, nuts, and fungi. Recently, Duszynski and Upton (2000) summarized the world literature on the coccidia known from this mammalian order and identified and described the 48 valid *Eimeria* species. In collaboration with Mastozoología en el Núcleo de Centroamérica, a Central American network of field biologists in Belize, Guatemala, Honduras, and the United States, we had the opportunity to examine the feces of 2 rarely caught shrews (*Cryptotis goodwini* and *Cryptotis merriami*). In this study, we report the results of our observations on the coccidia found in these unique animals.

MATERIALS AND METHODS

Shrews were captured in plastic pitfalls, snap traps, and Sherman live traps. Further details of shrews and localities were reported by T. J. McCarthy et al. (pers. comm.). Fecal samples from all shrews were collected between December 1994 and May 1998 in Guatemala and Honduras. Feces were taken directly from the lower intestine and were placed in vials containing 2% (w/v) aqueous potassium dichromate ($\text{K}_2\text{Cr}_2\text{O}_7$) solution, mixed thoroughly, and stored at ambient temperature for ~2–3 mo until they were received at the University of New Mexico (UNM) in the United States. On receipt at UNM, the samples were processed as detailed by Duszynski and Wilber (1997) and screened for coccidia. Oocysts were measured and photographed using both bright field and Nomarski differential interference contrast microscopy. Standardized abbreviations for oocyst–sporocyst structures are those used by Wilber et al. (1998)—oocyst characters: length (L), width (W), their ranges and ratio (L/W), micropyle (M), residuum (OR), polar granules (PG); sporocyst characters: length (L), width (W), their ranges and ratio (L/W), Stieda body (SB), substieda body (SSB), parastieda body (PSB), residuum (SR), sporozoites (SP), refractile bodies (RB), and nucleus (N) in SP. All measurements are given in micrometers (μm) with size ranges in parentheses following the means.

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RESULTS

Of the 12 shrews examined for coccidia, 11 (92%) had eimerian oocysts in their feces, including 8 of 8 *C. goodwini* and 2 of 2 *C. merriami* from Honduras and 1 of 2 *C. goodwini* from Guatemala (Table I).

Eimeria whitakeri Upton and McAllister, 1991

Description of sporulated oocyst: Oocyst shape, subspheroidal; number of walls, 2; wall thickness, 1.5–2.0; wall characteristics, outer, lightly sculptured or rough and brownish, inner, darker, ~1/4 of the total thickness; $L \times W$ ($n = 71$), 17.0×15.5 ($15\text{--}20 \times 14\text{--}17$); L/W ratio, 1.1 (1.0–1.3); M and OR, absent; PGs, present, large. Distinctive features of oocyst, thick wall and large PG.

Description of sporocyst and sporozoites: Sporocyst shape, ovoidal; $L \times W$, 9.0×6.0 ($7\text{--}11 \times 4.5\text{--}7.5$); L/W ratio, 1.5 (1.2–1.8); SB, present; SSB, present, twice as wide as SB; PSB, absent; SR, present; SR characteristics, a cluster of medium-sized globules lying in the center between SP or to 1 side of sporocyst against wall; SP, lie head to tail and have a large RB located at their rounded end. Distinctive features of sporocyst, none.

Taxonomic summary

Type host: *Cryptotis parva parva* (Say, 1823), least shrew.

Other hosts: *Cryptotis goodwini* Jackson, 1933.

Type locality: Johnson County, Texas, North America.

Geographic distribution: Texas, North America; Parque Nacional de Celaque, Departamento de Lempira, Honduras, Central America, 2,075 m ($14^{\circ}33'N$, $88^{\circ}40'W$).

Prevalence: In 2 of 19 (10.5%, original description) and 4 of 8 (50%, this study) *C. goodwini* from Honduras and 1 of 2 *C. goodwini* from Guatemala; it was absent in both *C. merriami* from Honduras.

Sporulation: Exogenous (Upton and McAllister, 1991).

Prepatent and patent periods: Unknown.

Site of infection: Unknown. Oocysts recovered from feces.

Material deposited: Symbiotype host is deposited in the Section of Mammals, Carnegie Museum of Natural History, Pittsburgh, Pennsylvania (CM 112878). Photosyntypes (oocysts in 10% neutral buffered formalin) are deposited in the U.S. National Parasite Collection (USNPC), Beltsville, Maryland, No. 81476 (Upton and McAllister, 1991).

TABLE I. Shrews (*Cryptotis goodwini*, and *Cryptotis merriami*) collected from various localities in Honduras and Guatemala, examined for coccidia, and found to be infected with *Eimera whitakeri* (*E.w*), *Eimera hondurensis* (*E.h*), or both species.

Country/shrew spp.	Departamento	Date collected	No. infected/ no. collected (%)	No. infected with 1 species	No. infected with both species
Honduras					
<i>C. goodwini</i>	Cortes	December 1994	2/2 (100)	2/2 (<i>E.h</i>)	NA*
	Lempira	February 1998	6/6 (100)	5/6 (2 <i>E.h</i> , 3 <i>E.w</i>)	1/6
<i>C. merriami</i>	Cortes	December 1994	1/1 (100)	1/1 (<i>E.h</i>)	NA
	Lempira	February 1998	1/1 (100)	1/1 (<i>E.h</i>)	NA
Guatemala					
<i>C. goodwini</i>	Zacapa	April 1998	1/1 (100)	NA	1/1
	El Progreso	May 1998	0/1	NA	NA
2 Countries/2 species	4 Departments		11/12 (92)	9/11 Singly infected	2/11 Multiply infected

* NA = not applicable.

Remarks

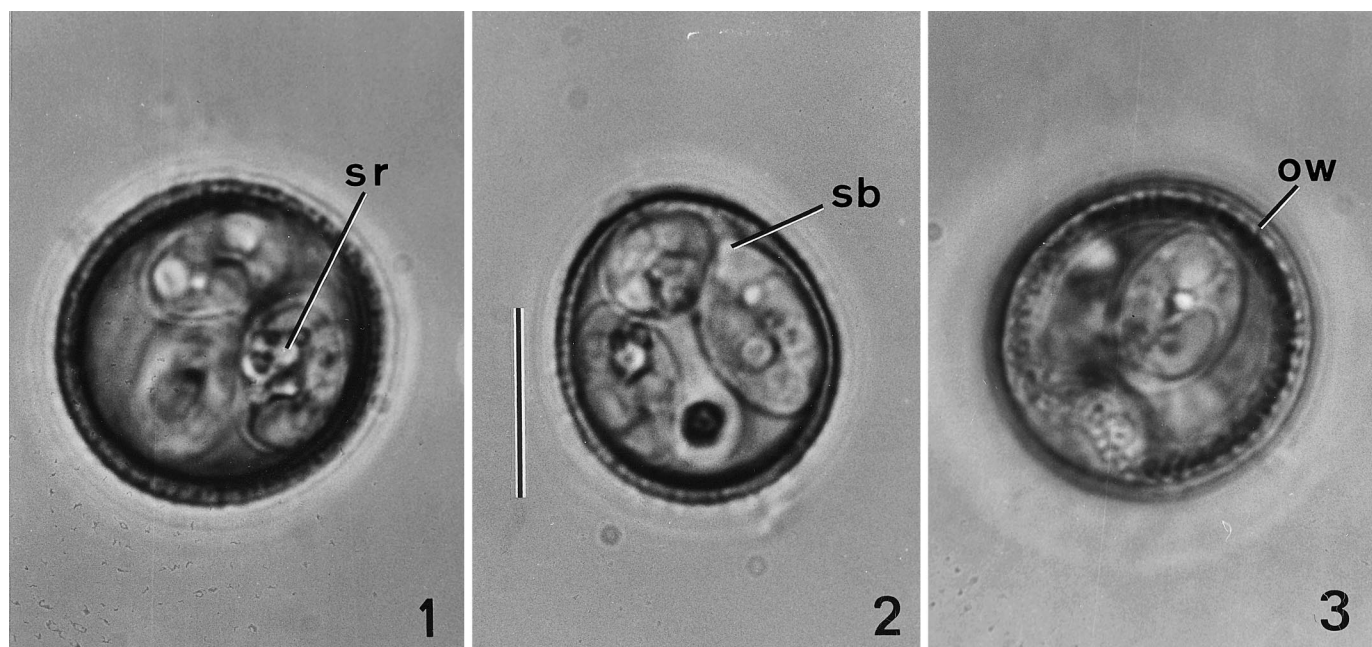
This species was first described by Upton and McAllister (1991), who found it in only 2 of 19 (10.5%) *C. parva parva* they collected from 4 counties in north-central Texas. The oocysts they measured were 17.4×16.4 ($15-19 \times 13-18.5$) with a L/W ratio of 1.1 (1.0–1.2), which are nearly identical in size to those observed by us. However, their sporocysts measured 11.2×7.5 ($9.5-12 \times 6.5-8$), with a L/W ratio of 1.5 (1.4–1.6), whereas the sporocysts in *C. goodwini* from Honduras were slightly smaller, 9.0×6.0 ($7-11 \times 4.5-7.5$), but their L/W ratio was the same, i.e., 1.5. All other qualitative features were identical between the oocysts studied by Upton and McAllister (1991) and those studied by us.

Eimeria hondurensis n. sp.

(Figs. 1–4)

Description of sporulated oocyst: Oocyst shape, spheroidal to subspheroidal; number of walls, 2; wall thickness, 1.2–2.0 (1.5); wall characteristics, outer, lightly pitted or sculptured giving a strongly striated appearance in optical cross section, inner, darker, only $\sim 1/4$ of total thickness; L \times W (n = 59), 16.8×15.7 ($14-20 \times 13-19$); L/W ratio, 1.1 (1.0–1.2); M and OR, absent; PGs, 1–2. Distinctive features of oocyst, strongly striated appearance of outer wall.

Description of sporocyst and sporozoites: Sporocyst shape, ovoidal; L \times W, 8.4×6.0 ($6-10 \times 4.5-7.5$); L/W ratio, 1.4 (1.2–1.8); SB, nipplelike, present at pointed end; SSB, absent;



FIGURES 1–3. Photomicrographs of sporulated oocysts of *Eimeria hondurensis* from *Cryptotis goodwini* collected in Honduras. Bar = 10 μ m. Note: Shape of oocyst and sporocyst and strongly striated oocyst wall; presence of a Stieda body and sporocyst residuum but absence of substieda body. Abbreviations: sb, Stieda body; sr, sporocyst residuum; ow, oocyst wall (striated).

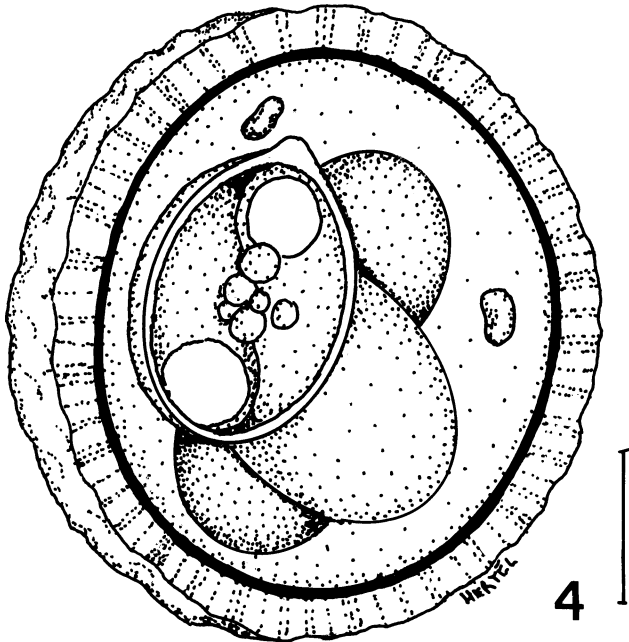


FIGURE 4. Line drawing of sporulated oocyst of *Eimeria hondurensis*. Bar = 4 μm .

PSB, absent; SR, present; SR characteristics, a cluster of a few small and large globules lying in the center of sporocyst between SP or against sporocyst wall; SP, lie head to tail and have a posterior RB that varies in size. Distinctive features of sporocyst, nipplelike SB.

Taxonomic summary

Type host: *Cryptotis goodwini* Jackson, 1933.

Other hosts: *Cryptotis merriami* Thomas, 1898.

Type locality: Campamento Don Tomás, Parque Nacional Celaque, Departamento de Lempira, Honduras, Central America, 2,075 m (14°33'N, 88°40'W).

Other localities: Parque Nacional de Cusuco, Departamento de Cortes, Honduras, Central America; Reserva Biosfera de la "Sierra de las Minas," Departamento de Zacapa, Guatemala.

Geographic distribution: Guatemala, Honduras, Central America.

Prevalence: In 6 of 8 (75%) *C. goodwini* from Honduras, 1 of 2 (50%) *C. goodwini* from Guatemala, and 2 of 2 (100%) *C. merriami* from Honduras.

Sporulation: Probably exogenous. Oocyst–fecal suspensions were kept in vials of 2% (w/v) aqueous $\text{K}_2\text{Cr}_2\text{O}_7$ solution for 2 mo at ~ 24 C before discovery and measurement.

Prepatent and patent periods: Unknown.

Site of infection: Unknown. Oocysts recovered from feces.

Material deposited: Symbiotype host deposited in the Section of Mammals, Carnegie Museum of Natural History, Pittsburgh, Pennsylvania (CM 112880). Photosyntypes of sporulated oocysts deposited in the USNPC, Beltsville, Maryland, No. 092569.00 (document 399).

Etymology: The nomen triviale is derived from the country and the Latin word *ensis* (belonging to).

Remarks

To date, there are only 2 other eimerians described from *Cryptotis*: *Eimeria cryptotis* McAllister and Upton, 1989, and *E. whitakeri*, described and discussed above. They are very similar in both mensural and qualitative features, and both are remarkably similar in the size of their sporulated oocysts (16.4×15.3 [14–18 \times 13–17] and 17.4×16.4 [15–19 \times 13–18.5], respectively) to those of *E. hondurensis* (16.8×15.7 [14–20 \times 13–19]). Also, all 3 have identical L/W ratios of 1.1 and thick oocyst walls. However, the sporocysts of the other 2 described species are both larger (10.6×7.0 [9–11 \times 6–8] and 11.2×7.5 [9.5–12 \times 6.5–8], respectively) than those of *E. hondurensis* (8.4×6.0 [6–10 \times 4.5–7.5]), and *E. hondurensis* lacks a SSB, which the other 2 species possess.

DISCUSSION

There are now 49 valid species of *Eimeria* described from insectivores, but this must be only a small fraction of the species that actually parasitize potential hosts in this order. For example, of the 428 extant insectivore species on earth, only 38 species (8.9%) have ever been examined for coccidia. In their seminal work on the coccidia of insectivores, Duszynski and Upton (2000) listed 75 valid eimeriid coccidia known to infect members of this host order including 48 *Eimeria*, 22 *Isospora*, and 5 *Cyclospora* species; on the basis of calculations from all insectivore species and their known coccidia, they estimated that there may be 1,200 coccidia species yet to be discovered!

Unfortunately, with so little known about these parasites at this time, few generalizations can be made. From the limited information provided in the summary by Duszynski and Upton (2000), it appears that insectivore coccidia species can be shared between members of the same genus but not between genera within the same family. Thus, it is not unexpected that *E. whitakeri* could be found in both *C. parva* in Texas and in *C. goodwini* in Honduras; likewise, it is not surprising to find *E. hondurensis* in *C. goodwini* from Guatemala and Honduras and in *C. merriami* from Honduras.

We note that all 3 *Eimeria* species described to date from *Cryptotis* species lack an oocyst residuum, but all possess sporocysts with Stieda bodies. These 2 morphologic structures are of interest because, recently, it has been shown that their presence or absence may be associated with different genetic lineages of coccidia (Barta et al., 1997; Zhao and Duszynski, 2001). Thus, these 3 eimerians may be genetically closely related.

Clearly, there is still much work to be done with the coccidia of not only shrews but also all other insectivores. Because oocysts can be collected easily in the field and represent the stage most used to date for the identification of coccidia, mammalogists, wildlife biologists, and all others who work with vertebrates can play a pivotal role in our understanding of the coccidia from their particular host group by properly collecting fecal samples to preserve oocysts (as outlined by Duszynski and Wilber, 1997).

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