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THREE NEW COCCIDIA (APICOMPLEXA) FROM THE HOOD ISLAND LIZARD, *TROPIDURUS DELANONIS*, FROM THE GALÁPAGOS ARCHIPELAGO

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ABSTRACT: Fecal samples of 14 *Conolophus subcristatus* from Isla Plaza Sur and of 24 *Tropidurus delanonis* from Isla Española and several satellite islets, Galápagos Islands, Ecuador, collected during June and July 1987 were examined for coccidian oocysts. None of the samples from *C. subcristatus* contained oocysts, but 11 of 24 (46%) samples from *T. delanonis* had oocysts when examined. Two *Eimeria* and 1 *Isospora* spp. were present, which we describe here as new species. Sporulated oocysts of *Eimeria tropidura* n. sp. are ellipsoidal, 32.5×23.8 ($21\text{--}38 \times 19\text{--}30$) μm , with spheroidal to subspheroidal sporocysts, 8.2×7.9 ($7\text{--}10 \times 5\text{--}10$) μm . Sporulated oocysts of *Eimeria galapagoensis* n. sp. are cylindroidal, 32.8×14.0 ($27\text{--}36 \times 12\text{--}17$) μm , with spheroidal sporocysts 7.5 (7.5) μm . Sporulated oocysts of *Isospora insularius* n. sp. are spheroidal to subspheroidal, 24.5×22.3 ($19\text{--}30 \times 18\text{--}27$) μm , with lemon-shaped sporocysts, 16.6×9.3 ($9\text{--}17 \times 7\text{--}13$) μm . Each of the 11 positive fecal samples had oocysts of only 1 coccidian species, i.e., the different coccidian species did not share individual hosts.

During June and July 1987, we had the opportunity to collect fresh fecal samples from 2 species of Galápagos lizards, *Conolophus subcristatus* and *Tropidurus delanonis*. A number of the *T. delanonis* examined were passing coccidian oocysts that, upon closer study, represented 3 species, an isosporan and 2 eimerians that we describe here as new.

MATERIALS AND METHODS

During June 1987, we collected fresh fecal samples from 14 *C. subcristatus* from Isla Plaza Sur, and during July 1987, fresh samples were taken from 24 *T. delanonis* from Isla Española (5), Isla Gardner por Española (8), Isote Osborn (7), and an unnamed islet (4) in Gardner Bay, the Galápagos Islands, Ecuador. All hosts were live-captured and fecal samples collected were placed in 2% (w/v) aqueous potassium dichromate ($\text{K}_2\text{Cr}_2\text{O}_7$) and kept at ambient temperature. Once the samples were brought to Albuquerque in late July 1987, we followed the procedures outlined by Aquino-Shuster and Duszynski (1989) for storing, processing, measuring, and photographing oocysts. All measurements are in μm with ranges in parentheses following the means.

As the Galápagos Islands constitute a national park, it was not possible to keep the hosts; thus, after collecting feces from hosts, each was released.

RESULTS

None of the fecal samples taken from 14 *C. subcristatus* had oocysts in them. Of the samples

taken from *T. delanonis*, 11 of 24 (46%) had coccidian oocysts representing 3 species that we describe below as new. The different coccidian species did not share individual hosts, i.e., each of the 11 infected fecal samples had oocysts of only 1 coccidian species when examined.

Eimeria tropidura n. sp.

(Figs. 1–3, 10)

Description

Oocyst ellipsoidal, wall ~ 2.0 , composed of 2 or 3 layers, that appear colorless under transmitted light; micropyle, oocyst residuum, and polar granule absent; sporulated oocysts ($n = 54$) 32.5×23.8 ($21\text{--}38 \times 19\text{--}30$) with L:W ratio 1.4 (1.0–1.6); sporocysts ($n = 54$) spheroidal to subspheroidal, 8.1×7.9 ($7\text{--}10 \times 5\text{--}10$) with L:W ratio 1.05 (1.0–1.5); Stieda, sub- and parastieda bodies absent; sporocyst residuum a compact mass $\sim 4.5\text{--}5.0$; sporozoites with a spheroidal posterior refractile body $\sim 2\text{--}3$.

Taxonomic summary

Type host: *Tropidurus delanonis* Baur, 1890 (Reptilia, Iguanidae).

Type locality: Isote Osborn, Galápagos, Ecuador.

Prevalence: Found in 9 of 24 (38%) *T. delanonis* including 6 of 7 (86%) from Isote Osborn and 3 of 4 (75%) from East Islet.

Site of infection: Unknown, oocysts collected from feces.

Material deposited: Syntypes (=phototypes, see Bandoni and Duszynski, 1988) of sporulated oocysts in the U.S. National Museum, Beltsville, Maryland, Parasite Collection (USNMPC) no. 80919.

Etymology: The nomen triviale is derived from the generic name of the host.

Remarks

Of the 53 eimerian species previously described from all lizards and geckos (see Discussion), sporulated

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FIGURES 1-9. Photomicrographs of sporulated oocysts of coccidia collected from the feces of *Tropidura delanonis*. $\times 1,200$. 1-3. *Eimeria tropidura* n. sp. Note multiple layers of oocyst wall, nearly spheroidal shape of sporocysts without Stieda or substieda bodies, and granular sporocyst residuum. 4-6. *Eimeria galapagoensis* sp. n. Note spheroidal shape of sporocysts without Stieda or substieda bodies and the sporocyst residuum of large refractile granules. 7-9. *Isospora insularius* sp. n. Note distinct Stieda body and substieda body (arrows).

oocysts of *E. tropidura* are similar in size and/or shape to those of only 5 other species: *Eimeria ahtanumensis* Clark, 1970, from *Sceloporus occidentalis* from Washington, U.S.A.; *Eimeria hispidi* Bastardo de San Jose, 1974, from *Tropidurus hispidus* from Venezuela; *Eimeria molochis* Bovee and Telford, 1965, from *Moloch horridus* from Australia; *Eimeria noctisauris* Bovee and Telford, 1965, from *Klauberina riversiana* from California, U.S.A.; and *Eimeria umis* Bovee, 1969, from *Uma notata* from California, U.S.A. They differ from those of *E. ahtanumensis* by having oocysts with a smaller L/W ratio (1.4 vs. 1.7) and 2–3 obvious wall layers (vs. 1) that combined are thicker (2 vs. 1) and by having nearly spheroidal (8.1 × 7.9) vs. ellipsoidal sporocysts (11 × 9). They differ from those of *E. hispidi* by being larger (33 × 24 vs. 28 × 26) with a larger L/W ratio (1.4 vs. 1.1) and by having nearly spheroidal sporocysts vs. those that are ellipsoidal (11 × 9). They differ from those of *E. molochis* by having a thicker oocyst wall with 2–3 layers (vs. 1) and by having spheroidal (vs. ovoidal) sporocysts that are smaller with a different L/W ratio (1.05 vs. 1.3). They differ from those of *E. noctisauris* by being smaller with a smaller L/W ratio (1.4 vs. 1.7) and a thicker wall (2.0 vs. 1.3) and by having smaller sporocysts with a different L/W ratio (1.05 vs. 1.4). Finally, they differ from those of *E. umis* by being less cylindroidal with a smaller L/W ratio (1.4 vs. 1.9) and a thicker wall (2 vs. 1).

***Eimeria galapagoensis* n. sp.**
(Figs. 4–6, 11)

Description

Oocyst cylindroidal, wall ~2.0, with 2 colorless layers; micropyle, oocyst residuum, and polar granule absent; sporulated oocysts (n = 50) 32.8 × 14.0 (27–36 × 12–17) with L:W ratio 2.4 (1.9–2.7); sporocysts (n = 50) spheroidal, 7.5, with L:W ratio 1.0; Stieda, sub- and parastieda bodies absent; sporocyst residuum an irregular mass of highly refractile granules, ~3.0.

Taxonomic summary

Type host: *Tropidurus delanonis* Baur, 1890 (Reptilia, Iguanidae).

Type locality: Isla Gardner por Española, Galápagos, Ecuador.

Prevalence: Found in 1 of 8 (12%) *T. delanonis* from Isla Gardner por Española and 1 of 24 (4%) of all *T. delanonis* sampled.

Site of infection: Unknown, oocysts collected from feces.

Material deposited: Syntypes (=phototypes) of sporulated oocysts, USNMPC no. 80920.

Etymology: The nomen triviale is derived from the name of the island group from which the hosts were collected and *-ensis* (L., belonging to).

Remarks

Only 8 eimerian species of the 53 described to date from lizards and geckos have sporulated oocysts with a L/W ratio greater than 2.0: *Eimeria basilisci* Duszynski, 1969 (2.1); *Eimeria delalandii* Matuschka and Bannert, 1986 (2.1); *Eimeria japaluri* Bovee, 1971 (2.3); *Eimeria japonicus* Bovee, 1971 (2.1); *Eimeria koidzumii* Matubayasi, 1941 (2.1); *Eimeria pellopleuris* Bovee, 1971 (2.2); *Eimeria subcylindrica* Arcay-de-

Peraza and Bastardo de San Jose, 1970 (2.2); and *Eimeria turcicus* Upton, McAllister, and Freed, 1988 (2.1). However, only *E. subcylindrica*, found in the gall bladder of *Ameiva ameiva* from Venezuela (Arcay-de-Peraza and Bastardo de San Jose, 1970), has spheroidal sporocysts. *Eimeria galapagoensis* differs from *E. subcylindrica* by being considerably smaller (33 × 14 vs. 41 × 19) and having smaller sporocysts (7.5 vs. 10.8).

***Isospora insularius* n. sp.**
(Figs. 7–9, 12)

Description

Oocyst spheroidal to subspheroidal, wall 2.0, composed of 2 colorless layers; micropyle and oocyst residuum are absent, but highly refractile polar body is present; sporulated oocysts (n = 50) 24.5 × 22.3 (19–30 × 18–27) with L:W ratio 1.1 (1.0–1.3); sporocysts (n = 50) ovoidal (lemon-shaped), 12.6 × 9.3 (9–17 × 7–13), with L:W ratio 1.3 (1.1–1.8); Stieda and substieda bodies present with substieda body 2× wider than Stieda body, but parastieda body absent; sporocyst residuum a compact mass, ~5.3.

Taxonomic summary

Type host: *Tropidurus delanonis* Baur, 1890 (Reptilia, Iguanidae).

Type locality: Isla Española, Galápagos, Ecuador.

Prevalence: Found in 1 of 5 (20%) *T. delanonis* from Isla Española and 1 of 24 (4%) of all *T. delanonis* sampled.

Site of infection: Unknown, oocysts collected from feces.

Material deposited: Syntypes (=phototypes) of sporulated oocysts, USNMPC no. 80921.

Etymology: The nomen triviale combines *insula* (L., an island) and *-arius* (L., denotes belonging to), emphasizing the habitat of the host.

Remarks

Looking at the 32 named and unnamed isosporan species described from all saurian hosts worldwide (see Discussion) we are struck by the remarkable similarity between sporulated oocysts of many of the species, especially when only oocyst and sporocyst shapes and length/width dimensions are considered. For example, oocysts and sporocysts of *I. insularius* resemble those of at least 12 other described species in general size and shape: *Isospora ablephari* Cannon, 1967; *Isospora amphiboluri* Cannon, 1967; *Isospora caryophila* Rogier and Colley, 1976; *Isospora gymniodactyli* Ovezmukhammedov, 1972; *Isospora hemidactyli* Carini, 1936; *Isospora manchacensis* Atkinson and Ayala, 1987; *Isospora phrynocephali* Ovezmukhammedov, 1971; *Isospora* sp. Cannon, 1967; *Isospora tarentolae* Matuschka and Bannert, 1986; *Isospora thavari* Else and Colley, 1975; *Isospora varani* Yakimoff, 1938; and *Isospora viridanee* Matuschka, 1989.

Only by looking at the original papers describing these 12 species can we confidently eliminate 5 of them (*I. gymniodactyli*, *I. hemidactyli*, *I. phrynocephali*, *I. thavari*, *I. varani*) because they all have sporocysts that lack a substieda body and most have other qualitative features (e.g., consistent absence of a polar body) or quantitative differences (e.g., a thin, single-layered

FIGURES 10–12. Line drawings of sporulated oocysts of coccidia collected from feces of *Tropidura delanonis*. Bar = 10 μ m. 10. *Eimeria tropidura*. 11. *Eimeria galapagoensis*. 12. *Isospora insularius*.

oocyst wall). Separating oocysts of *I. insularius* from the other 7 species noted above is not so easy.

Both *I. ablephari* and *I. amphiboluri* described, respectively, from *Ablepharus boutonii* and *Amphibolurus barbatus* in Australia by Cannon (1967), have sporocysts with a thickening at the pointed end (presumably a Stieda body) "surmounting a large refractile globule." We interpret this latter structure to be a substieda body, but it is not possible to conclude from his illustration that this is what he meant. Both species also lack polar bodies. Otherwise, the oocyst wall structure, size and shape of the oocysts and sporocysts, and presence or absence of structures such as residua are identical to those of *I. insularius* oocysts. Only the hosts and continents on which the hosts are found are different.

Oocysts and sporocysts of *I. caryophila* described from *Gonyocephala grandis* from Kuala Lumpur, Malaysia (Rogier and Colley, 1976) are identical in size and shape to those of *I. insularius*. Although a substieda body is not mentioned in the description, the drawing by Rogier and Colley (1976) shows that one is present, as is a polar body; unfortunately, there is no published photomicrograph to confirm their drawing. The only structural difference is that the oocyst wall of *I. caryophila* is described as simple (the drawing shows only 1 layer), yellowish, and 0.6 "thick."

Oocysts of *I. manchacensis* from the Louisiana ground skink, *Scincella lateralis*, are identical to those of *I. insularius*, except that they appear to have only 1 oocyst wall layer and they lack a polar body (Atkinson and Ayala, 1987).

Cannon (1967) also measured a few oocysts from *Phyllurus cornutus*, a rain forest gecko from Queensland, Australia, and said they were similar to those of *I. ablephari* (and, therefore, similar to those of *I. insularius*), but he did not name or describe these oocysts further.

Measurements, photomicrographs, and all qualitative features of *I. tarentolae* oocysts described from the

gecko *Tarentola delalandis* from Tenerife in the Canary Islands (Matuschka and Bannert, 1986a) are identical to those of *I. insularius* except that *I. tarentolae* oocysts are described as lacking a polar body and having a bilayered oocyst wall ~ 1.0 , whereas the oocyst wall of *I. insularius* is bilayered, but clearly thicker, ~ 2.0 .

Finally, oocysts of *I. viridanuae*, recently described from the skink, *Chalcides viridanus*, also from Tenerife (Matuschka, 1989), are spheroidal, 22 (18–32), and lack a polar body, but otherwise they are indistinguishable from those of *I. insularius*. Although Matuschka (1989) did not state the thickness of the oocyst wall or its number of layers, his photomicrographs show an oocyst wall identical to that of *I. insularius*.

Given that we know of no isosporan or eimerian from lizards that has ever been shown to cross generic boundaries (although no one has tested this), let alone continents, we name the isosporan described here from *T. delanonis* as a new species.

DISCUSSION

As best we can determine, there are about 53 named eimerian species described from saurians including 14 listed by Matuschka and Bannert (1986b), 30 by Matuschka and Bannert (1987), and 1 each by Arcay-de-Peraza and Bastardo de San Jose (1970), Bastardo de San Jose (1974), Borst et al. (1975), Levine (1988), Matuschka and Bannert (1986a), Upton and Barnard (1987), McAllister et al. (1988, 1990), and Upton et al. (1988). In addition, there are also 32 named and 3 unnamed isosporan species described, to date, from lizards (Upton et al., 1988; Amoudi, 1989; Matuschka, 1989). Of interest in this study and to others who will examine lizards for coccidians

is that the eimerians from these hosts produce oocysts that are quite distinctive structurally, whereas sporulated oocysts of many isosporans described from unrelated host species worldwide are virtually indistinguishable.

The strong similarity of these sporulated isosporan oocysts creates a nightmare for taxonomists, especially because no phototypes of oocysts are available for comparative purposes (see Bandoni and Duszynski, 1988). On the other hand, the patterns of oocyst structure seen, highly distinctive eimerian oocysts vs. highly similar isosporan oocysts, may present an interesting comparison about the relative rates of evolution of oocyst structure in these 2 genera of common lizard parasites. It would seem that oocyst structure may be evolving more rapidly in eimerians than in isosporans found in lizards. In both, however, the evolution of structural traits may be considered conservative when compared to the evolution of host specificity (see Barker et al., 1989).

The fact that coccidians are relatively prevalent in *T. delanonis* (46%), but are absent from *C. subcristatus* in the same archipelago, needs further study. Although these 2 host species are never sympatric in the Galápagos, other *Tropidurus* species do occur with *C. subcristatus*; unfortunately, there are no data available on the coccidian parasites of these other species.

It may be possible to compare some gross aspects of the physiological ecology of *Conolophus* and *Tropidurus* to help explain their differences in susceptibility, but the data that are available are not informative. The body temperatures of the 2 lizard species are apparently equal (Stebbins et al., 1967; Werner, 1977; Snell and Christian, 1985; Snell et al., 1988). Therefore, the thermal environment provided by these potential hosts to coccidians is not different enough to explain their apparent variations in susceptibility.

The 2 lizard species differ somewhat in diet, with *C. subcristatus* being almost exclusively herbivorous (Snell and Tracy, 1985), whereas the level of herbivory in *T. delanonis* depends upon size (and age), with juveniles being less herbivorous than large adults (Werner, 1977; Schluter, 1984). Contaminated vegetation can be imagined to play an important role in the transmission of coccidian oocysts, but given the known dietary patterns of the 2 species, it might be predicted that *C. subcristatus* should be more likely

to harbor coccidians, which we did not find to be the case.

One important difference between these species of lizards that may contribute to the infection patterns seen is their respective population densities. *Tropidurus delanonis* on Isla Española average 154.8 individuals per hectare (Werner, 1977), whereas *C. subcristatus* on Isla Plaza Sur average only 55.4 per hectare (Snell and Christian, 1985). The greater density of *T. delanonis* certainly could contribute to the maintenance of a higher infection rate for parasites with 1-host life cycles.

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