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ABSTRACT: From 1990 through 1994, fecal samples were collected and examined for coccidian parasites from 26 giant land tortoises Geochelone nigra, from 715 lava lizards Tropidurus spp., from 139 land iguanas Conolophus subcristatus, and from 128 marine iguanas Amblyrhynchus cristatus, all of which inhabit various islands in the Galápagos Archipelago. None of the samples from A. cristatus or from C. subcristatus was infected with coccidia. Only 1 of 26 (4%) G. nigra was infected with a single Eimeria species that we describe here as new. A total of 262 of 715 (37%) individuals representing 3 species of Tropidurus discharged oocysts of 1-3 different coccidian species; these included 2 previously described species Eimeria tropidura and Isospora insularius, and an eimerian that we describe here as new. Additionally, 104 fecal samples from Tropidurus spp. were from 31 animals recaptured in either 2 or 3 yr; 21 had no infections in any year, 15 were infected at least once, 14 were infected in 2 yr, and only 1 was infected during 3 yr. No animal was recaptured and sampled during each of the 4 yr of this study. Of the 262 infected individuals, 30 (12%) had multiple coccidial infections at the time of collection (eimerian and isosporan, or 2 eimerians). Where determination of the sexes was possible in the lava lizards, there was no difference in prevalence rates between males (39%) and females (41%). Sporulated oocysts of the new eimerian from Tropidurus are ellipsoidal, 27.1 ± 15.6 (25-31 × 14-18) μm, with a polar body, but without a microple or oocyst residuum; they contain ellipsoidal sporocysts, 11.8 ± 6.7 (10-14 × 6-8) μm, without Stieda, sub-, or parastieda bodies, but with a sporocyst residuum. Sporulated oocysts of the new eimerian from G. nigra are ellipsoidal to ovoidal, 21.6 ± 18.1 (18-25 × 16-20) μm, with a large polar body, but without a microple or oocyst residuum; they contain ellipsoidal sporocysts 10.7 ± 7.0 (8-12 × 5-8) μm, with Stieda body but no sub- or parastieda bodies. Also present is a sporocyst residuum of medium to large granules randomly distributed among the sporocysts.

MATERIALS AND METHODS

Between 1990 and 1994, fecal samples were collected from 715 lava lizards representing 3 species of live-caught Tropidurus (T. delanoinis, T. albemarleinsis, and T. xivittatus) from 18 islands, from 139 land iguanas (C. subcristatus) from 3 islands, from 26 giant land tortoises (G. nigra, 4 subspecies) located at the Charles Darwin Research Station on Isla Santa Cruz, and from 128 marine iguanas (A. cristatus) from 6 islands of the Galápagos Archipelago. Samples were collected opportunistically using noninvasive techniques and most samples were collected during the morning. The lava lizard samples were obtained from coastal study areas on each island; 1990-1993 samples were collected between May and August and 1994 samples were collected between January and April. Most of the marine iguanas (4 of 6 populations) and land iguanas (2 of 3 populations) were obtained by sampling from the entire population of a given island; samples from the remaining populations were obtained from coastal study areas in the mornings between May and August. The tortoise samples came from captive animals, all of which were housed in outdoor pens at the Charles Darwin Research Station on Isla Santa Cruz; these samples were collected in the mornings of August 1991. Samples were placed in separate vials containing 2% (w/v) aqueous potassium dichromate (K₂Cr₂O₇), mixed thoroughly, and stored at ambient temperature. Upon arrival in Albuquerque, the samples were processed using the procedure outlined by Duszynski et al. (1982), and oocysts were measured and photographed between 60- and 800-days-old, and stored at 4°C. All measurements are given in μm with size ranges in parentheses following the means. In addition, when it was possible, the sex of each animal was determined to see if prevalence differed by gender. Finally, because all of the hosts are protected species and are part of the Galápagos National Park system, they were released once fecal samples were collected.

RESULTS

Of 715 Tropidurus samples collected, 262 (37%) were infected; 3 different coccidians were found representing 2 species of eimerian and 1 species of isosporan (Table 1). Only 1 fecal sample from the other 3 reptile species examined was infected; of 26 samples from G. nigra, 1 contained a previously undescribed eimerian and no coccidian oocysts were found in 139 fecal samples from C. subcristatus or in 128 samples from A. cristatus.
Of the 262 positive *Tropidurus* samples, 30 (11%) were infected with 2 coccidian species: 17 of 184 (9%) positive *T. delanonis* samples had both *Eimeria tropidura* and *Isospora insularius* and 13 of 78 (17%) positive *T. albemarlensis* were infected with both *E. tropidura* and a new eimerian. The distributions of the 2 species of coccidia infecting *T. delanonis* were not independent of one another. Instead, there was a tendency for the 2 species of coccidia to be positively associated with one another (chi-square contingency table, $x^2 = 3.83$, $P = 0.05$, df $= 1$). This trend was not significant in *T. albemarlensis* (chi-square contingency table, $x^2 = 2.35$, $P > 0.13$, df $= 1$).

Prevalence of coccidians in *Tropidurus* varied by island, species of coccidia, and species of lizard. Between islands, prevalence varied from 0 to 75% (Table I); part of this variation is attributed to small sample size on specific islands. Across all islands, *E. tropidura* was the most prevalent coccidian, occurring in 28% of all hosts, whereas the other 2 species occurred only in 5–7% of all hosts sampled. Time of year appeared to have no effect on the prevalence of coccidia in lava lizards. Finally, different species of lava lizard were infected with different species of coccidia. For example, *I. insularius* was found only in *T. delanonis* and the new species of eimerian only in *T. albemarlensis*. Male and female lava lizards did not differ in prevalence (males $= 99/255$, 39%; females $= 89/218$, 41%, $x^2 = 0.12$, $P = 0.7$, df $= 1$).

In addition, 104 samples came from 51 animals recaptured either 2 or 3 yr. Twenty-one had no infections in any year, 15 were infected in at least 1 yr, 14 were infected in 2 yr, 1 was infected 3 yr, and no lizard was recaptured during all 4 yr. Interestingly, of the 29 infected lizards captured in 2 or 3 yr, 15/29 (52%) were infected with at least the same coccidian at their second or third capture as they were during their first capture (Table II).

Only 1 of 26 (4%) *G. nigra* was infected with a single eimerian species, but great numbers of oocysts were present in the 1 sample. Because of the large number and good structural condition of the oocysts observed, we suspect it is not a spurious infection or a pseudoparasite and have included a description of the new eimerian (also see Remarks section).

**DESCRIPTION**

*Eimeria tropidura* Aquino-Shuster, Duszynski, and Snell, 1990

Sporulated oocysts did not differ qualitatively or quantitatively from those found in *T. delanonis* samples collected prior to 1990 as described by Aquino-Shuster et al. (1990) (U.S. National Museum Parasite Collection [USNPC] no. 80919).
TABLE II. Tropidurus spp. that were recaptured 2 or more times from 1990 to 1994 and infected with 1 or more coccidian species during at least 1 capture (E. trop = E. tropidura, I. ins = I. insularius, and E. alb. = E. albemarlensis n. sp.).

<table>
<thead>
<tr>
<th>Island (sp)</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Española (T. delanonis)</td>
<td>526</td>
</tr>
<tr>
<td>1057</td>
<td>E. trop.</td>
</tr>
<tr>
<td>170</td>
<td>E. trop.</td>
</tr>
<tr>
<td>225</td>
<td>E. trop.</td>
</tr>
<tr>
<td>288</td>
<td>E. trop.</td>
</tr>
<tr>
<td>329</td>
<td>I. ins.</td>
</tr>
<tr>
<td>1131</td>
<td>I. ins.</td>
</tr>
<tr>
<td>Osborn (T. delanonis)</td>
<td>12</td>
</tr>
<tr>
<td>56</td>
<td>E. trop.</td>
</tr>
<tr>
<td>90</td>
<td>E. trop.</td>
</tr>
<tr>
<td>207</td>
<td>E. trop.</td>
</tr>
<tr>
<td>208</td>
<td>E. trop.</td>
</tr>
<tr>
<td>222</td>
<td>E. trop</td>
</tr>
<tr>
<td>263</td>
<td>E. trop.</td>
</tr>
<tr>
<td>264</td>
<td>E. trop.</td>
</tr>
<tr>
<td>269</td>
<td>E. trop.</td>
</tr>
<tr>
<td>276</td>
<td>E. trop.</td>
</tr>
<tr>
<td>328</td>
<td>E. trop.</td>
</tr>
<tr>
<td>1187</td>
<td>E. trop.</td>
</tr>
<tr>
<td>Plaza Sur (T. albemarlensis)</td>
<td>5</td>
</tr>
<tr>
<td>9</td>
<td>E. trop.</td>
</tr>
<tr>
<td>12</td>
<td>E. alb.</td>
</tr>
<tr>
<td>15</td>
<td>E. alb.</td>
</tr>
<tr>
<td>18</td>
<td>E. trop.</td>
</tr>
<tr>
<td>Xarifa (T. delanonis)</td>
<td>47</td>
</tr>
<tr>
<td>79</td>
<td>E. trop.</td>
</tr>
<tr>
<td>110</td>
<td>E. trop.</td>
</tr>
<tr>
<td>155</td>
<td>E. trop.</td>
</tr>
<tr>
<td>7005</td>
<td>E. trop.</td>
</tr>
</tbody>
</table>

Taxonomic summary

Prevalence: Found in 35 of 471 (7%) T. delanonis including 14 of 154 (9%) from Isla Española, 12 of 142 (8%) from Isla Gardner, 1 of 10 (1%) from Islote Oeste, 5 of 85 (6%) from Islote Osborn, and 3 of 80 (4%) from Islote Este.

DESCRIPTION

Eimeria albemarlensis n. sp.

(Figs. 2-6, 10)

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FIGURES 2-9. Photomicrographs of sporulated oocysts of coccidia collected from the feces of Tropidurus albemarlensis (Figs. 2-6) and Geochelone nigra (Figs. 7-9). 2-6. Eimeria albemarlensis n. sp. Note sporocyst residuum of large granules (sr) and distinct refractile polar body (pb). Also note the platelike structures produced from the collapsing of the sporocysts while the oocyst wall remains intact (arrows, 3-6). 7-9. Eimeria geochelona n. sp. Note large granular sporocyst residuum and distinct Stieda body (sb). The polar body is just visible in Figure 8. Scale bar in Figure 8 = 10 μm for all figures.

more detail using SEM or TEM. To our knowledge, this is the first time that a member of the genus Eimeria has been identified to have sporocysts with wall plates that previously were thought to be characteristic of 2-host coccidians (see discussion in Box et al. [1980]).

DESCRIPTION

Eimeria geochelona n. sp.
(Figs. 7-9, 11)

Sporulated oocysts ellipsoidal to ovoidal, wall ~1.5, composed of 2 smooth, clear layers; outer wall ~1/2 the size of inner wall; micropyle and oocyst residuum absent, but 1–2 distinct large, irregular-shaped refractile polar bodies present (Fig. 8); sporulated oocysts (n = 50) 21.6 x 18.1 (18–25 x 16–20) with length:width ratio (~SI) 1.2 (1.1–1.4); sporocysts (n = 50) ellipsoidal, 10.7 x 7.0 (8–12 x 5–8) with SI 1.5 (1.3 x 1.9); Stieda body present, but sub- and parasitidae bodies absent (Fig. 7–9); sporocyst residuum of medium to large granules randomly distributed among sporocysts (Figs. 7, 9); sporozoites lie side by side along length of sporocyst.

Taxonomic summary

Type host: Geochelone nigra (Quoy and Gaimard, 1824) (Testudines: Testudinidae).

FIGURES 10, 11. Line drawings of sporulated oocysts collected from the feces of Tropidurus albemarlensis and Geochelone nigra, respectively. Bar = 10 μm. 10. Eimeria albemarlensis n. sp. 11. Eimeria geochelona n. sp.
To be less common than expected by chance, with the less prevalent coccidian species, we would expect multiple infections to help resolve this issue. If *E. tropidura* is competitively superior to other coccidian species, this pattern could be due to competitive superiority of *E. tropidura*, or it could be due to other factors such as chance.

Data from lizards with infections by more than one species may provide some natural resistance to infection (as described below) and for other reasons noted earlier (see Remarks), we describe what we presume to be a new species.

Initially, we assumed that information on the coccidians from the land iguana *C. subcrisatus* and the marine iguana *A. cristatus*, could provide us with interesting comparisons with *Tropidurus*, especially because 1 or both of these lizards inhabit the same islands as the *Tropidurus* spp. However, neither genus of iguana harbored coccidia. A simple explanation may be related to the diets of the different lizards. Both *C. subcrisatus* and *A. cristatus* are herbivores, but under stressful conditions they become opportunists; *C. subcrisatus* feeds primarily on fallen or low-growing vegetation, but occasionally will eat insect parts, whereas *A. cristatus* feeds on the algae growing at water level along the base of the island rocks, although they have been seen to eat fish parts and sea lion refuse (H. Snell, pers. obs.). *Tropidurus* spp., on the other hand, routinely feed on both insects and plant material (Stebbins et al., 1967; Schulte, 1984). One conclusion that could be drawn is that insects, by acting as mechanical vectors, may be helping to transmit oocysts to the *Tropidurus* spp.

Because *C. subcrisatus* and *A. cristatus* tend to be herbivorous, it may be that herbivory provides protection against coccidial infections in these animals. For example, certain plants may contain antiparasitic compounds detrimental in some way to the parasite (Crompton, 1987; Lozano, 1991). Other studies conducted with wild chimpanzees in Tanzania have indicated that consumption of some plant materials by the chimp was used for medicinal purposes (Huffman and Seifu, 1989). Where-as we do not mean to imply that the Galápagos lizards are “intentionally” eating certain plants for their medicinal value, the plant material they normally eat fortuitously may provide some medicinal benefit against certain parasites. Conversely, Sharma et al. (1973) found that in chickens, diets high in protein have been shown to increase susceptibility to infection with coccidia. Because the typical diet of *Tropidurus* spp. consists of insects that have a high protein content, perhaps they, in turn, make themselves more susceptible to infection by certain parasites like coccidians.

One of the interesting observations in this study is the apparent disappearance of *Eimeria galapagoensis* Aquino-Shuster, Duszynski, and Snell, 1990 from *T. delanonis* on Isla Gardner. None of our lava lizard samples from the same island (n = 142), or from 4 other islands that support *T. delanonis* (n = 329), was infected with this coccidian. Although the prevalence of *E. galapagoensis* as reported by Aquino-Shuster et al. (1990) was low (4%), we were surprised not to find it in any of the fecal

**Remarks**

McAllister and Upton (1989) recently summarized the coccidian species described from all turtles. Sporulated oocysts of *Eimeria nigrum* resemble in shape and size those of *Eimeria paynei* Ernst, Fincher, and Stewart 1971 from the gopher tortoise *Gopherus polyphemus* from Georgia, U.S.A. and of *Eimeria carinii* Lainson, Costa and Shaw 1990 from the “jabori” tortoise *Gopherus denticulata* from Brazil. They differ from *E. paynei* in having somewhat smaller sporocytes (10.7 x 7.0 vs. 13.2 x 8.1) and by having randomly distributed, medium to large granules for their sporocyst residuum rather than a mass of small granules enclosed by a thin membrane. They differ from *E. carinii* by being slightly larger (21.6 x 18.1 vs. 19.2 x 18.6), by not having a distinct oocyst residuum, by the presence of a polar body, and by having slightly larger sporocytes (10.7 x 7.0 vs. 8.8 x 7.3) that contain Stieda bodies, which those of *E. carinii* lack.

Ordinarily, we would not describe a new species when it is found only in 1 host because there is a likelihood the coccidian may be a pseudodaparasite. We have done so here for the following reasons: (1) there were large numbers of oocysts being discharged by the tortoise and all of the oocysts studied had good structural integrity, which suggests a true infection; (2) the tortoises sampled are kept in pens where contact with most other animals (that may be passing oocysts to result in spurious infections) is limited; (3) only vegetation contaminated by bird or possibly rodent feces might be a source for extraneous oocysts; however, passerine birds have mostly isosporan infections and rodents are not endemic to Isla Santa Cruz; (4) this coccidian does not resemble the eimerian oocysts from introduced pest species, e.g., *Rattus* spp., and (5) these tortoises are strict vegetarians (H. L. Snell and P. A. Stone, pers. obs.) and are not inclined to practice coprophagy.

**DISCUSSION**

Most studies reporting coccidia that infect reptiles are taxonomic reports. Very little information is available about the evolutionary pressures on, or the physiological ecology of, reptilian hosts as it relates to their coccidial infections. As we do not mean to imply that the Galápagos lizards are “intentionally” eating certain plants for their medicinal value, the plant material they normally eat fortuitously may provide some medicinal benefit against certain parasites. Conversely, Sharma et al. (1973) found that in chickens, diets high in protein have been shown to increase susceptibility to infection with coccidia. Because the typical diet of *Tropidurus* spp. consists of insects that have a high protein content, perhaps they, in turn, make themselves more susceptible to infection by certain parasites like coccidians.

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samples. We have no evidence to speculate on the reason(s) for the disappearance of *E. galapagoensis* from the Archipelago, but given our large sample size, this eimerian may now be locally extinct, or it may be that *E. galapagoensis* was actually a pseudoparasite the lizards acquired while feeding.

**ACKNOWLEDGMENTS**

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**LITERATURE CITED**


