J. Parasitol., 99(6), 2013, pp. 1086–1088
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THREE NEW SPECIES OF COCCIDIA (APICOMPLEXA: EIMERIIDAE) FROM SKINKS, *LIPINIA* SPP. (SAURIA: SCINCIDAE), FROM OCEANIA

Chris T. McAllister, Donald W. Duszynski*, Christopher C. Austin†, and Robert N. Fisher‡

Science and Mathematics Division, Eastern Oklahoma State College, Idabel, Oklahoma 74745. Correspondence should be sent to: *cmcallister@se.edu*

ABSTRACT: Between September 1991 and March 1993, 25 moth skinks (*Lipinia noctua*) were collected from various localities on the Cook Islands, Fiji, Papua New Guinea (PNG), and Vanuatu and examined for coccidians. In addition, a single Roux's lipinia skink (*Lipinia rouxi*) was collected from PNG and examined for coccidia. Sixteen (64%) *L. noctua* were found to harbor 2 new eimerians, and *L. rouxi* harbored another new *Eimeria* sp. Oocysts of *Eimeria lipinia* n. sp. from 9 (36%) *L. noctua* from the Cook Islands, Fiji, and PNG were subspherical with a bilayered wall and measured (L × W) 18.6 × 16.9 μm, with a L/W ratio of 1.1. Both micropyle and oocyst residuum were absent, but a polar granule was present. Oocysts of *Eimeria melanesia* n. sp. from 6 (24%) *L. noctua* from Fiji and Vanuatu and a single *L. rouxi* from PNG were subspherical to ellipsoidal with a bilayered wall and measured 19.8 × 17.5 μm, and L/W was 1.1. Both micropyle and oocyst residuum were absent, but a single or fragmented polar granule was present. Oocysts of *Eimeria lessoni* n. sp. from 1 (4%) *L. noctua* from PNG were cylindroidal with a bilayered wall and measured 28.1 × 15.7 μm, and L/W was 1.8. Both micropyle and oocyst residuum were absent, but a single polar granule was present. These represent the third report of *Eimeria* spp. reported from any host on PNG and the only coccidians, to our knowledge, ever described from *L. noctua* and *L. rouxi* and from the Cook Islands and Vanuatu.

The genus *Lipinia* includes at least 26 species of skinks ranging from the Andaman and Nicobar Islands of India eastward to Thailand, Cambodia, the Malay Peninsula, Sumatra, Borneo, and the Philippines to New Guinea and the Republic of Belau (Das and Austin, 2007; Uetz, 2012). One of these, the moth skink (*Lipinia noctua*), has an extensive range that extends from the Papuan region throughout Oceania northeast to Hawaii and southeast to Pitcairn Island (Austin, 1999). However, another species, Roux's lipinia skink (*Lipinia rouxi*), is restricted to the island of New Ireland, PNG (Austin, 1995). *Lipinia noctua* and *L. rouxi* are found in broad sympatry from an elevation of sea level to approximately 900 m on the island of New Ireland (Greer and Mys, 1987).

Although information is available on nematode parasites of *L. noctua* (Goldberg et al., 2010; Goldberg and Bursey, 2012), nothing, to our knowledge, has been published on coccidia from this lizard. Similarly, nothing, to our knowledge, has been documented on coccidia from *L. rouxi*. Herein we provide descriptions of 3 new *Eimeria* spp. from *L. noctua* and *L. rouxi*.

MATERIALS AND METHODS

Between September 1991 and March 1993, 25 adult *L. noctua* were collected by hand, with the use of a blowpipe, or with mouse glue boards from localities in the Cook Islands ($n = 3$), Fiji ($n = 13$), PNG ($n = 3$), and Vanuatu ($n = 6$) and examined for coccidians. In addition, a single adult *L. rouxi* collected from PNG was examined. Fresh fecal samples were placed in individual vials containing 2.5% (w/v) aqueous potassium dichromate ($K_2Cr_2O_7$) and examined for coccidia by light microscopy after flotation in Sheather's sugar solution (specific gravity = 1.30). Measurements were taken on 25 sporulated oocysts using a calibrated ocular micrometer and reported in micrometers (μm) with means followed by the ranges in parentheses; photographs were taken using Nomarski interference-contrast (NIC) optics. Oocysts were ~300 days old when measured and photographed. Descriptions of oocysts and sporocysts follow guidelines of Wilber et al. (1998) as follows: oocyst length (L) and width (W), their ranges and ratios (L/W), micropyle (M), oocyst residuum (OR), polar granules (PG), sporocyst length (L) and width (W), their ranges and ratio (L/W), sporocysts (SP), Stieda body (SB), sub-Stieda body (SSB), para-Stieda body (PSB), sporocyst residuum (SR), sporozoites (SZ), anterior (ARB) and posterior (PRB) refractile bodies, and nucleus (N). Unfortunately appropriate tissues (gall bladder, intestine) were not available from hosts for study of endogenous stages. Host vouchers were accessioned into the Texas Natural History Collection (TNHC), University of Texas, Austin, Texas, California Academy of Sciences, San Francisco, California, and the Smithsonian National Museum of Natural History, Washington, D.C. Photosyntypes of sporulated oocysts were accessioned into the United States National Parasite Collection (USNPC), Beltsville, Maryland. Lizard taxonomy follows the reptile database (Uetz, 2012).

DESCRIPTION

Eimeria lipinia n. sp.

(Figs. 1, 4)

Description of sporulated oocyst: Oocyst shape: subspheroidal, with a bilayered wall, ~1.4–1.6 thick, outer is smooth, ~1.0–1.4, inner is ~0.4–0.5; L × W: 18.6 × 16.9 (15–22 × 15–20); L/W 1.1 (1.0–1.2); M, OR: both absent; PG: present, fragmented.

Description of sporocyst and sporozoites: SP shape: ellipsoidal, ~ 0.5 thick, with a smooth single-layered wall composed of 2 valves joined by a longitudinal suture; L × W: 9.2 × 6.8 (8–11 × 6–8); L/W 1.4 (1.3–1.7); SB, SSB, PSB: all absent; SR: present; SR characteristics: spheroidal, 2.9 (2–4), composed of moderately sized globules dispersed between SZ; SZ: elongate with spheroidal PRB; single N slightly posterior to midpoint of body.

Taxonomic summary

Type host: Moth skink, *Lipinia noctua* (Lesson, 1826) (Sauria: Scincidae). Collected 31 October 1991. Symbiotype TNHC 51457.

Type specimens: Photosyntype deposited as USNPC 106815.

Type locality: Kavieng, New Ireland Province, PNG (2.566496°S, 150.798547°E).

Prevalence: In 9/25 (36%) *L. noctua* overall; 3/3 (100%) from Tupapa Stream, Rarotonga Island, Cook Islands (21.219057°S, 159.749763°E); 5/13 (38%) from between villages of Raviravi and Rukua, Marlin Bay Resort, Beqa Island, Fiji; 1/2 (50%) from New Ireland, PNG; 0/1 (0%) from Madang, PNG; 0/6 (0%) from Vanuatu.

Sporulation: Unknown. Specimens were collected in the field and not examined until 300 days later.

Prepatent and patent periods: Unknown.

Site of infection: Unknown, oocysts recovered from feces.

Endogenous stages: Unknown.

Cross-transmission: None to date.

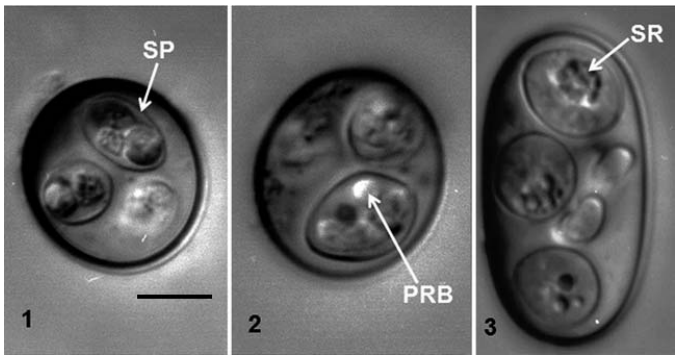
Received 16 April 2013; revised 10 June 2013; accepted 19 June 2013.

* Department of Biology, University of New Mexico, Albuquerque, New Mexico 87131.

† Department of Biological Sciences and Museum of Natural Sciences, Louisiana State University, Baton Rouge, Louisiana 70803.

‡ U.S. Geological Survey, Western Ecological Research Center, 4165 Spruance Road, Suite 200, San Diego, California 92101-0812.

DOI: 10.1645/13-276.1



FIGURES 1–3. NIC photomicrographs of oocysts of *Eimeria lipinia* n. sp., *Eimeria melanesia* n. sp., and *Eimeria lessoni* n. sp. (**1**) Oocyst of *E. lipinia* showing sporocyst (SP). (**2**) Oocyst of *E. melanesia* showing posterior refractile body (PRB). (**3**) Oocyst of *E. lessoni* showing sporocyst residuum (SR). Scale bar = 10 μm.

Etymology: The specific epithet is derived from the host genus. The name is given as a noun in apposition.

Remarks

We are unable at this time to place the new species in the genus *Acroeimeria* (sensu Paperna and Landsberg, 1989) for lack of tissue samples showing endogenous stages in the intestinal tract and/or distinct DNA sequences that separate *Eimeria* from this genus. However, the only eimeriid species known previously from scincid lizards that has subspheroidal oocysts is *Acroeimeria rouxi* Modrý and Jirků, 2006, from marble-throated skinks, *Marmorosphax tricolor* from New Caledonia (Modrý and Jirků, 2006). Although similar in oocyst size to those of *E. lipinia*, the sporocyst L/W ratio of *A. rouxi* is considerably smaller (1.1 vs. 1.4).

***Eimeria melanesia* n. sp.**

(Figs. 2, 5)

Description of sporulated oocyst: Oocyst shape: subspheroidal to ellipsoidal; bilayered wall, ~1.2–1.5 thick, smooth; outer layer, ~0.8–1.2 thick, inner layer, ~0.4–0.5; L × W: 19.8 × 17.5 (18–22 × 15–19); L/W 1.1 (1.0–1.3); M, OR: both absent; PG: present, fragmented (usually).

Description of sporocyst and sporozoites: SP shape: ellipsoidal to oblong, ~ 0.4 thick, with a smooth single–layered wall, composed of 2 valves joined by a longitudinal suture; L × W: 9.6 × 7.4 (9–11 × 6–8); L/W 1.3 (1.2–1.5); SB, SSB, PSB; all absent; SR: present; SR characteristics: subspheroidal, 4.2 × 3.8 (3–5 × 2–5), composed of moderately sized globules dispersed between SZ; SZ: elongated, 2.5 (2–3) wide, with subspheroidal PRB 2.7 × 2.4 (2–3 × 2–3); single N slightly posterior to midpoint of body.

Taxonomic summary

Type host: Roux's lipinia skink, *Lipinia rouxi* Hediger, 1934 (Sauria: Scincidae). Collected 27 October 1991. Symbiotype TNHC 51429.

Other hosts and localities: L. noctua, Fiji and Vanuatu.

Type specimens: Photosyntype deposited as USNPC 106816.

Type locality: Lelet Plateau, Lengkamen Village, New Ireland Province, PNG (3.430352°S, 151.998138°E).

Prevalence: In 1/1 (100%) *L. rouxi*; 6/25 (24%) *L. noctua* overall, 6/10 (60%) *L. noctua* from Vanuatu, 3/13 (23%) *L. noctua* from Fiji.

Sporulation: Unknown. Specimens were collected in the field and not examined until 300 days later.

Prepatent and patent periods: Unknown.

Site of infection: Unknown, oocysts recovered from feces.

Endogenous stages: Unknown.

Cross-transmission: None to date.

Etymology: The specific epithet is given for the subregion of Oceania (Melanesia) extending from the western end of the Pacific Ocean to the Arafura Sea and eastward to Fiji. The name is from the Greek *mela* for black and *nesia* for islands. The name is given as a noun in apposition.

Remarks

Eimeria melanesia is similar to *Eimeria lampropholidus* Cannon, 1967, from the pale-flecked garden sunskink, *Lampropholis guichenoti,* from Australia (Cannon, 1967) except that its SP are considerably smaller in length (7.7 vs. 9.6) and it does not possess a PG that is present in the new species.

***Eimeria lessoni* n. sp.**

(Figs. 3, 6)

Description of sporulated oocyst: Oocyst shape: cylindroidal, 1 side slightly concave, the other is convex; bilayered wall, ~1.2–1.4 thick; inner is 0.4–0.5 thick, outer, 0.8–1.0; L × W: 28.1 × 15.7 (27–30 × 15–17); L/W: 1.8 (1.7–1.9); M, OR: both absent; PG: 1, present at 1 end of oocyst.

Description of sporocyst and sporozoites: SP shape: oblong to pear-shaped, with a smooth thin single-layered wall composed of 2 valves joined by a longitudinal suture; L × W: 9.7 × 8.0 (9–11 × 8–9); L/W: 1.2 (1.1–1.4); SB, SSB, PSB: all absent; SR: present; SR characteristics: subspheroidal, 4.4 × 4.1 (3–5 × 3–5), composed of coarse granules dispersed between SZ; SZ: elongate, but neither ARB nor PRB were seen.

Taxonomic summary

Type host: Lipinia noctua (Sauria: Scincidae). Collected 31 October 1991. Symbiotype TNHC 51449.

Type specimens: Photosyntype deposited as USNPC 106817.

Type locality: Kavieng, New Ireland Province, PNG (2.566496°S, 150.798547°E).

Prevalence: In 1/25 (4%).

Sporulation: Unknown. Specimens were collected in the field and not examined until 300 days later.

Prepatent and patent periods: Unknown.

Site of infection: Unknown, oocysts recovered from feces.

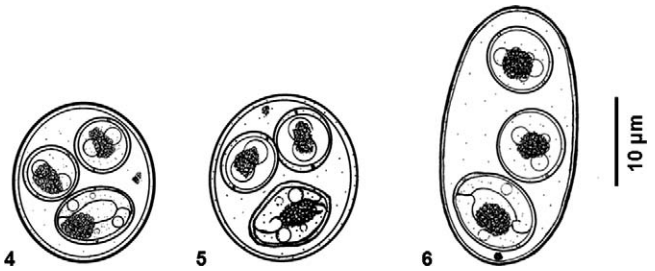
Endogenous stages: Unknown.

Cross-transmission: None to date.

Etymology: The specific epithet is given in honor of René-Primevère Lesson (1794–1849), French taxonomist, who described the host (in 1826), which is the type for this new eimerian.

Remarks

It is likely this eimerian should be placed in the genus *Choleoeimeria* (sensu Paperna and Landsberg, 1989), rather than *Eimeria*. Oocysts of the new species are cylindroidal with an L/W ratio typical of the former genus. In addition, its sporocysts lack a SB and SSB and are composed of 2 valves joined by a suture. However, without tissue samples showing endogenous stages in gall bladder epithelium and/or molecular data (see Jirků et al., 2002), we may never know for sure; perhaps the species will be rediscovered and samples processed in more detail. Nevertheless, *E. lessoni* is most similar in size to *Choleoeimeria auratae* Alyousiff and Al-Rasheid, 2001, from the golden grass mabuya, *Trachylepis* (=*Mabuya*) *aurata* from Saudi Arabia (Alyousiff and Al-Rasheid, 2001), *Choleoeimeruia jazanensis* Abdel-Baki, Al-Quraishy, and Abdel-Haleem, 2013, from *Scincus hemprichii* (no common name) from Saudi Arabia (Abdel-Baki et al., 2013), and *Choleoeimeria* (syn. *Eimeria*) *scincellae* Telford, 1997, from the ground skink, *Scincella lateralis,* from Florida, USA (Telford, 1997).



FIGURES 4–6. Composite line drawings of oocysts of *E. lipinia* n. sp., *E. melanesia* n. sp., and *E. lessoni* n. sp. (**4**) *E. lipinia*; (**5**) *E. melanesia*; (**6**) *E. lessoni*. Note: Only 3 of the 4 sporocysts are shown in each figure.

However, *E. lessoni* differs from the former in having a larger oocyst L/W ratio (1.8 vs. 1.5) and from all 3 in possessing a PG.

DISCUSSION

The coccidian fauna of skinks of the insular Pacific have been described for the first time during the last decade (Modrý and Jirků, 2006; McAllister, Duszynski, and Fisher, 2013; McAllister, Duszynski, Fisher, and Austin, 2013; McAllister, Seville et al., 2013), with these 3 new *Eimeria* bringing the total skink coccidian diversity in the region to 11 species. Thus far, all species of coccidia are restricted to individual genera of skinks (*Carlia*, *Emoia*, *Lamprolepis*, *Lipinia, Marmorosphax*), thus showing high generic specificity. *Eimeria lipinia* and *E. melanesia* are the first examples of widespread coccidia in skinks in the Pacific and are present in populations (Cook Islands, Fiji, and Vanuatu) where *L. noctua* is considered a recent invader (Austin, 1999). This endemism and diversity of coccidians in insular Pacific skinks contrasts that of insular Pacific geckos where there is generally low coccidian diversity and the species present occur across genera and over large ranges (Hanley et al., 1995; McAllister, unpubl. data).

Within *Lipinia*, other parasite groups are apparently in low prevalence and lack specificity or were not found in surveys within skink genera in contrast to coccidians (hematozoan parasites: Austin and Perkins, 2006; metazoan endoparasites: Goldberg et al., 2010; Acari: Fisher and Austin, unpubl. data). At present our sampling is too limited to understand what the evolutionary, historical, and/or ecological processes are that have led to this difference in coccidian diversity between skinks and geckos. Greater geographic- and species-level sampling and continued assessments of parasite communities in insular Pacific skinks by ourselves and other researchers will further illuminate the patterns and processes responsible for coccidian endemicity and diversity (McAllister, Duszynski, and Fisher, 2013; McAllister, Duszynski, Fisher, and Austin, 2013; McAllister, Seville et al., 2013).

ACKNOWLEDGMENTS

We thank the late Dr. Steve J. Upton for technical assistance and Dr. Scott L. Gardner (Manter Laboratory of Parasitology Collection, University of Nebraska–Lincoln) for parasitological training of R.N.F. Further appreciation is extended to Patricia A. Pilitt (USNPC) for expert curatorial assistance and Dr. George R. Zug (National Museum of Natural History, Washington, D.C.) for consultation on coccidian scientific epithets. The Department of Environments of the Cook Islands, Fiji, PNG, and Vanuatu supplied export permits for the lizard and parasite collections. This research was funded, in part, by National Science Foundation Grants DEB 1146033 to C.C.A. R.N.F.'s field work in Vanuatu and Fiji was supported in part by the Smithsonian Scholarly Studies Program funding to G. R. Zug. The use of trade, product, or firm names in this publication does not imply endorsement by the U.S. government.

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