

A new species of *Eimeria* Schneider, 1875 (Apicomplexa: Eimeriidae) from *Carlia* spp. (Sauria: Scincidae) from Papua New Guinea

Chris T. McAllister · Donald W. Duszynski ·
Robert N. Fisher · Christopher C. Austin

Received: 1 May 2013 / Accepted: 19 June 2013
© Springer Science+Business Media Dordrecht 2013

Abstract A new species of *Eimeria* Schneider, 1875 from rainbow skinks, *Carlia ailanpalai* Zug and *Carlia eothen* Zug is described from specimens collected in Papua New Guinea (PNG). Oöcysts of *Eimeria zugi* n. sp. from one of one (100%) *C. eothen* are ellipsoidal to cylindrical, with a smooth, colourless, bi-layered wall, measure $25.1 \times 15.5 \mu\text{m}$ and have a length/width ratio of 1.6. The micropyle and the oöcyst residuum are absent, but a polar granule is present. The sporocysts are ovoidal to ellipsoidal and $10.3 \times 7.1 \mu\text{m}$ in size and do not contain Stieda, sub-Stieda or para-Stieda bodies; and the sporocyst residuum is composed of a compact mass of large globules. The sporozoites are elongate, $12.8 \times 2.9 \mu\text{m}$ in size, and contain anterior and posterior refractile bodies with a nucleus between

them. This is the ninth species of coccidium described from skinks from PNG, and the new species described herein is apparently endemic to the skink genus *Carlia* (Gray).

Introduction

The scincid genus *Carlia* (Gray) is composed of at least 41 species with its center of diversity in Australia and New Guinea (Zug, 2004; Zug & Allison, 2006; Uetz, 2012). One species, *C. eothen* Zug, is a moderately-sized species (46–69 mm snout-vent-length [SVL]) that ranges from eastern Papua New Guinea (PNG) from around Milne Bay into the adjacent island groups (Zug, 2004). Another species, *C. ailanpalai* Zug, has 46 to 59 mm SVL and ranges from the main group of Admiralty Islands centered on Manus Island, but has also invaded Guam, the Marianas, Yap and Kosrae (Zug, 2004; Buden, 2009; Austin et al., 2011).

Little is known about the coccidian parasites of *Carlia* spp. Paperna (2006) provided a description of a new species of *Isospora* Schneider, 1881 from the blue-throated rainbow skink *Carlia rhomboidalis* (Peters) from north Queensland, Australia. In addition, Paperna (2007) described *Choleoeimeria sylvatica* Paperna, 2007 from *C. rhomboidalis*. Nothing else, to our knowledge, has been published on coccidia from *Carlia* spp. (see Modrý & Jirků, 2006). Herein we provide a description of a new species of *Eimeria* from *C. ailanpalai* and *C. eothen*.

C. T. McAllister (✉)
Science and Mathematics Division, Eastern Oklahoma
State College, Idabel, OK 74745, USA
e-mail: cmcallister@se.edu

D. W. Duszynski
Department of Biology, University of New Mexico,
Albuquerque, NM 87131, USA

R. N. Fisher
U.S. Geological Survey, Western Ecological Research
Center, San Diego Field Station, 4165 Spruance Road,
Suite 200, San Diego, CA 92101–0812, USA

C. C. Austin
Department of Biological Sciences and Museum of
Natural Sciences, Louisiana State University, Baton
Rouge, LA 70803, USA

Materials and methods

During September and December 1991, adult *C. ailanpalai* and *C. eothen* were collected by hand from two localities in PNG as follows: *C. ailanpalai* was taken in Kavieng, New Ireland Province and *C. eothen* was collected on Fergusson Island, Milne Bay Province. Fresh faecal samples were collected from each individual for examination of coccidia and placed in individual vials containing 2.5% (w/v) aqueous potassium dichromate ($K_2Cr_2O_7$) (Gardner et al., 2012). They were examined for coccidia by light microscopy after flotation in Sheather's sugar solution (specific gravity = 1.30) and measurements were taken on 25 oöcysts using a calibrated ocular micrometer and reported in micrometres with means followed by the ranges in parentheses. Photographs were taken using Nomarski interference-contrast (DIC) optics. Oöcysts were 300 days old when measured and photographed. Descriptions of oöcysts and sporocysts follow guidelines of Wilber et al. (1998). Voucher specimens of *C. ailanpalai* and *C. eothen* were accessioned into the Texas Natural History Collection (TNHC), Austin, Texas, USA. Photovouchers of sporulated oöcysts were accessioned into the United States National Parasite Collection (USNPC), Beltsville, Maryland, USA. Lizard taxonomy follows the TIGR reptile database (Uetz, 2012) and Zug (2013).

Eimeria zugi n. sp.

Type-host: *Carlia eothen* Zug (Sauria: Scincidae), symbiotype TNHC 51500 (field number CCA 877).

Type-locality: Fergusson Island, Milne Bay Province, PNG (9.664622°S, 150.792103°E).

Type-material: Photosyntype (see Duszynski, 1999) as USNPC 106945.

Prevalence: 1/1 (100%) *C. eothen*; 1/1 (100%) *C. ailanpalai*.

Other host and locality: Admiralty brown skink, *Carlia ailanpalai* Zug (Sauria: Scincidae), Kavieng, New Ireland Province, PNG (2.566466°S, 150.798547°E), symbiotype TNHC 51469 (field number CCA 756).

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

Site of infection: Unknown. Oöcysts were passed in faeces.

Prepatent and patent periods: Unknown.

Pathogenicity: Unknown.

Etymology: The specific epithet is given in honour of Dr. George R. Zug, Curator Emeritus, Smithsonian Institution, National Museum of Natural History, Washington, D. C., USA, who described the host species and has coauthored seminal publications on lizards of Pacific Islands. His mentoring of RNF and CCA for decades has been greatly appreciated.

Description (Figs. 1–3)

Sporulated oöcyst

Oöcyst (n = 25) colourless, smooth, ellipsoidal to cylindroidal, 25.1×15.5 ($21\text{--}29 \times 14\text{--}17$); length/width (L/W) ratio 1.6 (1.5–1.8). Wall bi-layered, 1.4–1.6, outer layer 0.8–1.0, inner layer 0.4–0.6. Micropyle absent, oöcyst residuum absent (1–2 oöcyst-like globules adhere to oöcyst wall); when freshly sporulated polar granule present (1), disintegrates with age.

Sporocyst

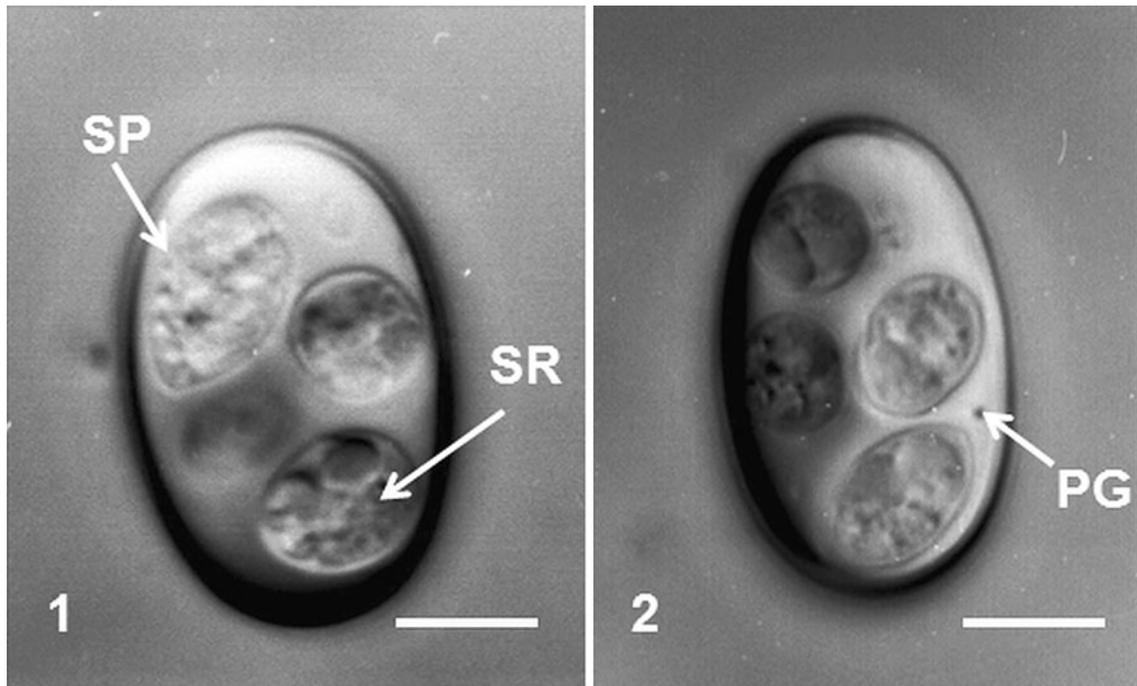
Sporocysts (n = 20) two, colourless, smooth, ovoidal to ellipsoidal, 10.3×7.1 ($10\text{--}11 \times 7\text{--}9$); L/W ratio 1.5 (1.2–1.7); wall single-layered, 0.4; Stieda body, sub-Stieda and para-Stieda body absent; sporocyst residuum composed of compact mass of large granules in distinct cluster.

Sporozoite

Sporozoite (n = 10) comma-shaped, 12.8×2.9 ($12\text{--}14 \times 2.6\text{--}3.2$) *in situ*; single spherical anterior refractile body, 1.8 (1.6–2.4), and ellipsoidal posterior refractile body, 3.8×2.6 ($3\text{--}5 \times 2\text{--}3$), with nucleus between them present.

Remarks

Oöcysts that are most similar to *E. zugi* are those of *Eimeria ablephari* Cannon, 1967 from the snake-eyed skink, *Cryptoblepharus* (= *Ablepharus*) *boutonii* (species uncertain) from Australia that measure 23.1×17.7 μm and has a L/W ratio of 1.3 (Cannon, 1967) and those of *Eimeria beyerae* Ovezmukammedov, 1977 from the desert lidless skink, *Ablepharus deserti* from northern Turkmenistan (Ovezmukammedov, 1977) measuring 23.1×16.2 (L/W ratio = 1.4).



Figs. 1–2 DIC photomicrographs of oocysts of *Eimeria zugi* n. sp. *Abbreviations:* PG, polar granule; SP, sporocyst; SR, sporocyst residuum. *Scale-bars:* 10 μ m

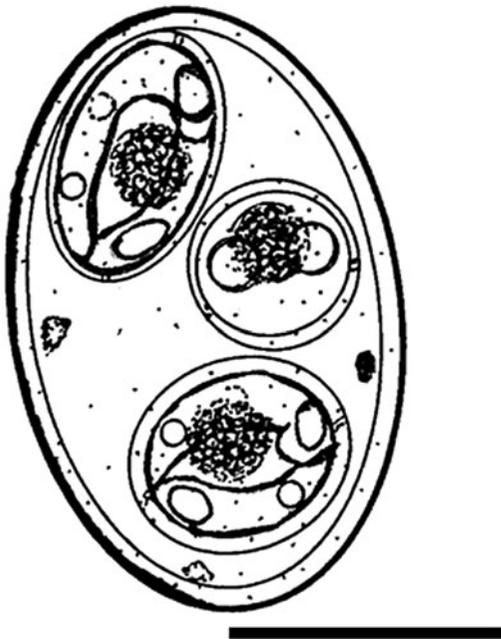


Fig. 3 Composite line drawing of oocyst of *Eimeria zugi* n. sp. *Scale-bar:* 10 μ m

However, *E. zugi* can be differentiated as follows: *E. zugi* possesses a polar granule which *E. ablephari* and *E. beyerae* do not; the oocyst L/W ratio of *E. zugi* (1.6) is considerably larger than that of either species; and sporocysts of *E. zugi* are slightly larger than those of *E. ablephari* ($8.9 \times 6.6 \mu\text{m}$) and smaller than those of *E. beyerae* ($11.5 \times 8.1 \mu\text{m}$). Therefore, these morphological features are distinct and we consider the coccidian described herein as new to science. This is the fourth genus of skinks from PNG to have an endemic coccidian fauna.

Discussion

To date, ~ 17 species of *Choleoimeria/Eimeria* have been reported from 13 members of Scincidae from various localities in Australia, Cook Islands, Egypt, Fiji, India, Japan, Papua New Guinea, Turkmenistan, Vanuatu, and South America (Carini, 1938; Cannon, 1967; Ray et al., 1942; Bovee, 1971; Ovezmukhammedov, 1977; Daszak & Ball, 1991; McAllister et al.,

1993, 2014a, b; Paperna, 2007; Yang et al., 2013). The low scientific effort in this part of the world, however, suggests that much of the eimerian diversity remains to be discovered as very few hosts have been surveyed.

The two species of *Carlia* examined in this study belong to the *Carlia fusca* complex, a group of more than 18 morphologically similar species found mainly on New Guinea and surrounding islands (Zug, 2004; Zug & Allison, 2006; Donnellan et al., 2009). The morphological uniformity of this group combined with historical taxonomic inattention has led to confusion as to the biodiversity and species distributions of this complex. Work by Zug (2004) delineated species boundaries in the *fusca* complex based on detailed morphological analysis. Multi-locus DNA sequence data by Austin et al. (2011) uncovered greater diversity than previously recognised as well as documented some of the problems with this group associated with morphological conservatism and we expect further changes to the taxonomy of this group in the coming years. The systematic and taxonomic uncertainty of these host lizards has a cascading effect on our knowledge of their *Eimeria* spp. and, likely, other parasites.

Acknowledgements We thank the late Steve J. Upton (Kansas State University, Manhattan, KS, USA) for technical assistance, and Scott L. Gardner (Manter Parasite Collection, Lincoln, NE, USA) for parasitological training of RNF. Further appreciation is extended to Patricia A. Pilitt (USNPC) for expert curatorial assistance. The PNG Department of Environment and Conservation supplied export permits to CCA for the lizard and parasite collections. This work was funded in part by IBN 9311139 and DEB 1146033 to CCA. The use of trade, product, or firm names in this publication does not imply endorsement by the U.S. Government.

References

- Austin, C. C., Rittmeyer, E. N., Oliver, L. A., Andermann, J. O., Zug, G. R., Rodda, G. H., & Jackson, N. D. (2011). The bioinvasion of Guam: inferring geographic origin, pace, pattern and process of an invasive lizard (*Carlia*) in the Pacific using multi-locus genomic data. *Biological Invasions*, *13*, 1,951–1,967.
- Bovee, E. C. (1971). New species of *Eimeria* from lizards from Japan. *Transactions of the American Microscopical Society*, *90*, 336–343.
- Buden, D. W. (2009). *Carlia ailanpalai* (Reptilia: Scincidae): an invasive species of lizard in the Federated States of Micronesia. *Pacific Science*, *63*, 243–251.
- Cannon, L. R. G. (1967). New coccidia from Australian lizards. II. *Eimeria*. *Parasitology*, *57*, 237–250.
- Carini, A. (1938). *Eimeria maboia* n. sp. parasite do intestino do *Mabuja maboia*. *Arquivos de Biologia*, *22*, 10.
- Daszak, P., & Ball, S. J. (1991). Five new species of *Eimeria* (Apicomplexa: Eimeriidae) from lizards. *Systematic Parasitology*, *20*, 141–147.
- Donnellan, S. C., Couper, P. J., Saint, K. M., & Wheaten, L. (2009). Systematics of the *Carlia 'fusca'* complex (Reptilia: Scincidae) from northern Australia. *Zootaxa*, *2227*, 1–31.
- Duszynski, D. W. (1999). Critical comment: revisiting the code: clarifying name-bearing types for photomicrographs of Protozoa. *Journal of Parasitology*, *85*, 769–770.
- Gardner, S. L., Fisher, R. N., & Berry, S. J. (2012). Chapter 7. Voucher specimens; Collecting and preserving parasites during reptile biodiversity surveys. In: McDiarmid, R., Foster, M., Guyer, C., Gibbons, J. E., & Chernoff, N. (Eds) *Reptile Biodiversity: Standard Methods of Inventory and Monitoring*. Berkeley: University of California Press, pp. 114–121.
- McAllister, C. T., Duszynski, D. W., Austin, C. C., & Fisher, R. N. (2014a). Three new species of coccidia (Apicomplexa: Eimeriidae) from skinks, *Lipinia* spp. (Sauria: Scincidae), from Oceania. *Journal of Parasitology*, *100* (in press).
- McAllister, C. T., Duszynski, D. W., Fisher, R. N., & Austin, C. C. (2014b). Four new species of coccidia (Apicomplexa: Eimeriidae) from Owen Stanley skinks, *Papuascincus stanleyanus* (Sauria: Scincidae) from Papua New Guinea. *Journal of Parasitology*, *100* (in press).
- McAllister, C. T., Upton, S. J., & Garrett, C. M. (1993). *Eimeria sternfeldi* n. sp. (Apicomplexa: Eimeriidae) from the Australian blue-tongued skink, *Tiliqua multifasciata* (Sauria: Scincidae). *Journal of Parasitology*, *79*, 681–683.
- Modrý, D., & Jirků, M. (2006). Three new species of coccidia (Apicomplexa: Eimeriorina) from the marble-throated skink, *Marmorophax tricolor* Bavay, 1869 (Reptilia: Scincidae), endemic to New Caledonia with a taxonomic revision of *Eimeria* spp. from scincid hosts. *Parasitology Research*, *99*, 416–428.
- Ovezmukhammadov, O. (1977). New species of coccidia *Eimeria beyeri* sp. n. of the desert lizard (*Ablepharus deserti* Stauch, 1868) in Turkmenistan. *Izvestiya Akademii Nauk Turkmenskoi SSR Seriya Biologicheskikh Nauk*, *0(4)*, 83–84.
- Paperna, I. (2006). *Isospora carliae* sp. n. (Apicomplexa: Eimeriidae) from the skink *Carlia rhomboidalis* (Peters) from Daintree Forest, North Queensland, Australia: description and fine-structural account of endogenous development. *Folia Parasitologica*, *53*, 249–254.
- Paperna, I. (2007). New species of *Choleoimeria* (Apicomplexa: Eimeriidae), coccidia of bile-bladders of reptiles, illustrating a multiplicity of host cell-parasite interrelations. *Parassitologia*, *49*, 81–95.
- Ray, H. N., Raghavachari, K., & Sapre, S. N. (1942). On a new coccidium, *Eimeria minetti* n. sp., from the lizard *Mabuia* sp. *Proceedings of the 28th Indian Science Congress, Calcutta*, *28*, 170.
- Uetz, P. (2012). *The TIGR Reptile Database*. World Wide Web electronic publication. <http://www.reptile-database.org/>. Accessed 22 March 2013.
- Wilber, P. G., Duszynski, D. W., Upton, S. J., Seville, R. S., & Corliss, J. O. (1998). A revision of the taxonomy and

- nomenclature of the *Eimeria* spp. (Apicomplexa: Eimeriidae) from rodents in the Tribe Marmotini (Sciuridae). *Systematic Parasitology*, 39, 113–135.
- Yang, R., Brice, B., Ryan, U., & Bennett, M. D. (2013). *Eimeria tiliquae* n. sp. (Apicomplexa: Eimeriidae) from the shingleback skink (*Tiliqua rugosa rugosa*). *Experimental Parasitology*, 133, 144–149.
- Zug, G. R. (2004). Systematics of the *Carlia* “fusca” lizards (Squamata: Scincidae) of New Guinea and nearby islands. *Bishop Museum Bulletin in Zoology*, 5, 1–83.
- Zug, G. R. (2013). *Reptiles and amphibians of the Pacific Islands: a comprehensive guide*. Berkeley: University of California Press, 320 pp.
- Zug, G. R., & Allison, A. (2006). New *Carlia fusca* complex lizards (Reptilia: Squamata: Scincidae) from New Guinea, Papua-Indonesia. *Zootaxa*, 1237, 27–44.