A description of two new species of coccidia (Apicomplexa: Eimeriidae) from African reptiles with nomenclatural corrections for two *Caryospora* and one *Eimeria* species from snakes

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Abstract. Two new species of coccidian parasites are described from African reptiles. Oocysts of *Eimeria foulshami* sp. n. from the plated lizard *Gerrhosaurus major bottegoi* Del Prato of Sudan are ellipsoidal, 24.1×14.9 ($23-26.5 \times 14-17.8$) μm with a bilayered, colourless oocyst wall and lack polar granules. The ellipsoidal sporocysts average 8.6×4.6 ($7-10.6 \times 4.4-7$) μm and possess a prominent, globular, sporocyst residuum. Oocysts of *Caryospora regentensis* sp. n. from the green mamba *Dendroaspis viridis* Hallowell of Kenya are spherical to subspherical, 16.8×16.4 ($16-17.6 \times 15-17.2$) μm with a bilayered oocyst wall and a single polar granule. The ellipsoidal sporocysts average 13.0×10.3 ($10.2-14 \times 9.2-11$) μm and possess a Stieda and substieda body and a prominent globular sporocyst residuum. Oocysts of *Caryospora legeri* Hoare, 1933 are reported from a hissing sand snake, *Psammophis sibilans sibilans* L. from Nigeria, representing a new geographical record. The oocysts are slightly larger than the type, but otherwise identical. *Caryospora psammophi* Bray, 1960 and *C. hermae* Bray, 1960 from *Psammophis sibilans phillipsi*, oocysts of which are morphologically similar to and overlap in dimensions with *C. legeri* Hoare, 1933, are synonymised with the latter species. *Eimeria samiae* Iskander et Tadros, 1979 is emended to *E. samyadeli* to reflect the gender of the person the species was named after and because *E. sami* is preoccupied. In addition to these findings, *Eimeria bohemi* Modrý, Šlapeta et Koudela, 2000 and oocysts of an unidentified spherical *Eimeria* sp. are reported from *Chamaeleo dilepis dilepis* Leach from Cameroon.

The number of coccidia described from African reptiles is low in relation to the large size of the continent and diversity of reptile fauna. Most recent papers have concerned host species from outlying regions, such as North Africa (e.g. Amoudi 1989), Madagascar (e.g. Upton et al. 1990), Namibia (e.g. Upton et al. 1992) and Indian Ocean islands (e.g. Modrý et al. 1997). The current paper describes two new species of coccidia from reptiles of African regions south of the Sahara: *Gerrhosaurus major* Del Prato (Sauria: Cordylidae) and *Dendroaspis viridis* Hallowell (Serpentes: Elapidae). No coccidia have previously been reported from these species. There are no known coccidia from *Gerrhosaurus* spp. lizards or *Dendroaspis* spp. snakes. Only one eimerian has been reported from the family Cordylidae (Upton et al. 1993) and four caryosporans are known from elapid snakes (Cannon 1967, Matuschka 1982, Nandi 1985, Lainson et al. 1991).

MATERIALS AND METHODS

Faecal samples were collected from animals housed individually or in small groups of the same species at the Zoological Society of London (ZSL), Regent's Park, London, UK or at a dealer's premises. So as to eliminate the possibility

that the coccidia found were from hosts other than the normal species infected in the wild, only animals which had been caught, held and imported individually or in groups of the same species from the same locality were used in this study. Faecal samples were placed in 2.5% potassium dichromate in which the oocysts sporulated. Oocysts were photographed and measurements (given here in μm) were taken under oil using a Zeiss photomicroscope III fitted with an eyepiece micrometer. The oocysts observed were compared with those already reported from lizards of the Cordylidae (=Zonuridae) for *Gerrhosaurus major* and the Elapidae for *Dendroaspis viridis*.

RESULTS

APICOMPLEXA: Eimeriidae

Eimeria foulshami sp. n.

Figs. 1, 4

Description: Oocysts cylindroidal, $24.1 \pm 1.3 \times 14.9 \pm 1.0$ ($23-26.5 \times 14-17.8$), $n = 15$; shape index (SI, mean length/mean width) 1.62. Wall bilayered, smooth and colourless, about 0.7 thick. Micropyle, oocyst residuum and polar granules absent. Sporocysts ellipsoidal-cylindroidal, 8.6×4.6 ($7-10.6 \times 4.4-7$), $n = 20$; SI = 1.9, with prominent sporocyst residuum, Stieda and substieda bodies absent and a single posterior residual body usually visible.

Figs. 1-3. Nomarski differential interference contrast photomicrographs of sporulated oocysts of coccidian parasites from African reptiles. **Fig. 1.** Type for *Eimeria foulshami* sp. n. from *Gerrhosaurus major bottegoi*. **Fig. 2.** Type for *Caryospora regentensis* sp. n. from *Dendroaspis viridis*. **Fig. 3.** *Caryospora legeri* from *Psammophis sibilans sibilans*. Scale bars = 10 µm.

Type host: “Plated lizard” *Gerrhosaurus major bottegoi* Del Prato (Sauria: Cordylidae). The subspecific designation follows that of Broadley (1987). It was not possible to obtain permission to euthanise animals for deposition of a symbiotype.

Type locality: Near Loka, southern Sudan, 4°7’51’’N, 31°9’36’’E. Faecal sample collected one month after importation into the UK.

Type material: Phototype deposited at the Natural History Museum, London. The accession number for the holotype is 1999:12:3:4. The images will be digitised and kept in perpetuity as a computer file (“digitotype”).

Site of infection: Unknown; oocysts found in faeces.

Prevalence: 1/8 (12.5%) animals collected from various locations in Sudan and imported at different times were positive for *E. foulshami*.

Additional hosts and localities: None.

Etyymology: The specific name is given for Peter Foulsham, who greatly assisted in collection of faecal samples from an extensive collection of reptiles over a three-year period.

Caryospora regentensis sp. n.

Figs. 2, 5

Description: Oocysts spherical to subspherical (predominantly spherical), $16.8 \pm 0.53 \times 16.4 \pm 0.72$ ($16-17.6 \times 15-17.2$) $n = 20$; SI = 1.02. Wall double-layered, smooth and colourless, about 0.5 thick. Micropyle and oocyst residuum absent, single polar granule present. Sporocysts ovoidal, 13.0×10.3 ($10.2-14.1 \times 9.3-11.1$), $n = 20$; SI 1.26. Cap-like Stieda body and globular, ellipsoidal substieda body present. Stieda and substieda bodies are roughly the same length and width. Prominent, large sporocyst residuum present, consisting of numerous (15-20) large globules compacted within

the curvature of the sporozoites and filling up the sporocyst completely. A single posterior residual body is usually visible in the sporozoites.

Type host: “Green mamba”, *Dendroaspis viridis* Hallowell, 1844 (Serpentes: Elapidae). The host individual was an adult male, ZSL accession No. C190. The samples were collected 17 months after importation into the UK (arrival in UK: 28th April 1989, sample collected 9th October 1989). This individual was previously held at the National Museum of Kenya, Nairobi, Kenya for a short, but unknown period. Because this animal was part of a captive breeding programme, it was considered unethical to euthanise the individual for deposition of a symbiotype.

Type locality: Green mamba was captured at an unknown location in Kenya.

Type material: Phototypes deposited at the Natural History Museum, London. The holotype (accession number 1999:12:3:1) and two paratypes have been deposited (accession numbers 1999:12:3:2 and 1999:12:3:3). These will be digitised and kept in perpetuity in the form of computer files (“digitotypes”).

Site of infection: Unknown; oocysts found in faeces.

Prevalence: 1/1 individual harboured oocysts of *C. regentensis*.

Additional hosts and localities: None.

Etyymology: The specific name is given in honour of the Zoological Society of London, which has been located in Regent’s Park, London since the society’s founding in 1826. Through its zoological gardens and the Institute of Zoology, this learned society has conducted over 150 years of practical conservation work and scientific research. The name is derived from the addition of “-ensis” (“of the place”) to a latinisation of the proper noun “Regent’s” (“Regent”).

Figs. 4, 5. Composite line drawings of sporulated oocysts of coccidian parasites from African reptiles. **Fig. 4.** *Eimeria foulshami* sp. n. **Fig. 5.** *Caryospora regentensis* sp. n. Scale bars = 10 μ m.

Caryospora legeri Hoare, 1933

Fig. 3

Description: Oocysts subspherical, $33.0 \pm 1.7 \times 29.3 \pm 1.3$ ($29.8\text{--}36.0 \times 27\text{--}32.4$) $n = 100$; SI = 1.13. Micropyle, oocyst residuum and polar granule absent. Sporocyst ovoidal, $22.0 \pm 0.8 \times 13.1 \pm 0.8$ ($20.8\text{--}23.4 \times 12.6\text{--}14.2$) $n = 100$. Stieda and substieda bodies present, although substieda body difficult to distinguish in some oocysts. Substieda body slightly wider than Stieda body, but thinner. Granular sporocyst residuum present, consisting of a large elongate mass lying at the centre of the group of sporozoites and visible protruding between them.

Host: "Hissing sand snake", *Psammophis sibilans sibilans* L., 1758 (Serpentes: Colubridae).

Locality: Sokoto, northwestern Nigeria, $13^{\circ}11'19''\text{N}$, $5^{\circ}17'24''\text{E}$. Sample collected at a dealer's premises two months after importation into the UK.

Site of infection: Unknown; oocysts found in faeces.

Prevalence: 1/1 animal positive for oocysts.

Other findings

Examination of faecal samples from an individual *Chamaeleo dilepis dilepis* Leach, 1819 ("flap-necked chameleon") recently imported into the collection of the ZSL from Cameroon, West Africa, revealed large numbers of oocysts of *Eimeria bohemi* Modrý, Šlapeta et Koudela, 2000. These were cylindroidal $26.5 \pm 1.1 \times 17.0 \pm 0.63$ ($25\text{--}27.5 \times 16.2\text{--}17.5$), SI = 1.56, with ellipsoidal sporocysts, 9.5×6.0 ($8.8\text{--}10 \times 5\text{--}7.5$), SI = 1.6.

They differed only slightly from the type description, in oocyst and sporocyst shape indices. The same individual revealed very few oocysts of an unidentified spherical *Eimeria* species. The latter were spherical 24×24 ($24\text{--}24.2 \times 24\text{--}24.2$), SI = 1.0, $n = 3$. Micropyle, oocyst residuum and polar granules absent. Sporocysts ellipsoidal, 10.6×8.8 , SI = 1.21, $n = 3$.

DISCUSSION

Eimeria foulshami. Paperna and Landsberg (1989) proposed two new generic names for eimerian coccidia of reptiles based on the site of development of endogenous stages, the reaction of host cells to parasite development and common oocyst morphology (shape, presence/absence of a Stieda body and exogenous/endogenous sporulation). This form of classification has not been widely accepted and is not used in the current paper. However, should the criteria proposed by Paperna and Landsberg (1989) become recognised as sufficient for the designation of new genera and knowledge of the endogenous development of *E. foulshami* become available, its generic classification should be re-assessed. The cylindroidal-ellipsoidal oocysts of the following *Eimeria* species are the same width or wider than *E. foulshami*, but all are longer: *Eimeria urosauris* Bovee, 1966 (SI, 1.6) from *Urosaurus graciosus* in California (Bovee 1966); *Eimeria umis* Bovee, 1969 (SI, 1.86) from *Uma notata*

in California (Bovee 1969); *Eimeria basilisci* Duszynski, 1969 (SI, 2.14) from *Basiliscus basiliscus* in Costa Rica (Duszynski 1969); *Eimeria ahtanumensis* Clark, 1970 (SI, 1.73) from *Sceloporus occidentalis* in Central Washington State, USA (Clark 1970); and *Eimeria anolidis* Daszak et Ball, 1991 (SI, 1.96) from *Anolis carolinensis* in Florida (Daszak and Ball 1991). The only cylindroidal eimerian from the family Cordylidae, *Eimeria murphyi* Upton, McAllister et Garrett, 1993 from *Cordylus cataphractus* is much larger, truly cylindroidal (SI, 2.07) and possesses a polar granule (Upton et al. 1993).

***Caryospora regentensis*.** Five species of *Caryospora* have been previously described from snakes of the family Elapidae. Of these, *Caryospora constanciae* Lainson, Paiva do Nascimento et Shaw, 1991 from *Micrurus spixii spixii* in Brazil (Lainson et al. 1991) and *Caryospora demansiae* Cannon, 1967 from *Demansia psammophis* in Australia (Cannon 1967) are significantly larger with no overlap in oocyst or sporocyst ranges for the former. The presence of small dark-brown tubercles on the outer wall, predominant lack of polar granules and smaller sporocyst residuum further distinguishes *C. demansiae* from *C. regentensis*. *Caryospora cobrae* Nandi, 1985 from *Naja naja* in India (Nandi 1985) is larger with a distinct micropyle and without a polar granule. Oocysts of *Caryospora najae* Matuschka, 1982 from *Naja nigricollis pallida* in East Africa (Matuschka 1982) lack a polar granule, are markedly smaller than and overlap only slightly in size ranges with oocysts of *C. regentensis*. The sporocysts of *C. najae* also are smaller and contain a more scattered residuum consisting of less granules than those of *C. regentensis*. Both oocysts and sporocysts of *Caryospora micruri* Lainson, Paiva do Nascimento et Shaw, 1991 from *Micrurus spixii spixii* in Brazil (Lainson et al. 1991) overlap in size ranges with *C. regentensis*; however, the sporocyst residuum of *C. micruri* is less noticeable, consisting of smaller granules scattered loosely within the sporocyst. These morphological differences, combined with the geographical isolation and evolutionary distance between these hosts suggest that the two species are distinct.

Caryospora legeri Hoare, 1933. The oocysts described in the current paper are larger than the type, described from a *Psammophis s. sibilans* from Entebbe, Uganda (Hoare 1933); however, oocyst length ranges overlap although width ranges do not by 1.4 μm . Sporocyst width ranges overlap, but length ranges do not by 1.5 μm . The morphology of oocysts and sporocysts is identical between the two isolates. The only other difference is that Hoare (1933) reports a “minute funnel-shaped micropyle” which “can sometimes be made out” in *C. legeri* oocysts. The lack of this feature (which may simply be an erroneously identified polar granule attached to the oocyst wall) in another isolate

from the same host species is almost certainly not of enough significance to warrant designation of a separate species. For this reason and because there are overlaps in dimensions of both oocyst and sporocyst, we conclude that the species reported in the current paper is *C. legeri* and represents a new geographic record for the species.

Caryospora legeri Hoare, 1933. Syn.: *Caryospora psammophi* Bray, 1960; *Caryospora hermae* Bray, 1960. We propose that *C. psammophi* and *C. hermae* should be considered junior synonyms of *C. legeri*. The oocysts described for *C. psammophi* and *C. hermae* from *Psammophis sibilans phillipsi* from Liberia, west Africa are insufficiently distinct from each other and from those of *C. legeri* Hoare, 1933 from *P. s. sibilans* to warrant separate specific status.

***Caryospora psammophi*:** Oocysts of this species were originally described from the faeces of a Liberian *Psammophis sibilans phillipsi*, a western subspecies of the type host of *C. legeri*. The only differences between *C. psammophi* and *C. legeri* are size (which overlap significantly for length and width of both oocyst and sporocyst) and the lack of the micropyle (possibly a misidentified polar granule attached to the oocyst wall) reported in some oocysts of *C. legeri* (Hoare 1933, Bray 1960). It is unclear whether oocysts of *C. psammophi* possess a substieda body since although Bray (1960) does not state whether one is present or absent, his drawing shows an oocyst without a substieda, in contrast to those of *C. legeri* (Hoare 1933). However, substieda bodies were difficult to distinguish in many of the oocysts of *C. legeri* examined in the current study, suggesting that these differences are also probably insufficient to warrant separate specific status. Endogenous stages also showed no significant morphological differences from *C. legeri*. In their review of the genus *Caryospora*, Upton et al. (1986) suggested that *C. psammophi* “may, in time, prove to be a synonym of *C. legeri*” and commented that the two differ in the presence of a small, dubious micropyle. Measurement ranges of oocysts and sporocysts for the type *C. legeri* and *C. psammophi* overlap, as do ranges for *C. psammophi* and the oocysts reported as *C. legeri* in the current paper. We therefore propose that *C. psammophi* is a junior synonym of *C. legeri* Hoare, 1933.

***Caryospora hermae*:** Bray himself noted that the oocysts of his *C. hermae* only differed from *C. (psammophi) legeri* in size and from the type of *C. legeri* in size, lack of a micropyle, smaller amount of sporocyst residuum and an oval schizont (Bray 1960). Of these criteria, none appear to be valid. Firstly, the length and width ranges for both oocysts and sporocysts of *C. hermae* and *C. legeri* overlap. Secondly, the micropyle of *C. legeri* is only present on some oocysts. Thirdly, the amount of sporocyst residuum appears to be similar between the two species and finally,

schizonts of both species are oval in longitudinal section and, since the shape of endogenous stages of coccidia may vary, are not a valid criterion for distinguishing species. Thus we propose that *C. hermae* is a junior synonym of *C. legeri*. This brings the total number of *Caryospora* species found in *P. sibilans* to two: *C. legeri* Hoare, 1933 from *Psammophis sibilans sibilans* and *C. weyeriae* Bray, 1960 from *P. sibilans phillipsi*.

Eimeria samyadeli Iskander et Tadros, 1979 emend. *Eimeria samiae* Iskander et Tadros, 1979 was described from the intestinal contents and gall bladder of an Indonesian species of python, *Python "reticulata"* (Serpentes: Pythonidae), which died at Giza Zoo, Egypt. The senior author named the species after his son, Samy Adel Iskander and incorrectly used the feminine gender. The specific name should have read "samyi" to reflect the gender of the person honoured. However, emending to the correct gender may cause confusion with *Eimeria sami* described by Bovee (1971) from the scincid lizard *Eumeces oshimensis* of Amami Island, Japan and named in honour of Dr. Sam R. Telford. We have avoided this problem and conformed to the original aim of honouring the senior author's son by emending the specific name to the masculine genitive of Samy Adel: *samyadeli*. In addition to this correction, the specific name of the host was misspelled and should be corrected to *Python reticulatus* Schneider, 1801. A further potential problem exists with the original description of *E. samyadeli*. It is not possible to discern either sporocyst walls or sporozoites in the photomicrographs published by Iskander and Tadros (1979) and the lack of detail in the drawings makes it impossible to confirm that the species is an eimerian. Furthermore, the author's description of the sporocyst as "banana-like" and containing "two sporozoites which occur near its two extremities, leaving a small vacant place in its middle" is unusual. Oocysts of a number of *Eimeria* spp. of snakes have been described which contain very elongate sporocysts (Upton and McAllister 1990, Upton et al. 1992) and it may be that sporocysts of *E. samyadeli* are similar in appearance. However, it seems likely that a re-examination of this species would be useful and might allow a more detailed description.

Unidentified *Eimeria* sp. The only eimerians reported from the Chamaeleonidae with spherical or sub-spherical oocysts are an unidentified species recovered

from the gallbladder and intestinal tract, respectively, of seven *Chamaeleo* spp. in Madagascar (Brygoo 1963) and *Eimeria vencesi* and *Eimeria worthi* from Madagascan chameleons (Modrý et al. 2001). It is clear that Brygoo (1963) considered all samples of the spherical species conspecific and he therefore gave measurements for those from *Chamaeleo oustaleti* (25-26 oocyst diameter) and drew those from *Chamaeleo brevicornis* (19.7 oocyst diameter, 8.8 sporocyst diameter, measured from drawing). The spherical oocysts reported from *Chamaeleo dilepis* in the current paper are smaller than those reported from *C. oustaleti* and larger than those from *C. brevicornis* (Brygoo 1963). The two species found in Madagascan chameleons by Modrý et al. (2001) have smaller oocysts which do not overlap in range with the unidentified eimerian presented here. All other coccidia reported from chameleons are eimerians with cylindroidal oocysts (Modrý et al. 2000) or isosporans (Sergeant 1902, Modrý and Koudela 1995, Modrý et al. 2000). These data and the geographical and evolutionary distance between the Malagasy and African mainland chameleons suggest that the spherical *Eimeria* species reported in the current paper from *C. dilepis* is probably new and if further specimens become available, should be described as such.

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