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Coccidian Parasites (Apicomplexa: Eimeriidae) of Arkansas Herpetofauna: A Summary with Two New State Records

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Cover Page Footnote

We thank K. Carmen and C. Kerr (Univ. of Wyoming-Casper) for help processing oocysts from *H. turcicus*. Scientific Collecting Permits were issued to CTM, MBC, HWR, and SET by the Arkansas Game and Fish Commission. This contribution would not have been possible without the mentorship and training of CTM by the late S.J. Upton, Kansas St. Univ., Manhattan, KS., coccidian expert extraordinaire. This study was supported, in part, by a grant from the National Institute of General Medical Sciences (2P20GM103432), National Institutes of Health (NIH) to RSS. The content is solely the responsibility of the authors and does not necessarily represent the official views of the NIH.

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Coccidian Parasites (Apicomplexa: Eimeriidae) of Arkansas Herpetofauna: A Summary with Two New State Records

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Running Title: Coccidians of Arkansas Herpetofauna

Abstract

Coccidian parasites (Protista: Apicomplexa: Eimeriidae) commonly infect reptiles, and to a lesser degree, amphibians. The family Eimeriidae includes at least 18 genera and 3 of them, *Caryospora*, *Eimeria*, and *Isospora* have been reported previously from various Arkansas herpetofauna. Over the past 3 decades, our community collaborative effort has provided a great deal of information on these parasites found in amphibians and reptiles of Arkansas. Here, we provide a summary of all coccidians reported from herptiles of the state as well as provide 2 new state records for coccidians from non-native Mediterranean geckos, *Hemidactylus turcicus*.

Introduction

Coccidians (Eimeriidae) are endoparasites that belong to the protist phylum Apicomplexa, suborder Eimeriorina. They are some of the most ubiquitous of all taxa of protists found in vertebrate animals. However, except for some that are medically or of veterinary importance in domestic animals and humans, they are most likely the least studied and understood of all vertebrate endoparasites.

In general, coccidians have a rather complex life cycle (Fig. 1), with 3 sequential stages, including reproduction by endogenous (intracellular) merogony and gametogony followed by sporogony, which is extracellular (in the form of the oocyst). The oocyst represents the cyst containing the fertilized cell (zygote). Interestingly, the oocyst is highly resistant to all known fixative techniques, and the majority of all species descriptions (diagnoses) are based on the sporulated oocyst. No satisfactory methods are known to preserve the structural integrity of the oocyst

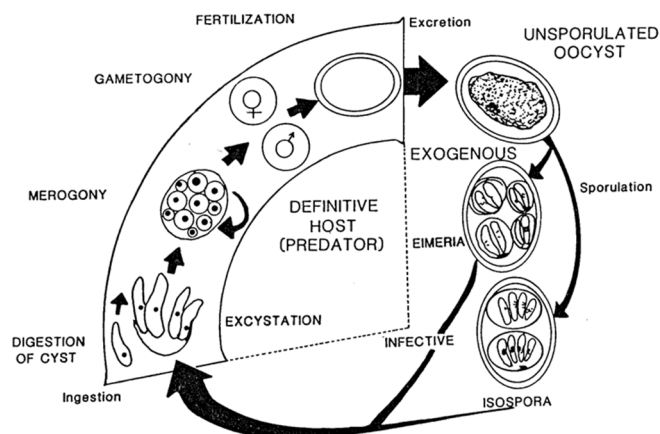


Figure 1. Life cycle of *Eimeria* and *Isospora* spp. (Redrawn from Fayer 1982).

permanently, so the taxonomy of coccidians has generally been non-specimen based. As a result, many species are described solely on measurements of morphological structures of the infective sporulated oocyst (Fig. 2), some additional key qualitative features (particularly shape), line drawings, photomicrographs, and consideration of host species and geographic range. Only within the last couple of decades have molecular techniques (amplifying DNA) been applied to coccidians to help supplement morphological data (see Morrison *et al.* 2004; Jirků *et al.* 2002, 2009; Megía-Palma *et al.* 2015).

There are distinct morphological and endogenous developmental differences in 5 of the genera of coccidians that occur in amphibians and reptiles in the state. The genus *Eimeria* Schneider, 1875 is the largest genus in the family with oocysts having 4 sporocysts, each with 2 sporozoites; *Isospora* Schneider, 1881 has oocysts with 2 sporocysts, each with 4 sporozoites; *Caryospora* Léger, 1904 has oocysts possessing a single

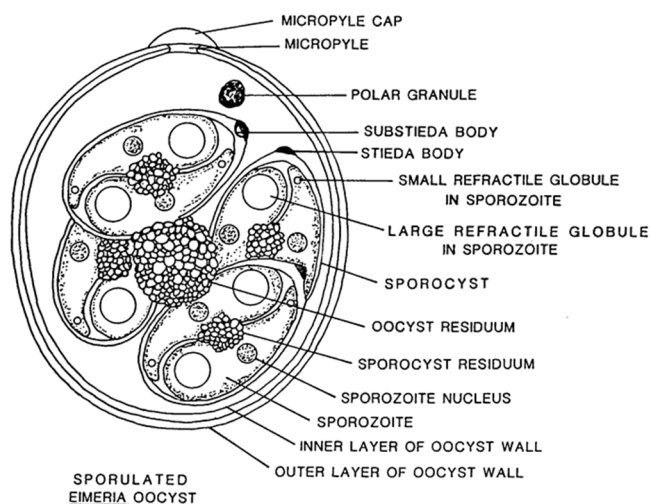


Figure 2. Sporulated *Eimeria* sp. oocyst showing morphological structures used to distinguish species. (Redrawn from Levine 1978).

sporocyst, each with 8 sporozoites; in addition, the typical life-cycle of a caryosporan species has both direct and facultatively heteroxenous life-cycle components (see Duszynski and Upton 2009); *Acrooimeria* Paperna and Landsberg, 1989 have oocysts that are small, spheroidal, and shed in the unsporulated condition, and, when sporulated, they are similar to those of *Eimeria* species, to which they are closely related; also, they have endogenous development with a parasitophorous vacuole that begins to bulge above the surface of the intestinal mucosal cells as meronts and gamonts continue to grow; the host cell cytoplasm expands as the parasite grows, giving rise to a short, stalk-like structure forming a layer on the surface of the gut mucosa; this endogenous development occurs above the host cell nucleus and below the brush border in the enterocytes of the ileum; lastly, the genus *Choleoimeria* Paperna and Landsberg, 1989 is restricted to coccidians infecting the gallbladder and biliary epithelium of reptiles, and possesses elongate-ellipsoidal oocysts (L/W ratio >1.5) with 4 sporocysts, each with 2 sporozoites; it is further characterized by sporocysts without a Stieda/substieda body complex, but with longitudinal sutures in their walls.

Among Arkansas herpetofauna, there are several reports of coccidians in reptiles, including those in turtles (McAllister *et al.* 1994a; Duszynski and Morrow 2014), lizards (McAllister *et al.* 1994b), and snakes (Duszynski and Upton 2009). On the other hand, there are fewer reports of coccidia in amphibians (Upton and McAllister 1988; McAllister *et al.* 1993, 2002; Upton *et al.* 1993; Duszynski *et al.* 2007).

In Arkansas, to our knowledge, there were no previous reports of coccidians infecting amphibians or

reptiles prior to 1975, when Leon W. Bone, then of the University of Arkansas, reported *Eimeria pseudemydis* Lainson from a red-eared slider, *Trachemys scripta elegans* from Lonoke County (Bone 1975). Since then, there has been an explosion of reports describing new and previously described coccidians of Arkansas herpetofauna (see citations in McAllister *et al.* 1994; Duszynski *et al.* 2007; Duszynski and Upton 2009; Duszynski and Morrow 2014) but a summary of those species in the state has never been published. Here, we provide a summary of the coccidian parasites within the largest family of the phylum (Eimeriidae) in the amphibians and reptiles of the state as well as document 2 coccidians from Arkansas for the first time.

Materials and Methods

A thorough examination of the published literature was conducted on coccidians previously reported from amphibians and reptiles of Arkansas. In addition, 3 adult Mediterranean geckos (*Hemidactylus turcicus*) were collected in October 2013 and April 2014 from El Dorado, Union County ($n = 2$), and one in April 2017 from Forrest City, St. Francis County (McAllister and Robison 2017). In addition, a single prairie kingsnake (*Lampropeltis calligaster calligaster*) was found dead on the road in October 2016 in Saline County; all were examined for coccidia. Fresh fecal samples were placed in individual vials containing 2.5% (w/v) aqueous potassium dichromate ($K_2Cr_2O_7$). Samples were examined for coccidia using an Olympus BX53 light microscope after flotation in Sheather's sugar solution (specific gravity = 1.30). Measurements were taken on 15 sporulated oocysts using Olympus® cellSens 1.14 digital software and reported in micrometers as means; photographs were taken using Nomarski interference-contrast optics. Oocysts were 780–960 days old when measured and photographed. For light microscopy, tissue samples from the intestine and gall bladder of *H. turcicus* were fixed in 10% neutral-buffered formalin and processed as histological sections following standard methods of staining with hematoxylin and eosin or Pollak trichrome stain (Presnell and Schreibman 1997). A host photovoucher was accessioned into the Arkansas State University Museum of Zoology (ASUMZ) Herpetological Collection, State University, AR as ASUMZ 33619. Photosyntypes of sporulated oocysts were accessioned into the Harold W. Manter Laboratory of Parasitology (HVML), Lincoln, NE.

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Results and Discussion

Of the amphibian hosts, there are only 5 species of valid coccidians known from the state whereas there are 50 valid species in the reptiles of Arkansas. Indeed, Upton *et al.* (1993) examined 238 caudate amphibians from Arkansas within 7 families and found only 9 (4%) harbored coccidians. Upton and McAllister (1988) also reported low prevalence in 4 anuran amphibians from the state. Concerning reptilian hosts, there are 50 taxa, 18 species in turtles, 8 species in lizards, and 24 coccidian species in snakes.

All 4 of the *H. turcicus* were found to be infected with coccidia as follows: 3 harbored *Acroeimeria lineri* and one was infected with *Choleoeimeria turcicus*. The single *L. c. calligaster* was found to be passing *Caryospora lampropeltis*. Data for each is listed below in the annotated checklist as well as those known from other Arkansas herpetofauna.

Annotated Checklist of Coccidians from Arkansas Herpetofauna

AMPHIBIA: CAUDATA: AMBYSTOMATIDAE

FAMILY EIMERIIDAE MINCHIN, 1903

GENUS *EIMERIA* SCHNEIDER, 1875

Eimeria opacum Upton, McAllister and Trauth, 1993

Host: Marbled salamander, *Ambystoma opacum*.

Locality: Grant Co.

Prevalence: 1/3 (33%).

PLETHODONTIDAE

Eimeria sp. of McAllister, Upton, and Trauth, 2002, *incertae sedis*

Host: Kiamichi slimy salamander, *Plethodon kiamichi*.

Locality: Polk Co.

Prevalence: 1/16 (6%).

Remarks: McAllister *et al.* (2002) found a single *P. kiamichi* passing oocysts they identified as an *Eimeria* species, but did not describe or name it. Duszynski *et al.* (2007) considered this eimerian an *incertae sedis*. Additional samples are needed to determine its identity. The host is a Species of Special Concern in the state.

GENUS *ISOSPORA* SCHNEIDER, 1881

Isospora hightoni Upton, McAllister, and Trauth, 1993

Host: Western slimy salamander, *Plethodon albagula*.

Localities: Grant (type), Independence, Lawrence, Montgomery, Perry, and Pope cos.

Prevalence: 1/6 (33%), 1/1 (100%), 1/2 (50%), 2/5 (40%), 1/2 (50%), and 2/2 (100%), respectively.

Remarks: Among the *ca.* 7,696 species of worldwide amphibians, there are only 11 valid species of *Isospora* (Duszynski *et al.* 2007).

ANURA: HYLIDAE

Isospora delicatus Upton and McAllister, 1988

Host: Illinois chorus frog, *Pseudacris illinoensis*.

Locality: Clay Co.

Prevalence: 1/8 (13%).

Remarks: This frog is found only in Clay County in far northeastern Arkansas (Trauth *et al.* 2004) and is a Species of Greatest Conservation Need in the state (Anonymous 2016).

RANIDAE

Eimeria fitchi McAllister, Upton, Trauth, and Bursey, 1995

Host: Wood frog, *Rana* (= *Lithobates*) *sylvaticus*.

Locality: Izard Co.

Prevalence: 11/13 (85%).

Remarks: This was the first ranid frog in the U.S. documented to harbor coccidia and the host is a Species of Special Concern in the state.

Eimeria menaensis McAllister, Seville, Bursey, Trauth, Connior, and Robison, 2014

Host: Green frog, *Rana* (= *L.*) *clamitans*.

Locality: Polk Co.

Prevalence: 1/20 (5%).

REPTILIA: TESTUDINES: CHELYDRIDAE

Eimeria chelydrae Ernst, Stewart, Sampson, and Fincher, 1969

Host: Common snapping turtle, *Chelydra serpentina*.

Localities: Benton, Boone, and Woodruff cos.

Prevalence: 1/1 (100%) in each co.

Remarks: Oocysts of *E. chelydrae* wrinkle easily in Sheather's sugar solution so it is recommended that the concentrated sugar solution be diluted 50:50 in distilled water when examining oocysts from *C. serpentina* (see McAllister and Hnida 2016).

Eimeria filamentifera Wacha and Christiansen, 1979

Host: *C. serpentina*.

Locality: Boone Co.

Prevalence: 1/1 (100%).

Eimeria harlani Upton, McAllister, and Trauth, 1992

Host: Alligator snapping turtle, *Macrochelys temminckii*.

Locality: Jackson Co.

Prevalence: 1/1 (100%).

Remarks: This is the only coccidian known to date from *M. temminckii*. The host is a Species of Special Concern in the state.

***Eimeria serpentina* McAllister, Upton, and Trauth, 1990**

Host: *C. serpentina*.

Localities: Boone (type) and Carroll cos.

Prevalence: 1/1 (100%) in both counties.

***Isospora chelydrae* McAllister, Upton, and Trauth, 1990**

Host: *C. serpentina*.

Localities: Benton 1/1 (100%), Carroll (type), and Woodruff cos.

Prevalence: 1/1 (100%) in each county.

Remarks: This is only the 4th isosporan known from ca. 350 species of turtles worldwide (Duszynski and Morrow 2014; Hnida 2015).

EMYDIDAE

***Eimeria carri* Ernst and Forrester, 1973**

Host: Three-toed box turtle, *Terrapene mexicana* (=carolina) *triunguis*.

Locality: Garland, Pope, and Sharp cos.

Prevalence: 3/9 (33%) overall.

***Eimeria chrysemydis* Deeds and Jahn, 1939**

Host: Common map turtle, *Graptemys geographica*.

Locality: Fulton Co.

Prevalence: 1/7 (14%).

***Eimeria doddi* McAllister, Motriuk-Smith, Kerr, Carmen, Seville, and Connior, 2017**

Host: Ornate box turtle, *Terrapene ornata*.

Locality: Benton Co.

Prevalence: 1/3 (33%).

Remarks: The host is a Species of Special Concern in the state.

***Eimeria graptemydos* Wacha and Christiansen, 1976**

Hosts: Southern painted turtle, *Chrysemys picta*, Mississippi map turtle, *Graptemys pseudogeographica kohnii*, *G. geographica*, and Mississippi mud turtle, *Kinosternon subrubrum hippocrepis*.

Localities: Arkansas (see Duszynski and Morrow 2014).

Prevalence: 1/1 (100%), 1/4 (25%), 1/7 (14%), and 2/6 (33%), respectively.

***Eimeria marginata* (Deeds and Jahn, 1939) Pellérdy, 1974**

Hosts: *C. picta*, *G. geographica*, and eastern river

cooter, Missouri River cooter, *Pseudemys concinna metteri*.

Localities: Cross and Fulton cos.

Prevalence: 1/1 (100%), 1/7 (14%), and 1/4 (20%), respectively.

***Eimeria mitraria* (Laveran and Mesnil, 1902) Doflein, 1909**

Hosts: *T. m. triunguis*.

Locality: Pope Co.

Prevalence: 1/9 (11%).

***Eimeria ornata* McAllister and Upton, 1989**

Host: *T. m. triunguis*.

Localities: Fulton, Pike, and Union cos.

Prevalence: 9/24 (38%) overall.

Remarks: McAllister *et al.* (2015) documented this coccidian from *T. m. triunguis* and Arkansas, for the first time.

***Eimeria pseudemydis* Lainson, 1968**

Host: Red-eared slider, *Trachemys scripta elegans*.

Locality: Lonoke Co.

Prevalence: 1/1 (100%).

***Eimeria pseudogeographica* Wacha and Christiansen, 1976**

Host: Ouachita map turtle, *Graptemys ouachitensis*.

Locality: Fulton Co.

Prevalence: 1/3 (33%).

Remarks: Bone's (1975) report of *E. pseudemydis* is apparently the first documenting a coccidian in any wild host from Arkansas.

***Eimeria somervellensis* McAllister and Upton, 1992**

Host: *P. c. metteri*.

Locality: Fulton Co.

Prevalence: 2/6 (33%).

***Eimeria tetradacrutata* Wacha and Christiansen, 1976**

Host: *G. geographica*.

Locality: Baxter Co.

Prevalence: 3/7 (43%).

TRIONYCHIDAE

***Eimeria apalone* McAllister, Upton, and McCaskill, 1990**

Host: Western spiny softshell, *Apalone spinifera hartwegi*.

Locality: Conway Co.

Prevalence: 1/3 (33%).

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KINOSTERNIDAE

Eimeria lutotestudinis Wacha and Christiansen, 1976Host: *K. s. hippocrepis*.

Locality: Columbia Co.

Prevalence: 1/6 (17%)

SAURIA: GEKKONIDAE

GENUS *ACROEIMERIA* PAPERNA AND LANDSBERG, 1989*Acroeimeria lineri* (McAllister, Upton, and Freed, 1988) Paperna and Landsberg, 1989Host: *H. turcicus*.

Localities: St. Francis and Union cos.

Prevalence: 1/1 (100%), 2/3 (67%).

Morphology/measurements: Ellipsoidal smooth-walled oocysts (Fig. 3A) were (L × W) 24.1 × 18.1, L/W ratio = 1.3; a polar granule was present but a micropyle and oocyst residuum were absent. Subspheroidal sporocysts measured 7.4 × 6.9, L/W ratio = 1.1; Stieda and substieda bodies were absent but a sporocyst residuum was present, composed of numerous granules in a spheroidal or ovoidal mass.

Site of infection: Intestinal epithelium (Fig. 4 A-B).

Remarks: These measurements are similar to those previously reported for *A. lineri* (McAllister *et al.* 1988) from *H. turcicus* in Louisiana and Texas. We document a new geographic record for *A. lineri*. This coccidian (HWML 139319) has now been reported from non-native populations of *H. turcicus* in Arkansas, Louisiana, and Texas, and native populations in Israel (Paperna and Landsberg 1989).

GENUS *CHOLEOEIMERIA* PAPERNA AND LANDSBERG, 1989*Choleoimeria turcicus* (Upton, McAllister, and Freed, 1988) Paperna and Landsberg, 1989Host: *H. turcicus*.

Locality: Union Co.

Prevalence: 1/3 (33%).

Morphology/measurements: Elongate to cylindroidal smooth-walled oocysts (Fig. 3B) were (L × W) 35.6 × 17.8, L/W ratio = 2.0; a polar granule was present but a micropyle and oocyst residuum were absent. Ovoidal sporocysts measured 9.7 × 8.2, L/W ratio = 1.2; Stieda and substieda bodies were absent but a sporocyst residuum was present, composed of a compact mass of granules of various sizes.

Site of infection: Gallbladder epithelium (Fig. 4C-D).

Remarks: These measurements are similar to those in the original description previously reported for *C. (=Eimeria) turcicus* (Upton *et al.* 1988) collected from *H. turcicus* in Texas. We document a new geographic

record for *C. turcicus*. This coccidian (HWML 139320) has now been reported from non-native populations of *H. turcicus* from Arkansas and Texas, and native populations from Israel (Paperna and Landsberg 1989) and Egypt (Abdel-Haleem *et al.* 2016).

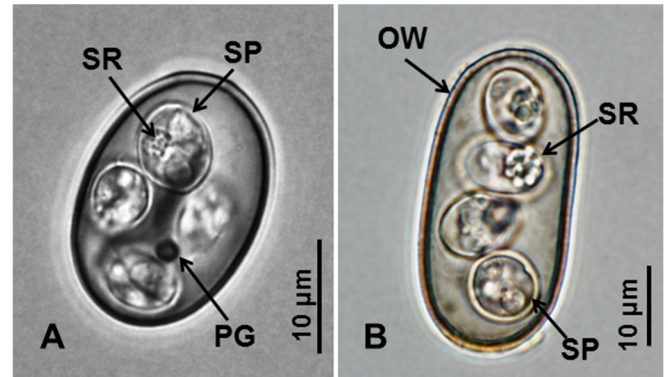


Figure 3. Coccidians from *Hemidactylus turcicus* (Union Co.). A. Sporulated oocyst of *Acroeimeria lineri*. B. Sporulated oocyst of *Choleoimeria turcicus*. Abbreviations: OW (oocyst wall); PG (polar granule); SP (sporocyst); SR (sporocyst residuum).

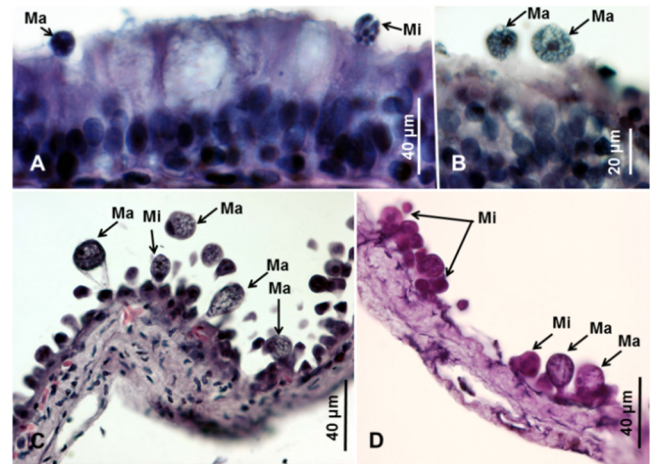


Figure 4. Endogenous stages of *Acroeimeria lineri* and *Choleoimeria turcicus* in *Hemidactylus turcicus* (Union Co.). A-B. Multinucleate microgamont (Mi) and Macrogamonts (Ma) of *A. lineri* in intestine of *H. turcicus*. C-D. Microgamonts (Mi) and macrogamonts (Ma) in gall bladder epithelium of *C. turcicus* in *H. turcicus*.

POLYCHROTIDAE

Eimeria robisoni McAllister, Seville, and Connor, 2014Host: Green anole, *Anolis carolinensis*.

Locality: Union Co.

Prevalence: 1/11 (9%).

SCINCIDAE

***Choleoimeria* (=Eimeria) *fasciatus* Upton, McAllister, and Trauth, 1991**

Host: Five-lined skink, *Plestiodon fasciatus*.

Localities: Pope, Washington, and Woodruff cos.

Prevalence: 1/1 (100%), 1/1 (100%), and 1/5 (20%), respectively.

Remarks: This coccidian was originally placed in the genus *Eimeria*; however, developmental stages were clearly shown in gall bladder epithelium (Fig. 5 of Upton *et al.* 1991). Paperna and Landsberg (1989) erected the genus *Choleoimeria* for eimeriid-like coccidians infecting the gallbladder epithelium of reptiles.

***Choleoimeria ouachitaensis* McAllister, Seville, Connior, Trauth, and Robison, 2014**

Host: Ground skink, *Scincella lateralis*.

Locality: Ouachita Co.

Prevalence: 2/6 (33%).

***Isospora koberi* McAllister, Seville, Connior, Trauth, and Robison, 2014**

Host: *S. lateralis*.

Localities: Calhoun, Marion (type), Ouachita, and Union cos.

Prevalence: 2/5 (20%), 2/2 (100%), 1/6 (17%), and 6/29 (21%), respectively.

***Isospora scinci* Upton, McAllister, and Trauth, 1991**

Host: *P. fasciatus*.

Localities: Bradley, Marion, Van Buren (type) and Woodruff cos.

Additional host and locality: Broadhead skink, *Plestiodon laticeps*, Independence Co.

Prevalence: 1/1 (100%), 1/2 (50%), 1/1 (100%), and 2/5 (40%), respectively; *P. laticeps*: (25%).

Remarks: McAllister *et al.* (1994) added *P. laticeps* to the host list and 20 yrs later, McAllister *et al.* (2014) provided an additional report of *I. scinci* from *P. fasciatus* and extended its range into Oklahoma.

TEIIDAE

***Choleoimeria* (*E.*) *sexlineatus* McAllister, Upton, and Trauth, 1991**

Host: Prairie racerunner, *Aspidoscelis sexlineatus viridis*.

Locality: Johnson Co.

Prevalence: 1/28 (4%).

Remarks: This is the only coccidian known from North American teiid lizards. It was originally placed in the genus *Eimeria* but developmental stages were clearly

shown in gall bladder epithelium (Fig. 3 of McAllister *et al.* 1991) which places the coccidian in the genus *Choleoimeria* sensu Paperna and Landsberg (1989).

OPHIDIA: COLUBRIDAE

***Eimeria arnyi* Upton and Oppert, 1991**

Host: Prairie ringneck snake, *Diadophis punctatus arnyi*.

Locality: Crawford and Marion cos.

Prevalence: 4/21 (19%).

***Eimeria attenuata* Wacha and Christiansen, 1974**

Hosts: Redbelly watersnake, *Nerodia erythrogaster*, broad-banded watersnake, *Nerodia fasciata confluens* western ribbon snake, *Thamnophis proximus proximus*.

Localities: Drew, Johnson, and Ouachita cos.

Prevalence: 2/20 (10%), 1/13 (8%), and 1/7 (14%), respectively.

***Eimeria conanti* McAllister and Upton, 1989**

Host: Mississippi green watersnake, *Nerodia cyclopion*, *N. erythrogaster*.

Locality: Mississippi Co.

Prevalence: 2/20 (10%).

***Eimeria cyclopion* McAllister, Upton, and Trauth, 1990**

Hosts: *N. cyclopion* (type), *N. erythrogaster*, *N. f. confluens*, diamondback watersnake, *Nerodia rhombifer*.

Locality: Mississippi Co.

Prevalence: 10/15 (67%), 1/1 (100%), 2/9 (22%), and 2/3 (67%), respectively.

Remarks: Oocysts of *E. cyclopion* degenerate rapidly, so it is recommended to measure and photograph specimens immediately after sporulation.

***Eimeria desotoensis* Upton, McAllister, and Trauth, 1992**

Host: Smooth earth snake, *Virginia valeriae elegans*.

Locality: Arkansas (see Duszynski and Upton 2009).

Prevalence: 1/3 (33%).

***Eimeria helmisophis* Wacha and Christiansen, 1974**

Hosts: Midwest worm snake, *C. a. helenae*, western worm snake, *Carphophis vermis*.

Localities: Carroll, Crawford, and Green cos.

Prevalence: 1/3 (33%) and 7/14 (50%).

Remarks: An *E. helmisophis*-like coccidian was reported from 3 taxa of watersnakes as follows: 5 of 20 (25%) *N. erythrogaster*, 3 of 13 (25%) *N. f. confluens*, and 11 of 30 (37%) *N. s. pleuralis* in Arkansas by

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McAllister *et al.* (1995a). This coccidian is morphologically similar to oocysts of *E. helmisophis*. Duszynski and Upton (2009) listed this eimerian as a *species inquirenda*. However, studies utilizing DNA sequences will be necessary to elucidate significant differences between oocysts from worm snakes and watersnakes.

***Eimeria hobartsmithi* Upton, McAllister, and Trauth, 1992**

Host: *V. v. elegans*.

Locality: Arkansas (see McAllister *et al.* 1995a).

Prevalence: 1/3 (33%).

***Eimeria hydrophis* Wacha and Christiansen, 1974**

Host: *N. erythrogaster*, *N. s. pleuralis*.

Localities: Crawford, Franklin, Johnson, Little River, Madison, Poinsett, and Saline cos.

Prevalence: 11/20 (10%) and 9/30 (37%).

***Eimeria iowaensis* Wacha and Christiansen, 1974**

Host: *N. f. confluens*.

Locality: Poinsett Co.

Prevalence: 1/13 (8%).

***Eimeria kennicotti* Upton, McAllister, Trauth, and Gage, 1995**

Host: *D. p. arnyi*.

Locality: Polk Co.

Prevalence: 2/2 (100%).

***Eimeria natricis* Wacha and Christiansen, 1975**

Host: *N. erythrogaster*, *N. f. confluens*, midland water snake, *Nerodia sipedon pleuralis*, *T. p. proximus*.

Localities: Craighead, Crawford, Jackson, Little River, and Ouachita cos.

Prevalence: 2/20 (10%), 1/13 (8%), 2/30 (7%), and 1/7 (14%), respectively.

***Eimeria rhombifera* Upton and McAllister, 1988**

Host: *N. rhombifer*.

Locality: Mississippi Co.

Prevalence: 1/6 (17%).

***Eimeria septemvittata* Upton, McAllister, and Trauth, 1991**

Host: Queen snake, *Regina septemvittata*.

Locality: Johnson Co.

Prevalence: 3/3 (100%).

***Eimeria serpenticola* Upton and McAllister, 1990**

Hosts: *N. f. confluens*, *N. s. pleuralis*, *T. p. proximus*.

Localities: Drew, Marion, Poinsett, and Sharp cos.

Prevalence: 1/13 (8%), 3/30 (10%), and 1/7 (14%), respectively.

***Eimeria sipedon* Wacha and Christiansen, 1975**

Hosts: *N. erythrogaster*, *N. f. confluens*, *N. s. pleuralis*.

Localities: Crawford, Drew, IZard, Jackson, Johnson, Lonoke, Poinsett, Ouachita, Saline, and Sharp cos.

Prevalence: 11/20 (55%), 2/13 (15%), and 6/30 (20%), respectively.

***Eimeria striatula* Upton and McAllister, 1990**

Host: Rough earth snake, *Virginia striatula*.

Localities: Arkansas and Texas (see Duszynski and Upton 1989).

Prevalence: 12/32 (38%) combined.

***Eimeria tenuis* Upton and McAllister, 1988**

Hosts: *N. erythrogaster*, *N. rhombifer*, *N. s. pleuralis*.

Localities: Crawford, Mississippi, and Sharp cos

Prevalence: 1/20 (5%), 3/6 (50%), and 2/30 (7%), respectively.

***Eimeria zamenis* Phisalix, 1921**

Hosts: Southern black racer, *Coluber constrictor priapus*, western rat snake, *Pantherophis obsoletus*.

Localities: Arkansas (see Duszynski and Upton 2009).

Prevalence: 1/10 (10%) and 2/13 (15%).

Remarks: McAllister *et al.* (1995) reported this species as an *E. zamenis*-like coccidian. They further mentioned that it was doubtful this coccidian is the same species found in European colubrids, and we concur. Duszynski and Upton (2009) noted that this "species" could be best called a *species inquirenda*. Additional research is ongoing to help possibly unravel this enigma, including examination of endogenous stages and DNA sequencing.

***Isospora wilsoni* Upton, McAllister, Trauth, and Bibb, 1992.**

Host: *T. gracilis*.

Locality: Crawford Co.

Prevalence: 2/12 (17%).

GENUS CARYOSPORA (LÉGER, 1904) LÉGER, 1911***Caryospora duszynskii* Upton, Current, and Barnard, 1984**

Hosts: Western coachwhip, *Coluber flagellum*, prairie kingsnake, *Lampropeltis calligaster calligaster*, speckled kingsnake, *Lampropeltis holbrooki*.

Localities: Conway, Franklin cos.

Prevalence: 1/3 (33%), 2/2 (100%), and 1/2 (50%), respectively.

Remarks: Modrý *et al.* (2005) demonstrated that mice (*Mus musculus*) are capable of indirectly transmitting infections of *C. duszynskii* to uninfected colubrid (rodent-feeding) snakes.

***Caryospora gracilis* Upton, McAllister, Trauth, and Bibb, 1992.**

Host: Flathead snake, *Tantilla gracilis*.

Locality: Crawford Co.

Prevalence: 1/12 (8%).

***Caryospora lampropeltis* Anderson, Duszynski, and Marquardt, 1968 (Fig. 5)**

Hosts: Eastern hognose, *Heterodon platirhinos*, *L. c. calligaster*, red milk snake, *Lampropeltis triangulum sypila*.

Localities: Ouachita; Lee and Saline cos; Lee Co.

Prevalence: 1/1 (100%), 1/6 (17%), 1/1 (100%), and 1/6 (17%), respectively.

Morphology/measurements: Oocysts (HWML 139321) were 25.6 × 21.3, a L/W ratio = 1.2, without a micropyle and oocyst residuum. Sporocysts measured 15.2 × 12.8, L/W ratio = 1.3, with Stieda and substieda bodies, and a sporocyst residuum. The outer wall of the oocyst was sculptured. These measurements and morphologies are similar to those in the original description of *C. lampropeltis* from *L. calligaster* from Illinois (Anderson *et al.* 1968) and those reported by McAllister *et al.* (2015) from *H. platirhinos* from Ouachita Co.

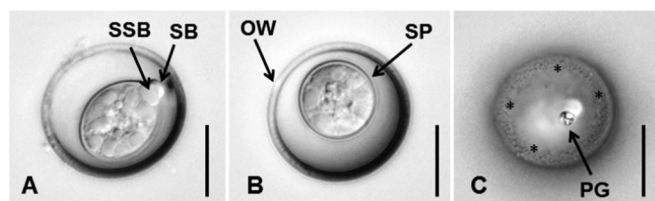


Figure 5. Oocysts of *Caryospora lampropeltis* from *Lampropeltis calligaster* from Saline Co. A. Oocyst showing Stieda body (SB) and substieda body (SSB). B. End-view of sporocyst (SP) showing oocyst wall (OW). C. Outer wall of oocyst showing sculptured appearance (*). Scale bars = 10 µm.

***Caryospora masticophis* Upton, McAllister, and Trauth, 1994**

Hosts: *C. flagellum* (type), *C. c. priapus*.

Locality: Saline Co.

Prevalence: 1/3 (33%) and 1/10 (10%).

VIPERIDAE

***Caryospora bigenetica* Wacha and Christiansen, 1982**

Hosts: Southern copperhead, *Agkistrodon contortrix contortrix*, timber rattlesnake, *Crotalus horridus*.

Localities: Polk Co.

Prevalence: 3/6 (50%) and 1/9 (11%).

Remarks: This species is pathogenic in secondary mammalian hosts (rodents, goats, dogs, pigs) and cause signs of clinical dermal coccidiosis, including markedly swollen facial tissue, ears, genitalia, and footpads (see Duszynski and Upton 2009).

CROCODYLIA: ALLIGATORIDAE

Coccidians have been reported from the American alligator, *Alligator mississippiensis* in southern Texas (McAllister and Upton 1990). However, none are known yet from this host in Arkansas.

Discussion

Interestingly, the latest phylogenetic studies on some coccidian parasites of lizards (e.g., caryosporans and isosporans) found evidence that support the polyphyletic origin of *Caryospora* and *Isospora* (Megía-Palma *et al.* 2015). Their results suggest that these 2 genera are artificial generic names because taxonomic names are based on a group monophyletic origin. Until this finding has been completely resolved and accepted using life-cycle information, we are herein using the current generic nomenclature.

We have provided a summary of the Eimeriidae of the state herpetofauna. However, there are other coccidians that have been reported from Arkansas reptiles, including *Sarcocystis* spp. (Lindsay *et al.* 1991, 1992; Upton *et al.* 1995) but we are yet to find *Cryptosporidium* spp. in any amphibian or reptile from the state (see Upton *et al.* 1989; McAllister *et al.* 1995b). With over 58 species and subspecies of amphibians and 78 taxa of reptiles (Trauth *et al.* 2004), Arkansas supports a vast array of herpetofauna in diverse physiographic regions, many of which still need to be examined. Thorough and systematic surveys will surely increase the number of coccidians reported from the herptiles of Arkansas, including the possibility of discovering new host and geographic records as well as new species.

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Coccidians of Arkansas Herpetofauna

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