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EIMERIA SPECIES (APICOMPLEXA: EIMERIIDAE) FROM ARCTIC GROUND SQUIRRELS (*SPERMOPHILUS PARRYII*) AND RED SQUIRRELS (*TAMIASCIURUS HUDSONICUS*) IN ALASKA AND IN SIBERIA, RUSSIA

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ABSTRACT: Fecal samples from arctic ground squirrels (*Spermophilus parryii*) collected in Alaska (n = 90) and Russia (n = 46) and from red squirrels (*Tamiasciurus hudsonicus*) in Alaska (n = 35) were examined for the presence of *Eimeria* spp. (Apicomplexa: Eimeriidae). Four species were recovered from arctic ground squirrels, including *Eimeria callospermophili* (prevalence = 18%), *Eimeria cynomysis* (23.5%), *Eimeria lateralis* (19%), and *Eimeria morainensis* (77%). A single species, *Eimeria tamiasciuri* (91%), was recovered from red squirrels. Eimerians recovered from arctic ground squirrels represent new host records, and the single species from red squirrels is a new geographic record. Alaskan arctic ground squirrel prevalence was higher for *E. callospermophili* (Alaska = 22% vs. Russia = 9%), *E. cynomysis* (34% vs. 2%), and *E. lateralis* (27% vs. 4%), but not *E. morainensis* (78% vs. 76%).

Arctic ground squirrels (*Spermophilus parryii* (Richardsoni, 1825)) occur in northwest Canada, Alaska, United States, and northeast Russia. They are sciurid rodents that include 5 genera and ~82 species adapted to a predominately fossorial–terrestrial existence (Wilson and Reeder, 1993). Wilber et al. (1998) reviewed all published literature on the coccidia known from marmotine rodents and recognized and provided descriptions for 26 valid *Eimeria* species.

Red squirrels (*Tamiasciurus hudsonicus* Erxleben, 1777) range from Alaska through the northeastern United States south to South Carolina. Some sciurids in the Tribe Tamiasciurini (3 genera and ~11 species) are adapted primarily to an arboreal existence (Wilson and Reeder, 1993). To date, only 2 species of coccidia—*Eimeria tamiasciuri* Levine, Ivens & Kruidenier, 1957, and *Eimeria toddi* Dorney, 1962—have been reported from red squirrels in the continental United States (Levine and Ivens, 1990).

In collaboration with the Beringian Coevolution project, which is systematically inventorying the mammals and associated parasites and pathogens of the Beringian region, we received feces from arctic ground squirrels collected from 2 unnamed locations and 5 national preserves in Alaska and 12 locations in northeastern Russia and red squirrels collected from 4 national preserves in Alaska. Here, we report results of our survey of eimerian species in arctic ground squirrels and red squirrels from these 2 regions and taxonomic details for the species recovered.

MATERIALS AND METHODS

Arctic ground squirrels were collected by shooting from 2 locations and 5 national preserves in Alaska (Bering Land Bridge National Preserve, Cape Krusenstern National Monument, Noatak National Preserve, Wrangle–St. Elias National Park [W-SENP], and Yukon-Charley Rivers National Preserve [Y-CRNP]), United States, and 12 locations in Magadanskaya oblast and Chukotka, Russia, during the summers of 2000, 2001, and 2002. Red squirrels were collected in Alaska from Kobuk Valley National Park, W-SENP, and Y-CRNP in 2001. Details regarding mammal collection are provided in Edingsaas et al. (2004). Fresh fecal samples were obtained from the colon of each host in the field and stored in vials containing 2% (w/v) aqueous potassium dichromate at ambient temperature to allow oocyst sporulation until examination at the University of Wyoming/Casper College Center and the University of New Mexico. Oocysts were isolated by flotation in saturated sucrose solution (specific gravity = 1.2) and identified with oil immersion lenses on a compound microscope with bright field and Nomarski differential interference contrast microscopy. Standardized abbreviations for oocyst and sporocyst characters, with a single exception (sporozoites = SZ), are those recommended by Wilber et al. (1998), including oocyst characters length (L) and width (W)—their ranges and ratio (L/W)—micropyle (M), residuum (OR), and polar granules (PG) and sporocyst characters length (L), width (W)—their ranges and ratio (L/W)—stieda body (SB), substieda body (SSB), parastieda body (PSB), residuum (SR), refractile bodies (RB), and nucleus (N). Measurements of standard morphologic parameters were made with an ocular micrometer and are reported as an average (μm) followed by the range in parentheses. Photomicrographs were produced, and photovouchers of sporulated oocysts were accessioned into the U.S. National Parasite Collection (USNPC), Beltsville, Maryland.

RESULTS

Fecal samples from 136 arctic ground squirrels and 35 red squirrels were examined, and 118 of the former and 32 of the latter were positive for the presence of *Eimeria* (87 and 91%, respectively). Four species were identified from arctic ground squirrels, including *Eimeria callospermophili* (prevalence = 18%), *Eimeria cynomysis* (23.5%), *Eimeria lateralis* (19%), and *Eimeria morainensis* (77%). Only a single species, *E. tamiasciuri* (91%), was identified from red squirrels. Table I presents summary data on prevalences for each species in each geographic region. Arctic ground squirrel species richness (number of eimerian species per animal/number hosts examined) was 1.4, with 67 animals (49.2%) having single-species infections and 35 (25.7%) with 2 species, 14 (10.3%) with 3 species, and 2 (1.5%) with 4 species infecting simultaneously.

DESCRIPTION

Eimeria callospermophili Henry, 1932

Oocyst shape spheroid to subspheroid; wall ~1–2 thick, with 2 layers: outer layer smooth and approximately two thirds of total thickness; L × W (n = 13) 23.5 × 20.9 (19–25.5 × 16.5–26); L/W 1.1 (1–1.2); M absent; OR present; OR characteristics compact, homogeneous mass, granular or smooth, 3–6 × 3–6; PG usually 1, but up to 4 present. Sporocysts (n = 10) lemon-shaped; L × W 10.5 × 8.2 (9–14 × 7–9); L/W 1.3 (1–1.6); SB present and nipplelike; SSB, PSB both absent; SR present as few dispersed granules.

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TABLE I. Country of origin, locations, geographic coordinates, sample sizes, and eimerian species present (number of animals infected) for samples collected from arctic ground squirrels (*Spermophilus parryii*).

Country	Location	Geographic coordinates	n	Species present (no. infected)*			
Russia	1	64.25°N, 172.32°W	5		EICY (1)		EIMO (2)
	2	64.25°N, 172.45°W	5	EICA (1)			EIMO (4)
	3	64.32°N, 172.45°W	4			EILA (1)	EIMO (4)
	4	64.39°N, 172.32°W	9	EICA (3)		EILA (1)	EIMO (7)
	5	64.52°N, 172.40°W	3				EIMO (3)
	6	65.13°N, 172.20°W	9				EIMO (5)
	7	60.79°N, 151.73°E	1				EIMO (1)
	8	60.83°N, 151.70°E	1				EIMO (1)
	9	61.85°N, 147.64°E	2				EIMO (2)
	10	63.35°N, 158.58°E	1				
	11	64.57°N, 177.32°E	3				EIMO (3)
	12	64.81°N, 177.55°E	4				EIMO (3)
Total			46	EICA (4)	EICY (1)	EILA (2)	EIMO (35)
United States	1	64.72°N, 163.98°W	7	EICA (5)	EICY (4)	EILA (3)	EIMO (5)
	2	64.90°N, 165.11°W	1				
	Bering Land Bridge National Preserve	65.38°N, 163.23°W	9	EICA (2)	EICY (4)	EILA (1)	EIMO (9)
		65.85°N, 164.70°W	8	EICA (2)	EICY (5)	EILA (3)	EIMO (7)
		66.39°N, 164.49°W	12	EICA (1)	EICY (5)	EILA (5)	EIMO (11)
	Cape Krusenstern National Monument	67.52°N, 163.60°W	4	EICA (4)		EILA (2)	EIMO (4)
		67.52°N, 163.58°W	3	EICA (1)	EICY (2)	EILA (2)	EIMO (3)
	Noatak National Preserve	67.47°N, 162.22°W	5		EICY (3)		EIMO (3)
		68.34°N, 158.75°W	3		EICY (2)	EILA (2)	EIMO (2)
	Yukon–Charley Rivers National Preserve	65.05°N, 140.97°W	14	EICA (4)	EICY (1)		EIMO (11)
	Wrangle–St. Elias National Park	60.99°N, 142.03°W	6		EICY (2)	EILA (1)	EIMO (3)
		61.00°N, 142.75°W	4				EIMO (3)
		61.07°N, 143.90°W	2	EICA (1)		EILA (2)	EIMO (2)
		61.32°N, 144.24°W	5		EICY (2)	EILA (1)	EIMO (5)
		61.79°N, 141.21°W	1				EIMO (1)
		61.83°N, 141.83°W	4		EICY (1)	EILA (2)	EIMO (1)
		62.03°N, 141.13°W	2				
Total			90	EICA (20)	EICY (31)	EILA (24)	EIMO (70)

* Abbreviation: EICA, *Eimeria callospermophili*; EICY, *Eimeria cynomysis*; EILA, *Eimeria lateralis*; EIMO, *Eimeria morainensis.*

Taxonomic summary

Synonyms: Seven (see Wilber et al., 1998).

Type host: Spermophilus lateralis (Say, 1823), golden-mantled ground squirrel.

Other hosts: Twenty-five species in the genera *Cynomys* (3 species), *Marmota* (5), and *Spermophilus* (17) (see Wilber et al., 1998); *S. parryii* (this study).

Type locality: North America: Placer County, California, United States.

Geographic distribution: Asia: Kazakhstan, Buriatia. North America: Alberta, Canada; Mexico; Colorado, Idaho, Illinois, Iowa, Montana, New York, New Mexico, Pennsylvania, Texas, Utah, and Wyoming, United States. In 2000–2003, collected from *S. parryii* in Alaska and in Magadanskaya oblast and Chukotka, Russia (this study).

Prevalence: One of three (33%) in type host; 76 of 123 (63%) *Cynomys gunnisoni* from Utah (Thomas and Stanton, 1994); 43 of 61 (71%) *Cynomys leucurus* and 25 of 39 (64%) *Cynomys ludovicianus* from Wyoming (Seville, 1997); 2 of 2 (100%) *Spermophilus beecheyi* from California (Henry, 1932); 211 of 1,007 (21%) and 36 of 69 (52%) *Spermophilus elegans* from Wyoming (Shults et al., 1990); 36 of 100 (36%) *Spermophilus richardsonii* from Alberta, Canada (Seville and Stanton, 1993); 5–80% *Spermophilus townsendii* in Idaho (Wilber et al., 1994); 6 of 81 (7%) *Spermophilus undulatus* from Kazakhstan (Matschoulsky, 1949); 4 of 7 (57%) *Spermophilus variegatus* from Utah (Thomas and Stanton, 1994); and 20 of 90 (22%) and 4 of 46 (9%) *S. parryii* from Alaska and Magadanskaya oblast and Chukotka, Russia, respectively (this study).

Sporulation: From 2.5 to 7 days (Crouch and Becker, 1931; Henry, 1932; Todd and Hammond, 1968a).

Prepatent period: Five to six days (Todd and Hammond, 1968a).

Patent period: Nine days (Todd and Hammond, 1968a).

Site of infection: Endogenous stages most numerous in the jejunum and upper ileum. The epithelium of the entire villus infected, but the endogenous stages were usually concentrated at the tips and along the distal one third. There was no observed pathogenicity (Todd and Hammond, 1968a).

Materials deposited: Photovouchers of sporulated oocysts from *S. parryii* deposited in USNPC 95305 (Russia) and 95306 (Alaska).

Remarks

The description of *E. callospermophili* from arctic ground squirrels from Alaska and Russia is similar to the composite description developed by reviewing all published descriptions of this species from all marmotine hosts by Wilber et al. (1998). In addition, the arctic ground squirrel specimens had 2-layered oocyst walls, with the outer layer two thirds of the total thickness; were slightly larger (L × W = 23.5 × 20.9 vs. 19.2 × 16.0); but had similar subspheroid sporocysts (L × W = 10.5 × 8.2 vs. 10.2 × 8.5), with SR consisting of few dispersed granules.

When oocysts from Alaska (n = 8) and Russia (n = 5) were com-

pared, few differences were noted. Oocyst L × W was similar (Alaska = 23.7 × 20.8 vs. Russia = 23.2 × 21.0), but Russian sporocysts were larger (L × W = 11.3 × 9.0 vs. 10.1 × 7.8).

Eimeria cynomysis Andrews, 1928

Oocyst shape ovoid; wall ~ 1.5 thick, with 2 layers: outer layer yellow/brown, rough; L × W (n = 28) 35.9 × 28.1 (34–39.5 × 25.6–32.5); L/W 1.3 (1.4–1.2); M present, 5.7–10 wide; MC absent; OR absent; 0–1 PG present. Sporocysts (n = 18) ovoid; L × W 18.2 × 10.1 (14–21 × 8–12); L/W 1.9 (1.6–2.1); SB present; SSB and PSB both absent; SR present as small granular mass or occasionally as large, membrane-bound granular mass located centrally between the sporozoites or occasionally below the SB.

Taxonomic summary

Synonyms: Two (see Wilber et al., 1998).

Type host: Cynomys ludovicianus (Ord, 1815), the black-tailed prairie dog.

Other hosts: Thirteen in *Cynomys* (2) and *Spermophilus* (11) (see Wilber et al., 1998); *S. parryii* (this study).

Type locality: North America: Ohio, United States (animals from a supply house, origin unknown, but analysis done in Ohio).

Geographic distribution: Europe: Czech Republic. North America: Alberta, Canada; California, Colorado, Idaho, Iowa, Ohio, Utah, and Wyoming, United States. In 2000–2003, collected from *S. parryii* in Alaska and in Magadanskaya oblast and Chukotka, Russia (this study).

Prevalence: Two of two (100%) in type host; 12 of 123 (10%) *C. gunnisoni* from Utah (Thomas and Stanton, 1994); 3 of 18 (17%; Shults et al., 1990) and 1 of 61 (2%; Seville, 1997) *C. leucurus* from Wyoming; 9 of 26 (35%) *Spermophilus columbianus* from Alberta, Canada (Hilton and Mahrt, 1971); 121 of 1,007 (12%; Shults et al., 1990) and 11% (number infected and sample size not reported; Seville et al., 1996) *S. elegans* from Wyoming; 2 of 8 (25%) *Spermophilus franklinii* from Alberta, Canada (Hilton and Mahrt, 1971); 2 of 3 (66%) *S. lateralis* from California (Henry, 1932); 6 of 100 (6%; Seville and Stanton, 1993) and 13 of 121 (11%; Hilton and Mahrt, 1971) *S. richardsonii* from Alberta, Canada; 35 of 788 (4%) *S. townsendii* from Idaho (Wilber et al., 1994); 6 of 18 (19%) from Iowa (Kietzmann and Kietzmann, 1987) and 2 of 56 (4%) *Spermophilus tridecemlineatus* from Wyoming (Seville et al., 1992); 2 of 7 (29%) *S. variegatus* from Utah (Thomas and Stanton, 1994); and 31 of 90 (34%) from Alaska and 1 of 46 (2%) *S. parryii* from Magadanskaya oblast and Chukotka, Russia (this study).

Sporulation: Eight to eleven days (Henry, 1932; Hall and Knipling, 1935; Todd et al., 1968).

Prepatent period: Ten to eleven days (Todd et al., 1968).

Patent period: Five to twenty-one days (Todd et al., 1968).

Site of infection: Todd et al. (1968) observed endogenous stages in the tips of the villi in the ileum and jejunum, but not in the duodenum. Little cell damage was observed, but infections did cause pathogenicity. Oocysts used for description recovered from feces.

Materials deposited: Phototype of sporulated oocyst in USNPC 87250. Photovouchers of sporulated oocysts from *S. parryii* deposited in USNPC 95307 (Alaska) and 95308 (Russia).

Remarks

The description of oocysts of *E. cynomysis* from arctic ground squirrels is consistent with the composite description developed by Wilber et al. (1998). Oocysts from arctic ground squirrels were longer and narrower (L × W = 35.9 × 28.1 vs. 35.4 × 30.0), making them more ellipsoidal (L/W 1.3 vs. 1.2); the micropyle width was more variable (6–10 vs. 5–6); the sporocysts were larger (L × W = 18.2 × 10.1 vs. no average reported, range 14–20 × 8–11.5 vs. 13–17 × 8–12); and the SR was either a small or large membrane-bound granular mass rather than coarsely granular in large amounts.

When oocysts from Alaska (n = 8) and Russia (n = 20) were compared, only minor differences were observed. Oocyst L × W was similar (Alaska = 36.4 × 28.0 vs. Russia = 35.7 × 28.2); Alaska sporocysts were smaller (L × W = 17.3 × 9.3 vs. 18.9 × 10.6); and oocysts from Alaska had a wider micropyle than those from Russia (MW = 7.2 vs. 8.8).

Eimeria lateralis Levine, Ivens, and Kruidenier, 1957

Oocyst shape ellipsoid to ovoid; wall ~ 2 thick, with 2 layers: outer layer rough, yellow/brown, and approximately two thirds of total thickness; L × W (n = 42) 31.7 × 24.7 (27–37.5 × 20–28); L/W 1.3 (1.1–1.5); M absent; OR absent; PG 0–4 present. Sporocysts (n = 43) ovoidal, L × W 15.8 × 10.0 (12–18 × 9–11); L/W 1.6 (1.4–1.8); SB present, nipplelike; SSB and PSB both absent; SR present as numerous, large granules dispersed throughout sporocyst or along edge of sporocyst.

Taxonomic summary

Synonyms: Five (see Wilber et al., 1998).

Type host: Spermophilus lateralis.

Other hosts: Eighteen in the genera *Cynomys* (3), *Marmota* (3), *Spermophilus* (10), and *Tamias* (2) (see Wilber et al., 1998); *S. parryii* (this study).

Type locality: North America: Point Imperial, Arizona, on the North Rim of the Grand Canyon, Grand Canyon National Park, United States.

Geographic distribution: Asia: Kazakhstan. North America: Alberta, Canada; Baja California, Mexico; Arizona, California, Colorado, Idaho, Illinois, Massachusetts, Montana, New York, Pennsylvania, Utah, Wisconsin, and Wyoming, United States. In 2000–2003, collected from *S. parryii* in Alaska and in Magadanskaya oblast and Chukotka, Russia (this study).

Prevalence: One of one (100%) in type host; 4 of 123 (3%) *C. gunnisoni* from Utah (Thomas and Stanton, 1994); 4 of 17 (24%) *C. leucurus* from Wyoming (Seville and Williams, 1989); 4 of 86 (5%) *C. ludovicianus* from Colorado (Vetterling, 1964); 4 of 25 (16%) *Marmota monax* (Dorney, 1965) from Pennsylvania; 21 of 38 (55%) *M. monax* from Illinois (McQuistion and Wright, 1984); 39 of 232 (17%) *M. monax* from New York (Fleming et al., 1979); 2 of 36 (6%) *Spermophilus beldingi* from California (Veluvolu and Levine, 1984); 2 of 36 *S. columbianus* from Alberta, Canada (Hilton and Mahrt, 1971); 168 of 1,007 (17%) *S. elegans* from Wyoming (Shults et al., 1990); 3 of 69 (4%) *S. elegans* from Wyoming (Shults et al., 1990); 18 of 121 (15%) *S. richardsonii* from Alberta, Canada (Hilton and Mahrt, 1971); 6 of 100 (6%) *S. richardsonii* from Alberta, Canada (Seville and Stanton, 1993); 1–5% *S. townsendii* from Idaho (Wilber et al., 1994); 9 of 56 (16%) *S. tridecemlineatus* from Wyoming (Seville et al., 1992); 3 of 96 (3%) *Tamias obscurus* from Baja California, Mexico (Hill and Duszynski, 1986); 12 of 84 (14%) *Tamias striatus* from Wisconsin (Dorney, 1962); 6 of 75 (8%) *T. striatus* from Massachusetts (Duncan, 1968); 21 of 189 (11%) *T. striatus* from Wisconsin (Dorney 1963, 1966); 3 of 41 (9%) *T. striatus* from Pennsylvania (Seville and Patrick, 2001); and 24 of 90 (27%) from Alaska and 2 of 46 (4%) *S. parryii* from Magadanskaya oblast and Chukotka, Russia (this study).

Sporulation: Two to four weeks at room temperature (Dorney, 1962); 50% of oocysts sporulated after 49 days in the laboratory (Dorney, 1965); 7–10 days in the laboratory (Vetterling, 1964); 10–14 days at room temperature (Duncan, 1968).

Prepatent period: Five days in *Spermophilus armatus* (Todd and Hammond, 1968b).

Patent period: Six and a half days in *S. armatus* (Todd and Hammond, 1968b).

Site of infection: Dorney (1962) observed endogenous stages primarily in the middle of the small intestine of *M. monax* (Dorney, 1962). Todd and Hammond (1968b) observed endogenous stages in the epithelial cells of the jejunum and ileum of experimentally infected *S. armatus*.

Materials deposited: Phototype of sporulated oocyst in USNPC 87251. Symbiotype in University of Illinois Natural History Museum 10300. Photovouchers of sporulated oocysts from *S. parryii* deposited in USNPC 95309 (Alaska) and 95310 (Russia).

Remarks

The description of *E. lateralis* from arctic ground squirrels is similar to the composite description by Wilber et al. (1998). Overall, the oocysts were smaller (L × W = 31.7 × 24.7 vs. 35.1 × 26.8) and more ellipsoid (L/W = 1.6 vs. 1.3). The sporocysts were similar in size (L × W = 16 × 10) and had a prominent SB, and the SR was present as numerous large, dispersed granules.

When oocysts from Alaska (n = 4) and Russia (n = 39) were com-

pared, oocysts were similar in all respects, including L × W (Alaska = 32.6 × 24.8 vs. Russia = 31.7 × 24.7); L/W (1.3 vs. 1.2), and sporocyst size (L × W = 15.5 × 10.1 vs. 15.8 × 10.0).

Eimeria morainensis Torbett, Marquardt, and Carey, 1982

Oocyst shape subspheroid; wall 1–1.5, with 2 layers of equal thickness; L × W (n = 47) 23.3 × 19.5 (19.5–28 × 14–22.5); L/W 1.2 (1–1.4); M absent; OR absent; PB 0–3 present, often bilobed. Sporocysts ellipsoidal; L × W (n = 37) 11.7 × 7.4 (7.9–14.0 × 5.5–9.0); L/W 1.6 (1.3–2); SB present and usually prominent, dark and buttonlike; SR present as compact, occasionally membrane-bound granular mass, dispersed granules, or both.

Taxonomic summary

Type host: Spermophilus lateralis.

Other hosts: Nine in the genera *Cynomys* (3), *Marmota* (1), *Spermophilus* (5) (see Wilber et al., 1998); *S. parryii* (this study).

Type locality: North America: Moraine Park in Rocky Mountain National Park, Colorado (T5N, R73W, S29), United States.

Geographic distribution: North America: Alberta, Canada; Colorado, Idaho, Utah, and Wyoming, United States. In 2000–2003, collected from *S. parryii* in Alaska and in Magadanskaya oblast and Chukotka, Russia (this study).

Prevalence: One of thirty-five (3%) in type host; 4 of 18 (22%) *C. leucurus* from Wyoming (Shults et al., 1990); 435 of 1,007 (43%) *S. elegans* from Wyoming (Shults et al., 1990); 36 of 69 (52%) *S. elegans* from Wyoming (Shults et al., 1990); 1 of 35 (3%) *S. lateralis* from Colorado (Torbett et al., 1982); 5–18% *S. townsendii* from Idaho (Wilber et al., 1994); 6 of 7 (86%) *S. variegatus* from Utah (Thomas and Stanton, 1994); and 70 of 90 (78%) from Alaska and 35 of 46 (76%) *S. parryii* from Magadanskaya oblast and Chukotka, Russia (this study).

Sporulation: Six to seven days (Torbett et al., 1982).

Prepatent period: Eight to nine days (Torbett et al., 1982).

Patent period: Nine days (Torbett et al., 1982).

Site of infection: Unknown. Oocysts recovered from feces.

Materials deposited: Phototype of sporulated oocyst in USNPC 82933. Photovouchers of sporulated oocysts from *S. parryii* deposited in USNPC 95311–95313 (Russia).

Remarks

The description of *E. morainensis* from arctic ground squirrels is similar to the composite description by Wilber et al. (1998). Oocysts were larger (L × W = 23.3 × 19.5 vs. 20.3 × 19.8), had shorter but wider sporocysts (L × W = 11.7 × 7.4 vs. 12.1 × 6.9), and possessed a buttonlike SB and a membrane-bound granular SR, or a row of globules along side the sporocyst wall, or both.

When oocysts from Alaska (n = 30) and Russia (n = 17) were compared, oocysts were similar in all respects. Russian oocysts were larger (L × W = 23.4 × 20.0 vs. 23.2 × 19.2), but sporocyst size was similar (L × W = 11.9 × 7.4 vs. 11.8 × 7.4).

Eimeria tamiasciuri Levine, Ivens, and Kruidenier, 1957

Oocyst shape elongate ellipsoid; L × W 29 × 16; M absent; OR absent; PB present. Sporocysts ellipsoidal; L × W 13 × 7; SB cone-shaped.

Taxonomic summary

Type host: Microtus montanus (Peale, 1848), the montane vole.

Other hosts: Sciurus aberti Woodhouse, 1853; *Sciurus griseus* Ord, 1818; *Tamias dorsalis* Baird, 1855; *Tamias merriami* J.A. Allen, 1889; *T. obscurus* J.A. Allen, 1889; *Tamiasciurus mearnsi* (Townsend, 1897); *T. hudsonicus*.

Type locality: North America: north rim of the Grand Canyon, near the entrance to Grand Canyon National Park, Arizona, United States.

Geographic distribution: North America: Baja California, Mexico; California, New Mexico, and Wisconsin, United States. In 2000–2003, collected from *T. hudsonicus* in Alaska (this study).

Prevalence: One of five (20%) in type host; 3 of 9 (33%) *S. aberti* from Arizona (Hill and Duszynski, 1986); 4 of 11 (36%) *S. aberti* from New Mexico (Patrick and Wilson, 1995); 1 of 1 (100%) *S. griseus* from California (Hill and Duszynski, 1986); 1 of 12 (8%) *T. dorsalis* from Arizona (Hill and Duszynski, 1986); 1 of 50 (2%) *T. merriami* from California (Hill and Duszynski, 1986); 1 of 96 (1%) *T. obscurus* from Baja California Norte, Mexico (Hill and Duszynski, 1986); 3 of 5 (60%) *T. mearnsi* from Baja California Norte, Mexico (Hill and Duszynski, 1986); 2 of 2 (100%) *T. hudsonicus* from New Hampshire (Bullock, 1959); 49 of 50 (98%) *T. hudsonicus* from Wisconsin (Dorney, 1962); 149 of 152 (98%) *T. hudsonicus* from Wisconsin (Dorney, 1966); 12 of 13 (92%) *T. hudsonicus* from Ontario, Canada (Soon and Dorney, 1969); 166 of 171 (97%) *T. hudsonicus* from Alberta, Canada (Mahrt and Chai, 1970); 88 of 89 (99%) *T. hudsonicus* from Alberta (Mahrt and Chai, 1972); 3 of 12 (25%) *T. hudsonicus* from New Mexico (Patrick and Wilson, 1995); 1 of 1 (100%) *T. h. mogollonensis* from Arizona (Hill and Duszynski, 1986); and 32 of 35 (91%) *T. hudsonicus* from Alaska (this study: 28/31 [90%] Yukon Charley; 2/2 [100%] Wrangle St. Elias; 2/2 [100%] Kobuk).

Sporulation: Three days (Soon and Dorney, 1969).

Prepatent period: Unknown.

Patent period: Unknown.

Site of infection: Unknown. Oocysts recovered from feces.

Materials deposited: Phototype of sporulated oocyst in USNPC 87256. No photovoucher from this host produced.

Remarks

The description of *E. tamiasciuri* from red squirrels from Alaska is similar to the original description by Levine et al. (1957) from the same host species in Arizona. Oocysts and sporocysts were smaller (oocyst L × W = 29 × 16 vs. 33 × 19; sporocyst L × W = 13 × 7 vs. 16 × 8), but there were no differences in overall morphology, including the elongate ellipsoid oocyst shape and cone-shaped SB. The recovery of *E. tamiasciuri* from *T. hudsonicus* establishes a new geographic record for the parasite.

DISCUSSION

Previously, Wilber et al. (1998) suggested that because members of the rodent tribe Marmotini arose fairly recently and are likely to harbor closely related parasites and that few cross-transmission or molecular studies have been conducted, the morphologic species concept was the only practical approach to naming and identifying *Eimeria* spp. in this rodent group. Comparison of the morphologies of the different species we observed in samples from arctic ground squirrels from both continents and with species reported from other marmotine hosts from other regions strongly supports conspecificity both across the different marmotine host species and between the eimerians recovered from arctic ground squirrels in Russia and in Alaska. However, because Alaska marmotine populations and their parasites have likely been isolated from Russia since the last Beringian land bridge, which was broken approximately 15,500 yr ago (Pielou, 1991), we suggest that molecular and cross-transmission studies be conducted to verify conspecificity.

Prevalences for all species in arctic ground squirrels except *E. morainensis* were significantly higher for the Alaskan than the Russian populations (Table I). Although we cannot offer a definitive explanation, one plausible reason could be that Alaskan samples were collected from National Parklands, so estimated prevalences represent undisturbed conditions, whereas Russian populations might have been subject to human disturbance via habitat disruption or squirrel population control, although we are unable to confirm this possibility.

There have been few surveys of arctic sciurids for coccidia, and this is the first to examine a large number of samples from a single host species. Arctic marmotine hosts not adequately sampled include *Marmota broweri*, *Marmota caligata*, *Marmota camtschatica*, and *Tamias sibiricus*. Being the first survey

of arctic ground squirrels and red squirrels in Beringia for coccidia, this report constitutes new host and geographic ranges for *E. callospermophili*, *E. cynomysis*, *E. lateralis*, and *E. morainensis* and a new geographic record for *E. tamiasciuri* in red squirrels. *Eimeria cynomysis* and *E. morainensis* are now documented to occur from the central United States to arctic Alaska and eastern Russia, *E. callospermophili* and *E. lateralis* from Mexico to arctic Alaska and eastern Russia, and *E. tamiasciuri* from Alaska to Mexico and the eastern United States.

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