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# DESCRIPTION OF A NEW *EIMERIA* SPECIES AND REDESCRIPTION OF *EIMERIA MAYERI* (PROTOZOA: EIMERIIDAE) FROM WILD REINDEER *RANGIFER TARANDUS* IN ICELAND

**B. Gudmundsdottir and K. Skirnisson***
Institute for Experimental Pathology, Keldur, University of Iceland, IS-112 Reykjavik, Iceland. *e-mail: karlsk@hi.is*

ABSTRACT: Altogether, 195 fecal samples of reindeer calves (*Rangifer tarandus*) were collected from the ground in 3 distinct areas in eastern Iceland, where geographically isolated reindeer populations graze during the summer months. The samples were examined for coccidian parasites. Two species were found, and all infections were monospecific. *Eimeria mayeri* was found in calves in all sampling areas, with 1–4% prevalence and 450–167,700 oocysts per gram (opg). The sporulated oocyst lacks a polar granule but has an inconspicuous micropyle, and a small Stieda body is present on sporocysts, which are ovoid but not pointed as reported in the original description. The other coccidian, found in single calves in 2 of the 3 areas (prevalence 1 and 4%, 150 and 500 opg, respectively) is described here as a new species. The oocysts are ovoid, average 34.9 × 27.6 μm, and have 2 distinct walls. Wall thickness is ~1.9 μm, and the outer wall, ~¾ of total thickness, is generally smooth and appears bicolored. The outermost portion is pale red and the innermost portion yellow to pale brown. The inner wall is grey to dark brown and separated from the outer wall by a dark brown line. Oocysts contain a prominent micropyle, ~5 μm, and enclose 4 spindle-shaped sporocysts, slightly pointed at the end opposite the Stieda body. Average size of sporocysts is 18.6 × 9.2 μm. Sporocysts contain granular sporocyst residuum and usually 2, sometimes 1, large refractile bodies in each sporozoite.

Previously, 4 species of *Eimeria* and 1 of *Isospora* were described from the feces of reindeer, *Rangifer tarandus*. For all species, the original descriptions were based on oocysts recovered from feces collected from reindeer in north and northwest Russia. The species are: *Eimeria arctica* Yakimoff, Matschoulsky, and Spartansky, 1939; *Eimeria mayeri* Yakimoff, Sokoloff, and Matschoulsky, 1936; *Eimeria mühlensi* Yakimoff, Sokoloff, and Matschoulsky, 1936; *Eimeria tarandina* Yakimoff, Sokoloff, and Matschoulsky, 1936; and *Isospora rangiferis* Yakimoff, Matschoulsky, and Spartansky, 1937 (Yakimoff, Sokoloff, and Matschoulsky, 1936; Yakimoff, Matschoulsky, and Spatansky, 1937, 1939; Pellérdy, 1974). *Eimeria polaris* Yakimoff and Sokoloff, 1935, nomen nudum, reported by Yakimoff (1935) and Yakimoff and Sokoloff (1935), is not considered to be a valid species because sporulated oocysts have never been described.

The reindeer population in Iceland has been isolated from other populations since 1787 when the ancestors (30 cows and 5 bucks) were captured in Finnmark in northern Norway and released in northeast Iceland. Concomitant with colonization, a rapid population growth was observed. During the first half of the 19th century, marked population changes were noted, but during the first half of the 20th century, the population reached a historical minimum when 100–300 reindeer were estimated to be left in an inland mountainous area in the eastern part of Iceland. By the middle of the 20th century, the population started to recover, and in the 1950s and 1960s marked expansions of the geographical range were observed, mainly to the east and southeast parts of the country. In past decades, hunting management has kept the population relative stable at ~4,000 individuals (Thorisson, 1993).

Considering the high degree of host specificity and the well-known and close host–parasite association in many eimeriids, we decided to systematically study whether *Eimeria* spp. occurred in Icelandic reindeer. Here, we describe 1 new species of *Eimeria* and provide a redescription of *E. mayeri* Yakimoff, Matschoulsky, and Spatansky, 1936.

## MATERIALS AND METHODS

Fecal samples from ~2–10-wk-old free-ranging reindeer calves were randomly collected from the ground during 7 June to 13 August 2003 in 3 distinct areas in the eastern and southeastern part of Iceland, where geographically isolated reindeer populations graze during the summer months. Ninety-five samples were collected in the mountainous inland area of Vesturöræfi (64°52′N, 15°27′W), 50 samples in mountains close to the coast at Gerpir in east Iceland (65°04′N, 13°40′W), and 50 samples in the Heinabergsdalur valley in southeast Iceland (64°20′N, 15°40′W). During sampling, the reindeer summer populations in these areas were estimated to be 2,600, 300, and 200 individuals, respectively (S. G. Thorisson, unpubl. data).

To detect coccidian oocysts, fresh fecal samples were examined by the McMaster method (Anonymous, 1987). When oocysts were found, values in oocysts per gram (opg) were estimated by counting oocyst numbers in 4 McMaster counting chambers. The average count was multiplied by a constant to obtain the opg estimate. For microscopy, oocysts were isolated in a saturated $MgSO_4$ solution. Remaining eimerid-positive fecal samples were sporulated in 3% (w/v) potassium dichromate ($K_2Cr_2O_7$) solution in a covered 50-ml plastic jar at room temperature, ~22–24 C, for 10–14 days. After sporulation, samples were refrigerated at 4 C until further examination with a Leica DMLB microscope equipped for differential interference contrast (DIC) microscopy (Nomarski). Several dozen sporulated oocysts were photographed with a Leica DC 300 digital camera. Measurements are in micrometers (mean ± SD μm) with the range and number (n) of stages measured in parentheses. Abbreviations used in the species descriptions are as suggested by Wilber et al. (1998). Oocyst characters include length (L), width (W), and their ranges and ratio (L/W); micropyle (M); residuum (OR); and polar granule (PG). Sporocyst characters include length (L), width (W), and their ranges and ratio (L/W); Stieda body (SB); sub-Stieda body (SSB); para-Stieda body (PSB); residuum (SR); sporozoites (SP); refractile bodies (RB); and nucleus (N) in SP. Photosyntypes and photoneosyntypes of sporulated oocysts (see Duszynski, 1999) are deposited in the U.S. National Parasite Collection (USNPC; Beltsville, Maryland).

## RESULTS

Overall, 195 fecal samples were collected (95 from Vesturöræfi, 50 from Gerpir, and 50 from Heinabergsdalur). Two species of *Eimeria* were identified. *Eimeria mayeri* was found in 1 calf from Vesturöræfi (prevalence = 1%) and in 2 calves each from Gerpir (4%) and Heinabergsdalur (4%). The other coccid-

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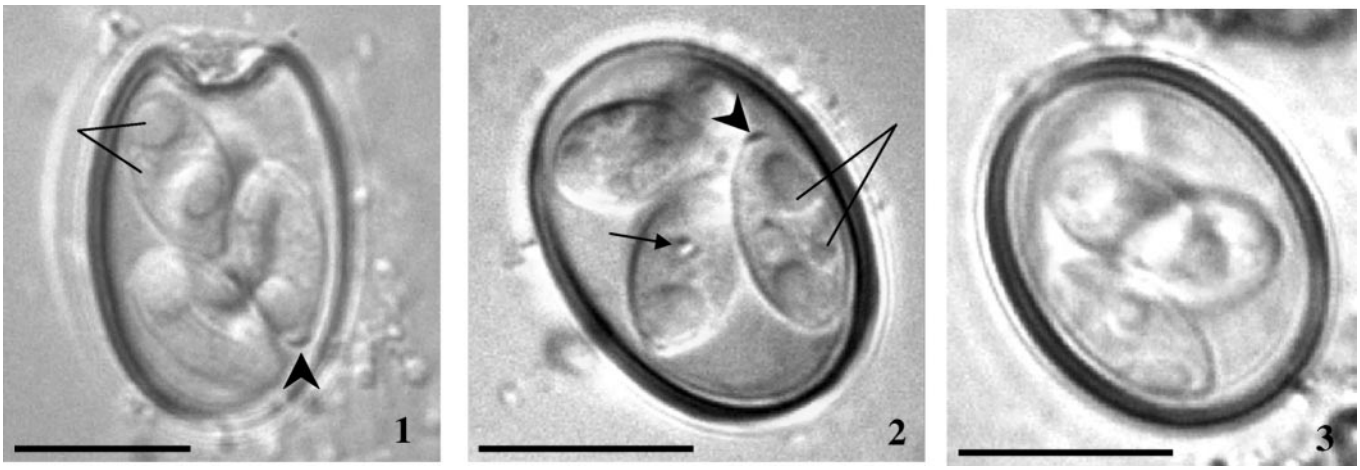
* To whom correspondence should be addressed.




FIGURES 1–3. Nomarski interference contrast photomicrographs (**1, 2**) and a photomicrograph (**3**) of sporulated *Eimeria mayeri* oocysts from a wild *Rangifer tarandus* calf in Iceland. Bar = 10 μm. **(1)** Collapsing and **(3)** refraction of light on one end of oocysts indicate a narrow micropyle on the oocyst walls. A nipplelike Stieda body (arrowheads) is visible at the pointed end of sporocysts in **(1)** and **(2)**. Two refractile bodies (lines) are visible in **(1)** and **(2)**. Inconspicuous, rounded ~0.5, membrane-bound sporocyst residuum (arrow) is visible in **(2)**.

ian was found in 1 calf each from Vesturöræfi (1%) and Heinabergsdalur (1%) and is described as a new species. All 7 infections detected were monospecific.

## REDESCRIPTION

### *Eimeria mayeri* Yakimoff, Sokoloff, and Matschoulsky, 1936

(Figs. 1–3, 7)

*Redescription of sporulated oocyst:* Oocyst shape subspheroidal to ellipsoidal or elongate ellipsoidal; number of walls, 2; wall thickness, 1.0. Wall characteristics: outer layer smooth, wall blue-green, refracting to yellowish-brown when the focus slightly changed (apochromatic lens); inner layer grey, ~⅛ of the total thickness; M present, occasionally indistinct, <1.0 wide; OR and PG absent; L × W, 17.2 ± 1.9 × 14.1 ± 0.9 (n = 150, 9.0–21.0 × 9.0–15.5); L/W ratio, 1.2 (1.0–1.5). A distinctive feature of the oocyst is the smooth, blue-green outer wall.

*Description of sporocyst and sporozoites:* Sporocyst shape ovoidal; L × W, 9.3 ± 0.7 × 5.1 ± 0.4 (n = 35, 8.0–11.0 × 4.0–6.0); L/W ratio, 1.8 (1.5–2.3); SB present, nipple-like; SSB and PSB absent; SR present, inconspicuous, rounded, ~0.5, and membrane-bound; SP usually lie head to tail, occasionally 1 large posterior RB, usually both; anterior RB, 1.2 (1.0–1.5), posterior RB, 2.8 (2.0–3.0). Distinctive features of sporocyst: nipplelike SB.

### Taxonomic summary

*Type host: Rangifer tarandus tarandus* L. 1758, reindeer.

*Type locality:* The tundra of Bolschaja Zemla, Murmansk area, Russia.

*Prevalence (this study):* In 5 of 195 (2.5%); 450, 700, 800, 102,850, and 167,700 opg.

*Prepatent and patent periods:* Unknown.

*Site of infection:* Unknown. Oocysts recovered from feces.

*Material deposited:* Photoneosyntypes of sporulated oocysts deposited in the USNPC (95003).

### Remarks

In the original description of *E. mayeri*, Yakimoff, Sokoloff, and Matschoulsky (1936) reported that sporocysts lacked a SB. All sporocysts we observed possessed a small SB (Figs. 1, 2), and we suggest that because of the small size, this character was overlooked in the original description. We also observed that the sporozoites possessed 1 pointed and 1 rounded end, whereas the original description reports that the sporozoites are pointed at both ends. Yakimoff, Sokoloff, and Matschoulsky (1936) were uncertain whether PGs were present, as indicated by insertion of the word ''wohl'', meaning maybe, in their description. We did not observe PGs in any oocysts. We observed a small (~0.5), inconspicuous, membrane-bound SR that was not reported in the original description. In the flotation medium, oocysts quickly developed indentations on the one end (Fig. 1), confirming the presence of a small, inconspicuous micropyle (Fig. 3). Other features of the oocysts, including oocyst size, wall characteristics, and sporocyst size, are consistent with the original description.

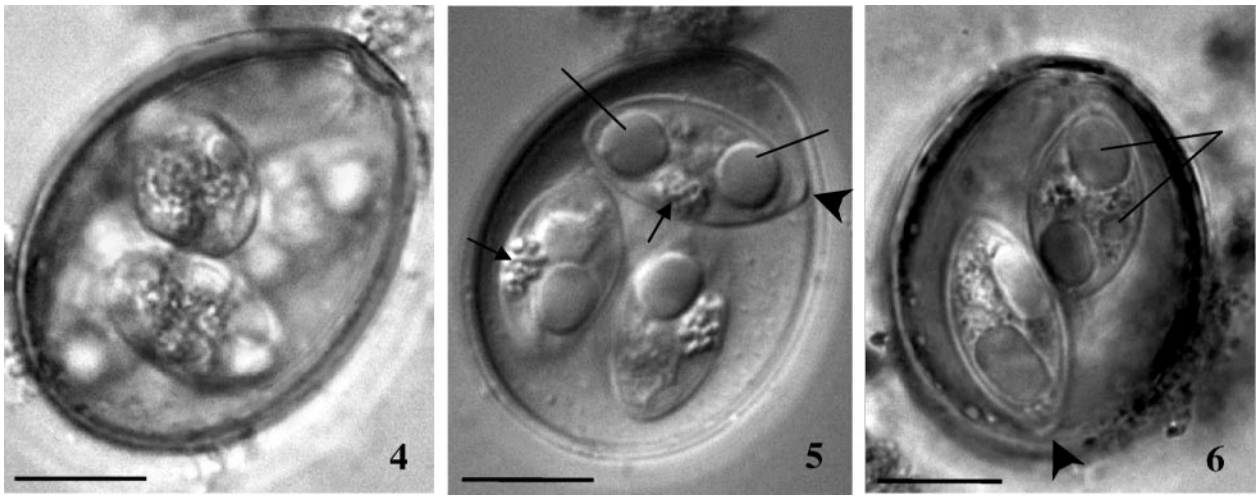
## DESCRIPTION

### *Eimeria rangiferis* n. sp

(Figs. 4–6, 8)

*Description of sporulated oocyst:* Oocyst shape, ovoidal; number of walls, 2; wall thickness, 1.9 (1.8–2.0); wall characteristics: outer wall generally smooth, thick, ~¾ of total thickness and appears bicolored, outermost portion pale red, innermost portion yellow to pale brown; inner wall grey to dark brown and separated from outer wall by dark brown line; M present, 5.0 (4.0–6.0) wide; L × W (n = 50), 34.9 ± 1.8 × 27.6 ± 1.0 (31.1–38.0 × 25.1–30.0); L/W ratio, 1.3 (1.1–1.4); OR and PGs absent. Distinctive features of oocyst: distinctive micropyle, thick bicolored outer wall with pale red outer portion and yellow or pale brown inner portion, inner wall grey to dark brown.

*Description of sporocyst and sporozoites:* Sporocyst spindle shaped, slightly pointed at end opposite to SB; L × W (n =




FIGURES 4–6. Nomarski interference contrast photomicrographs of sporulated *Eimeria rangiferis* oocysts from 2 wild *Rangifer tarandus* calves in Iceland. Bar = 10 μm. **(4)** Prominent micropyle is visible on the top of the oocyst. **(5)** Three sporocysts in view. Note the sporocyst residuum (arrows), 1 refractile body (line) in each sporozoite, and a Stieda body (arrowhead). **(6)** Two sporocysts in view. Two different-sized refractile bodies in each sporozoite (lines). Note the spindle-shaped sporocyst having a slightly pointed end opposite the prominent Stieda body (arrowhead).

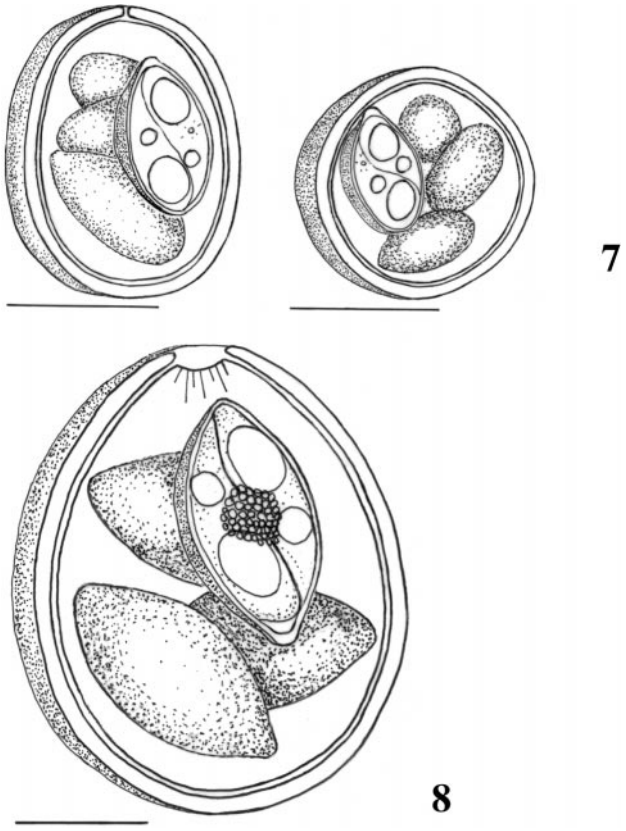



FIGURE 7. Line drawings of 2 sporulated *Eimeria mayeri* Yakimoff, Sokoloff, and Matschoulsky, 1936, oocysts from a wild *Rangifer tarandus* calf in Iceland. Bar = 10 μm.

FIGURE 8. Line drawing of sporulated oocysts of *Eimeria rangiferis* from a wild *Rangifer tarandus* calf in Iceland. Bar = 10 μm.

29), 18.6 ± 0.9 × 9.2 ± 0.5 (17.0–20.1 × 8.0–10.1); L/W ratio, 2.0 (1.8–2.2); SB present, nipplelike; SSB and PSB absent; SR present; SR characteristics: granules, either scattered or clustered, in the center between sporozoites; clustered SR 4.0 (3.0–5.0); SP most often have both anterior and posterior RB variable in size; anterior RB spheroid 2.8 (2.0–3.0), posterior RB spheroid, 5.0 or subspheroid 6.0 × 4.4 (5.0–7.0 × 4.0–5.0). Distinctive features of sporocyst: SB, granular SR and usually 2 large RBs in each SP.

### Taxonomic summary

*Type host: Rangifer tarandus tarandus* L. 1758, reindeer.

*Type locality:* Vesturöræfi (64°52′N, 15°27′W) and Heinabergsdalur (64°20′N, 15°40′W), east and southeast Iceland.

*Prevalence:* In 2 of 195 (1.0%); 150 and 500 opg.

*Prepatent and patent periods:* Unknown.

*Site of infection:* Unknown. Oocysts recovered from feces.

*Material deposited:* Photosyntypes (see Duszynski, 1999) of sporulated oocysts deposited in the USNPC (95004, 95005).

*Etymology:* The nomen triviale is derived from the scientific name of the host, rangifer, derived of the Latin word *ramus* (branch, antlers).

### Remarks

Sporulated oocysts of *E. rangiferis* resemble those of *E. arctica* described by Yakimoff, Matschoulsky, and Spatansky (1939). Oocyst size is similar; both lack PGs and an OR and have a distinct SR. However, the sporocysts of *E. arctica* are considerably smaller (12–14 × 7–9 vs. 17.0–20.1 × 8.0–10.1) and without a SB. Of the other eimerian species reported from reindeer, *E. tarantina* is smaller (18–24 × 16–22) and lacks a M, and *E. mühlensi* is similar in size (30–40 × 26–28), but is lemon-shaped and has a conspicuous and long SB on the sporocyst (Yakimoff, Sokoloff, and Matschoulsky, 1936).

## DISCUSSION

Several papers have mentioned eimerians in reindeer feces from different geographic regions, but the authors failed to identify oocysts to species because of the incomplete descriptions of the type material. Tøllefsen (1983) reported large (30–40) *Eimeria* sp. oocysts in reindeer feces from Reinøy, Norway. Christensson and Rehbinder (1975) found *Eimeria* spp. in reindeer calves in Sweden. Nikander (1986) and Oksanen et al. (1990) found 2 different-sized eimerian oocysts in feces from reindeer in Finland: a large (33–40 × 24–31) and a small type (20–22 × 18–20). Clausen et al. (1980), Thing and Clausen (1980), and Korsholm and Olesen (1993) all reported eimerians in reindeer from Greenland, and Frechette (1979) reported *Eimeria* sp. in a caribou herd of 200,000 head in Canada.

Results on the prevalence of *Eimeria* spp. infections in other reindeer populations usually report considerably higher values than reported in this study. In Norway, Tøllefsen (1983) found 23–50% of reindeer to be infected with *Eimeria* sp. during autumn and winter. During May–August, however, the author reported a considerably lower prevalence (6–13%). In Sweden, Christensson and Rehbinder (1975) found *Eimeria* spp. infections in 13.5% of fecal samples in 2-mo-old calves. When the same calves were examined at 4–6 mo of age, the same prevalence (14.3%) was observed. In Finland, Nikander (1986) reported 2 eimeriids of differing sizes in 125 fecal samples of reindeer in the Kaamanen Research Station. Animals up to 10 yr old were infected. The prevalence of infection was 8% in April, but 22% in December. In Finnish Lapland, Oksanen et al. (1990) reported *Eimeria* spp. oocysts of differing sizes in fecal samples collected in June and July at 6 different sampling sites. The total prevalence of infection was 35% but varied at the sampling sites from 20 to 45%. The low prevalence values of both *Eimeria* species found in this study (1–2.5%) are considered to be related to the young age (2–10 wk) of the calves and the sparse summer distribution of free-ranging cows and calves in the grazing areas.

Some authors reported numbers of *Eimeria* spp. oocysts. In the study of Nikander (1986), numbers remained low and never exceeded 1,800 opg. In Finnish Lapland, however, Oksanen et al. (1990) reported up to 800,000 opg and considered the heaviest infections to be pathogenic. Even higher numbers were reported by Clausen et al. (1980) and Thing and Clausen (1980), who observed up to 990,000 opg in reindeer calves in western Greenland, where some of the calves apparently suffered from coccidiosis. Most of the coccidian infections in this study were quite low, with <800 opg. Only in 2 cases, both *E. mayeri* infections, were >100,000 opg observed, which is still considerably lower than the highest numbers reported from Greenland (990,000 opg; Clausen et al., 1980; Thing and Clausen, 1980) and Finland (800,000 opg; Oksanen et al., 1990).

The reindeer imported from Norway to Iceland in 1787 must have been infected by both of the coccidian species recovered in this study. *Eimeria mayeri* was originally described from the Murmansk region in Russia, so it is likely to occur across the Palearctic. It is interesting that *E. rangiferis* has not been recovered in previous surveys of other reindeer populations, perhaps because of low prevalence levels, as observed in Iceland. Coccidians had not been previously reported from Iceland.

*Eimeria mayeri* and *E. rangiferis* persisted in Icelandic reindeer populations in spite of near extinction of these hosts during the first half of the 20th century when reindeer populations declined to 100–300 animals ranging over ~7,000 km$^2$. It is likely that seasonal group formation of hosts (during the rutting season in late summer and autumn, on lowland during harsh weather in winter, during the calving season in spring and early summer) played a key role in maintaining these parasites in this host during the population bottleneck.

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