

The third newly discovered *Eimeria* species (Protozoa: Eimeriidae) described from wild reindeer, *Rangifer tarandus*, in Iceland

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Abstract Fecal samples from 56 adult reindeer from eastern Iceland were examined for coccidian parasites. One *Eimeria* species was found in an 8-year-old male. Prevalence of infection was 1.8%; oocyst per gram (opg) value was 150. The coccidium was identified and described as a new species. The sporulated oocysts are ellipsoidal and average size is 30.0×21.1 µm. The oocyst has two distinct walls. Wall thickness is ~1.0 µm, and the outer wall, ~four-fifths of total thickness, is generally smooth and appears bicoloured. The outermost portion is light blue, and the innermost portion, yellow to pale brown. The inner wall is dark brown. Oocysts contain a prominent polar granule but are devoid of a micropyle. Oocysts enclose four spindle-shaped sporocysts with a rounded end opposite to the Stieda body. The average size of sporocysts is 15.3×6.5 µm. Sporocysts contain a granular sporocyst residuum that usually forms a cluster between the sporozoites and one large refractile body in each sporozoite.

Introduction

Previously, five species of *Eimeria* and one *Isospora* species have been described from the feces of reindeer, *Rangifer tarandus*. In five cases, the original descriptions are based on oocysts recovered from feces collected from reindeer in north and northwest Russia. The species are: *Eimeria arctica* (Yakimoff et al. 1939), *Eimeria mayeri* (Yakimoff et al. 1936), *Eimeria mühlensi* (Yakimoff et al. 1936), *Eimeria tarandina* (Yakimoff et al. 1936) and

Isospora rangiferis (Yakimoff et al. 1937) (Yakimoff et al. 1936, 1937, 1939; Pellérdy 1974). The sixth species, *Eimeria rangiferis* (Gudmundsdottir and Skirnisson 2005) was described from feces of wild reindeer calves in Iceland. *E. mayeri*, also found in the same study, was redescribed (Gudmundsdottir and Skirnisson 2005). *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 as sporulated oocysts have never been described.

The reindeer population in Iceland has been isolated from other populations since 1787, as the ancestors (30 cows and five bucks) were captured in Finnmark in northern Norway and released in northeast Iceland. Concomitant with their 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 to 300 reindeers 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 relatively stable at approximately 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 if *Eimeria* spp. occurred in Icelandic reindeer. Searching for coccidians in faeces of calves, we already have found *E. mayeri* and the previously undescribed *E. rangiferis* (Gudmundsdottir and Skirnisson 2005), and in searching for eimeriids in faeces from adult reindeer, we detected

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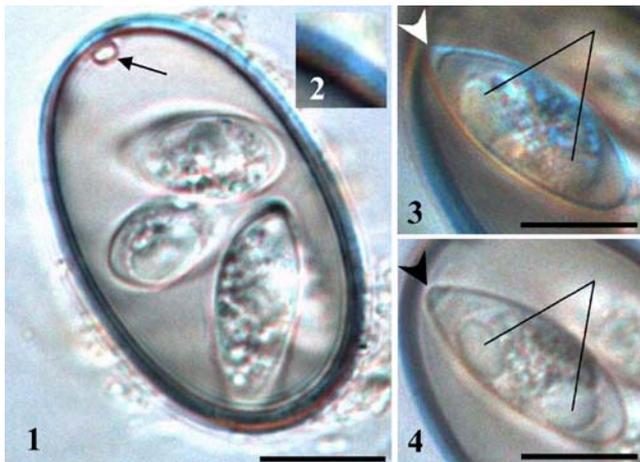


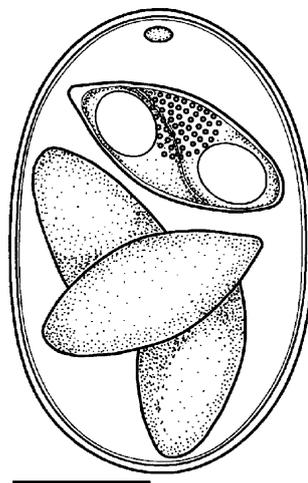
Fig. 1 Nomarski interference contrast photomicrograph of a sporulated *Eimeria hreindyria* oocyst (1) from an adult wild *Rangifer tarandus* in Iceland. Bar=10 μ m. (1) PG (arrow) is visible at the one end of the elongate ellipsoidal oocyst. (2) The outer wall is bicoloured. (3, 4) Nipple-like SB (arrowheads) is visible at the pointed end of sporocysts and one RB (line) is visible in each SP

another previously undescribed eimeriid. Here, we describe this new species and discuss its presence in Iceland.

Materials and methods

During 2003–2005, fecal samples were collected from the rectum of 56 adult reindeers that had been shot on different sites within the distribution area of reindeers in eastern and southeastern Iceland. To detect coccidian oocysts, samples were examined within 2–3 days using the McMaster method (Anonymus 1987). Oocysts per gram (opg) value was estimated by counting oocyst numbers in four McMaster counting chambers, and the average count multiplied by a constant to obtain the opg estimate. For microscopy, oocysts were isolated in a saturated magnesium sulphate ($MgSO_4$) solution. The remaining fecal sample was sporulated in 3% (w/v) aqueous potassium

Fig. 2 Line drawings of a sporulated *Eimeria hreindyria* oocyst from a wild *Rangifer tarandus* in Iceland. Bar=0 μ m



dichromate ($K_2Cr_2O_7$) solution in a covered 50-ml plastic jar at room temperature, ~ 22 – $24^\circ C$, for 10 days and then examined using a Leica DMLB microscope equipped for differential interference contrast (DIC) microscopy (Nomarski). Thirty-five sporulated oocysts were examined, and 15 were photographed with a Leica DC 300 digital camera. Measurements are in micrometers [mean \pm SD (μ m)] with the range and the number (n) of stages measured in parentheses. Abbreviations used in the species descriptions are as suggested by Duszynski and Wilber (1997) and 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

One *Eimeria* species was found in an 8-year-old male reindeer that was shot due to forelimb injury by the hunting management authorities after the hunting season, on November 2, 2004, in Jökuldalsheidi ($65^\circ 28' 522''$ N, $15^\circ 30' 486''$ W). The opg value was 150. The coccidium was identified and is described as a new species (Figs. 1 and 2).

Description

Eimeria hreindyria n. sp

Description of sporulated oocyst Oocyst shape: ellipsoidal; number of walls: 2; wall thickness: 1.0 (0.8–1.2); wall characteristics: outer wall generally smooth, thick, \sim four-fifths of total thickness and appears bicoloured, outermost portion light blue, innermost portion yellow to pale brown, inner wall dark brown. M absent. $L \times W$ ($n=35$), $30.0 (\pm 2.6) \times 21.1 (\pm 1.2)$, (23.8–35.0 \times 18.0–23.0); L/W ratio, 1.4 (1.2–1.6); OR absent. PG present, usually ellipsoid, sometimes irregular in shape, 1.7×2.5 (2.0–3.0 \times 1.0–2.5, $n=12$), or round, diameter ~ 2.2 (1.8–2.5, $n=6$). Distinctive features of oocyst: M absent, prominent PG, and thin bicoloured outer wall, with light blue outer portion and yellow to pale brown inner portion.

Description of sporocyst and sporozoites Sporocyst: spindle shaped, rounded at end opposite to SB; $L \times W$ ($n=29$), $15.3 (\pm 1.3) \times 6.5 (\pm 0.5)$, (13.0–18.0 \times 6.0–8.0); L/W ratio, 2.4 (1.8–2.8); SB, present, nipple like; SSB and PSB, absent; SR, present; SR characteristics: large granules usually form

clusters between the sporozoites, sometimes scattered; SP have one posterior RB variable in size and shape, spheroid, 3.7 (3.5–4.0), or subspheroid 4.2×3.2 (3.0–6.0×3.0–4.0). Distinctive features of sporocyst: nipple like SB, granular SR and one large RB in each SP.

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

Type locality: Jökuldalsheiði (65°28'522 N, 15°30'486 W) east Iceland.

Prevalence: in one of 56 (1.8%); 150 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 097472.00.

Etymology: the nomen triviale is derived from the Icelandic name of reindeer; hreindýr.

Remarks The ovoidal or piriform oocyst form of *E. mühlensi*, *E. arctica*, *E. rangiferis* and *E. tarandina* distinguish these species from the ellipsoidal-shaped oocyst form of *E. hreindyria*. Furthermore, the absence of a M also distinguishes *E. hreindyria* from *E. mühlensi*, *E. arctica*, *E. rangiferis* and *E. mayeri* which all have a M. Also, the measurements of *E. hreindyria* oocysts do not overlap with the size ranges reported for the other *Eimeria* species of reindeers (Yakimoff et al. 1936, 1937, 1939; Gudmundsdottir and Skirnisson 2005).

Discussion

The low infection prevalence (1.8%) of *E. hreindyria* in adult reindeers and the fact that the species was not detected in 195 fecal samples from calves in summer 2003 (Gudmundsdottir and Skirnisson 2005) indicate a rare occurrence of the species in Iceland. Similarly, low prevalence of infection was reported for the other eimeriid species detected in reindeer calves in Iceland; 2.6% for *E. mayeri* and 1% for *E. rangiferis*. Outside of Iceland, usually considerably higher prevalence of *Eimeria* spp. infections is reported in reindeer populations. In Norway, Tøllefsen (1983) found 23–50% of reindeer to be infected with an *Eimeria* sp. during autumn and winter. During May to August, however, the author reported a considerably lower prevalence (6–13%). In Sweden, Christensson and Reh binder (1975) found *Eimeria* spp. infections in 13.5% of fecal samples in 2-month-old calves. When the same calves were examined at 4 to 6 months of age, the same prevalence (14.3%) was observed. In Finland, Nikander (1986) reported two eimeriids of differing sizes in 125 fecal samples of reindeer in the Kaamanen Research Station. Up to 10-year-old animals 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 six different sampling sites. The total prevalence of infection was 35% but varied at the sampling sites from 20–45%. Thus, in this comparison, the 1–2.6% infection prevalence of the three *Eimeria* species found in Icelandic reindeers appear to be very low. A part of the explanation for these low prevalence values is regarded to be related to the relatively low density of reindeers in Iceland. In past decades, hunting management has kept the population relatively stable at approximately 4,000 individuals (Thorisson, 1993) that range free within an area of approximately 19,000 km².

With the exception of *E. rangiferis* and *E. hreindyria*, descriptions of reindeer eimeriids were based on material collected in north and northwest Russia in the 1930s (Yakimoff et al. 1936, 1937, 1939). Since then, several papers have mentioned eimerians in reindeer feces from other geographic regions. However, authors have 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 Reh binder (1975) found *Eimeria* spp. in reindeer calves in Sweden. Nikander (1986) and Oksanen et al. (1990) found two 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. Some of these infections might have been caused by the already well-defined species, *E. mayeri*, *E. rangiferis* or *E. hreindyria*, but as at least some eimeriids of reindeer are regarded to be pathogenic, we stress the need for the redescription of other species (*E. arctica*, *E. mühlensi*, *E. tarandina* and *I. rangiferis*). Also, further studies on coccidians within the distribution range of reindeers will probably reveal some additional species.

Coccidiosis has at least been reported in reindeers in Finland and Greenland but it remains open which species were responsible. Oksanen et al. (1990) reported opg values up to 800,000 of a species that was considered to be pathogenic. Even higher opg values 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, whereby, some of the calves apparently suffered from coccidiosis.

The reindeer that were transported from Norway to Iceland in 1787 must have been infected by the three eimeriid species recovered in Iceland in recent years. *E. mayeri* was originally described from the Murmansk region in Russia so, at least, it likely occurs across the palearctic.

E. mayeri, *E. rangiferis* and *E. hreindyria* 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 that ranged more than approximately 7,000 km². It is likely that seasonal group formation of hosts (during the rutting season in late summer and autumn, on lowland during harsh weather periods 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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