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# Coccidian parasites of red squirrels (*Sciurus vulgaris*) and grey squirrels (*Sciurus carolinensis*) in England

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One hundred and ninety-three Eurasian red squirrels (*Sciurus vulgaris*) and 57 grey squirrels (*Sciurus carolinensis*) in England were examined for enteric coccidian parasites. Three species of the genus *Eimeria* were recovered from each host. The prevalences in *S. vulgaris* were *Eimeria sciurorum* 66%, *Eimeria andrewsi* 38% and *Eimeria mira* 2.6%; and in *S. carolinensis they were Eimeria ascotensis* 100%, *Eimeria confusa* 23% and *Eimeria ontarioensis* 7%.

**Keywords:** *Sciurus vulgaris*; *Sciurus carolinensis*; *Eimeria* spp; England



## Introduction

The Eurasian red squirrel (*Sciurus vulgaris* Linnaeus, 1758), classed as native to the British Isles since the end of the last Ice Age (10,000 years ago), was once the only squirrel in Britain and widely distributed until about 100 years ago (Gurnell 1987). This species has now been replaced throughout much of its range in the British Isles by the invasive non-native North American grey squirrel, *Scuirus carolinensis* Gmelin, 1788 (Gurnell 1991). Apparently, the first release of grey squirrels in Britain was in Cheshire in 1876 but it is thought that they may have been present in 1830 Kenward and Holm 1989). In their review, Kenward and Holm (1989) noted that following a number of further introductions and translocations, the range of the grey squirrel rapidly increased during the middle of the twentieth century with a corresponding disappearance of the red squirrel. The grey squirrel has now spread to occupy almost all of England (Pepper and Patterson 2001). Sainsbury et al. (2008) consider the decline of the red squirrel to be the result of competition and reduced juvenile recruitment in the presence of grey squirrels. The grey squirrel is able to out-compete the red in almost every phase of its life history (Kenward and Holm 1989; Gurnell et al. 2004a, 2004b; Wauters et al. 2005). In addition, some infectious diseases have been suggested to play a part (Gurnell and Pepper 1988). Poxvirus is one agent suggested as a significant factor in the decline of red squirrel populations in East Anglia (Scott et al. 1981; Keymer 1983). When red squirrels become infected the probability of death within about 2 weeks is very high (Sainsbury and Gurnell 1995; Sainsbury and Ward 1996; Sainsbury et al. 2000; Tomkins et al. 2002). In contrast, poxvirus appears benign in grey squirrels. Coccidiosis, caused by species of *Eimeria*, has also been suggested as a cause of death in red squirrels (Keymer 1983). The site of infection of the *Eimeria* species so far studied in squirrels is the intestines (Carini

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1932; Pellérdy 1954; Prasad 1960; Joseph 1972a, 1972b) and destruction of cells alone under some circumstances, such as stress or intercurrent infections, could be detrimental. There are only a few reports mentioning *Eimeria* species occurring in squirrels in England (Prasad 1960; Webster 1960; Jawdat 1975; Britt and Molyneux 1979; Ball and Snow 1984).

During the last three decades, especially in the late 1900s and early 2000s, we examined red and grey squirrels to identify the *Eimeria* species present and to evaluate the prevalence of infection.

## Material and methods

The collection sites are indicated in Figure 1. Sites 1 and 2 had red squirrels only and site 3 had only grey squirrels. In contrast both squirrel species had been recorded in sites 4, 5 and 6. Samples from the colons of grey squirrels from Epping Forest, Essex were collected following culling by the forest keepers. Red squirrels from all other sites were obtained by trapping, and faecal samples were collected. Samples were stored in 2.5% (weight/volume) aqueous potassium dichromate at ambient temperature to allow oocyst sporulation. For consistency, each sample was placed in approximately twice its volume of dichromate solution, and within 6 months of collection the samples were examined by placing approximately 0.05 ml of the suspension under 22 × 22-mm coverslips on slides. The whole coverslip was viewed at × 400 magnification before a sample was recorded as negative. Oocysts were measured under oil at × 1000. Prevalence of eimerian infection was compared between male and female squirrels using Fisher's exact test.

## Results

A total of 193 faecal samples from *S. vulgaris* and 57 samples from *S. carolinensis* were examined (Tables 1 and 2). On the basis of morphology and size of the sporulated oocyst, three *Eimeria* species were identified from each species of squirrel. The dimensions of these, in micrometres, are given to allow comparison with the original descriptions. The measurements of oocysts from *S. vulgaris* were from hosts in the Isle of Wight and those from *S. carolinensis* were from Epping Forest.

From *S. vulgaris*:

*Eimeria sciurorum* Galli-Valerio, 1922 measured 15.2 × 26.8 (range 12.5–17.5 × 19.5–32.5) ($n$ = 100), SI (Shape Index = mean length/mean width) = 1.8

*Eimeria andrewsi* Yakimoff and Gousseff, 1935 measured 14.4 × 21.1 (12.5–17.5 × 17.5–25) ($n$ = 100), SI = 1.5

*Eimeria mira* (Lubimov, 1934) Pellérdy, 1954 measured 23.1 × 32.5 (20–25 × 27.5–37.5) ($n$ = 20), SI = 1.4; and had the characteristic pyriform shape with micropyle 4.6 in diameter ($n$ = 6).

From *S. carolinensis*:

*Eimeria ascotensis* Levine and Ivens, 1965 measured 17.5 × 29.5 (13–22 × 25–34) ($n$ = 100), SI = 1.7

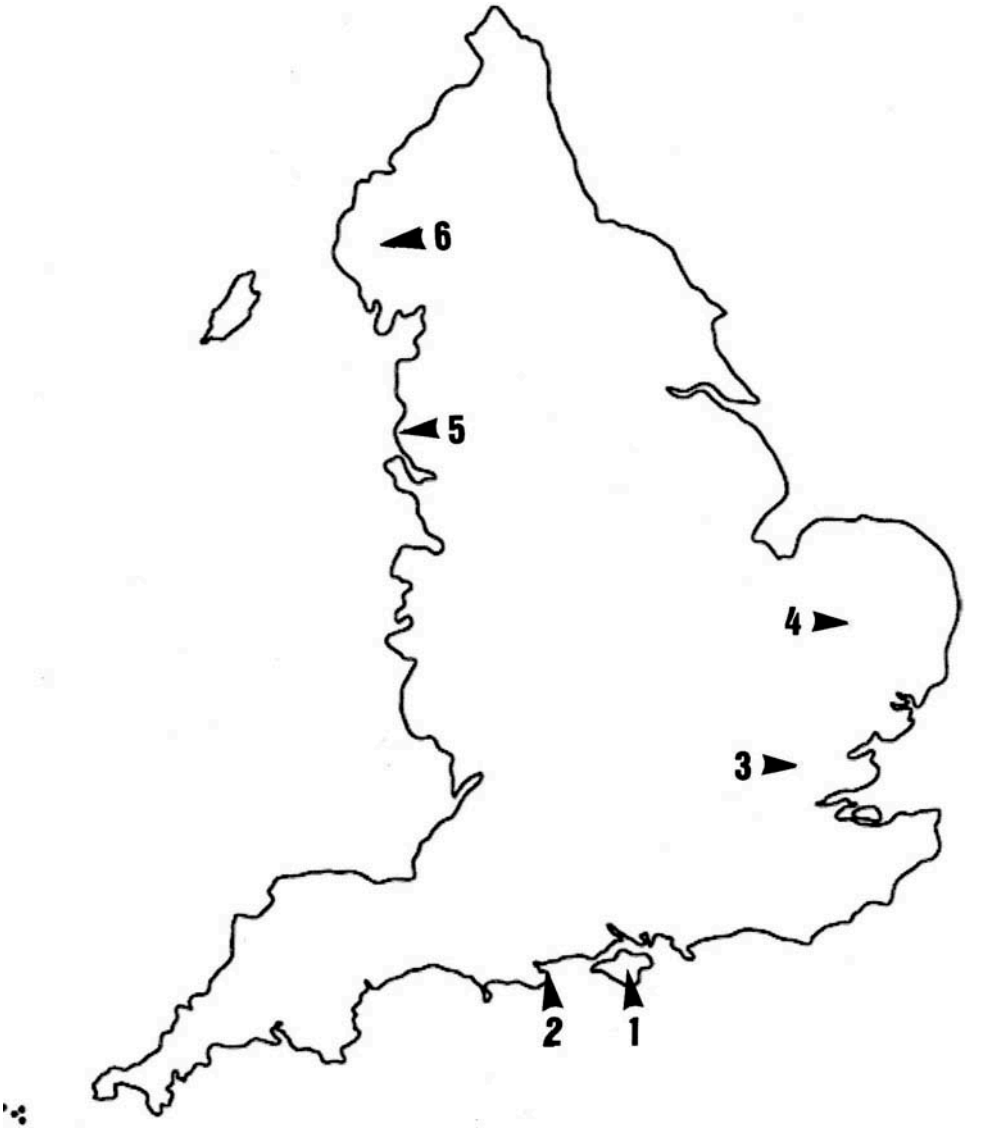


Figure 1. Outline map of England indicating collection sites. 1. Isle of Wight; 2. Fursey Island; 3. Epping Forest; 4. Thetford Chase; 5. Formby; 6. Cumbria.

*Eimeria confusa* Joseph, 1969 measured 28.1 × 36.5 (24–34 × 30–42) ($n$ = 100), SI = 1.3

*Eimeria ontarioensis* Lee and Dorney, 1971 measured 25.7 × 38.2 (22–28.6 × 30–46.2) ($n$ = 100), SI = 1.5, and with a pyriform shape and a micropyle at the narrow end.

In samples from *S. vulgaris* of known sex, the prevalence of coccidians was marginally higher in males (23/25; 92%) than in females (37/42; 88%) but not

Table 1. Prevalence of *Eimeria* spp. in *Sciurus vulgaris*.

| Locality | Red squirrels infected with: | | | | | |
|---|---|---|---|---|---|---|
| | *Eimeria sciurorum* | | *Eimeria andrewsi* | | *Eimeria mira* | |
| | *n* | % | *n* | % | *n* | % |
| Isle of Wight (*n* = 26) | 14 | 54 | 18 | 69 | 1 | 4 |
| Furzey Island, Poole Harbour, Dorset (*n* = 12) | 12 | 100 | 3 | 25 | | |
| Thetford Chase, Norfolk/Suffolk border (*n* = 143) | 95 | 66 | 47 | 33 | 4 | 2.8 |
| Cumbria (*n* = 9) | 6 | 67 | 5 | 56 | | |
| Formby, Lancashire (*n* = 3) | 1 | 33 | 1 | 33 | | |
| Total 193 | 128 | 66 | 74 | 38 | 5 | 2.6 |

Table 2. Prevalence of *Eimeria* spp. in *Sciurus carolinensis*.

| Locality | Grey squirrels: infected with: | | | | | |
|---|---|---|---|---|---|---|
| | *Eimeria ascotensis* | | *Eimeria confusa* | | *Eimeria ontarioensis* | |
| | *n* | % | *n* | % | *n* | % |
| Epping Forest (*n* = 57) | 57 | 100 | 13 | 23 | 4 | 7 |

significantly so ($p$ = 1.0). Also there was no significant difference between the prevalence of infection between male (31/32) and female (22/25) *S. carolinensis* ($p$ = 0.85). Therefore the numbers of infected males and females of each host have been grouped together (Tables 1 and 2).

In the samples from *S. vulgaris*, 34.7% had one eimerian species, 19.6% had two species and no squirrel was found to be infected by all three species simultaneously. In contrast, for the samples from *S. carolinensis* from Epping Forest, 19% of squirrels harboured one *Eimeria* species, 44% had two species and 14% were infected with three species.

## Discussion

The populations of native red squirrels and introduced grey squirrels studied have a high prevalence of eimerian coccidia. Jawdat (1975) found that of 151 grey squirrels examined from an area near Reading, Berkshire, England all were infected with *Eimeria* spp. Faecal samples from 12 grey squirrels examined by Britt and Molyneux (1979) from Cheshire all revealed eimerian oocysts, as did faecal samples from 44 grey squirrels from Northern Ireland (Scantlebury et al. 2010). These latter workers also reported that there were no differences in the prevalence of infection between sexes of the host; our results are in accord with these observations. Bertolino

et al. (2003) examined red squirrels from the Alps and found *E. sciurorum* in 111 of 143 (78%) and *E. andrewsi* in 61 of 143 (43%), which are 12% and 5%, respectively, greater than our findings.

The high prevalence of *E. sciurorum* and *E. andrewsi* suggests that a strong immunity does not develop and that hosts are either chronically infected or more likely being continually re-infected. Heavily infected young grey squirrels approximately 3 weeks old have been recovered from dreys, suggesting that infection is being passed from parents acting as carriers (Ball, S.J. and Withers, P., unpublished results).

In his review, Duszynski (1986) suggested that in mammals host specificity may not be as rigid as previously thought and gives examples of shared *Eimeria* species, especially in the Scuiridae. However it is not known whether *S. vulgaris* and *S. carolinensis* share coccidia but it would be interesting to determine whether the two species (*E. ontarioensis* and *E. mira*) could infect both hosts. Evidence from other squirrel species is scarce. Motriuk-Smith et al. (2009) identified *E. ontarioensis* and *Eimeria lancasterensis*, originally described from the grey squirrel, in the tree squirrel, *Sciurus niger*. In addition, *E. confusa* from the grey squirrel has been successfully transmitted to the fox squirrel (*S. niger rufiventer*) by Joseph (1975).

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