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Long-term study of *Sarcoptes scabiei* infection in Norwegian red foxes (*Vulpes vulpes*) indicating host/parasite adaptation

Rebecca K. Davidson [a,*], Set Bornstein [b], Kjell Handeland [a]

[a] *Section for Wildlife Diseases, National Veterinary Institute, P.O. Box 8156 Dep., NO-0033 Oslo, Norway*
[b] *Department of Parasitology (SWEPAR), National Veterinary Institute, P.O. Box 7073, S-750 07 Uppsala, Sweden*

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Abstract

The red fox (*Vulpes vulpes*) population, in Norway, was naïve to *Sarcoptes scabiei* prior to the late 1970s when this parasite was first recorded and a still ongoing epidemic started. During the course of this protracted epidemic some degree of host/parasite adaptation, with the occurrence of healthy antibody positive foxes, might be expected. In the present study the prevalence of sarcoptic mange and serologically identified *S. scabiei* exposure was investigated in 363 Norwegian red foxes, shot by hunters during two different study periods (1994–1995 and 2002–2005). The sarcoptic mange diagnosis was based upon the presence of clearly visible lesions in the skin of the cadaver with confirmatory demonstration of *S. scabiei*. The serodiagnosis was based on an indirect-ELISA. There was a significant decrease in prevalence of both mange cases and seropositive animals from the first to the second study period. Whilst the mange prevalence fell more than threefold, from 30.0% to 6.6%, the seroprevalence dropped less dramatically from 53.3% to 19.1%. The smaller decrease in seroprevalence compared to mange cases reflected a significantly higher ratio of seropositive-mange negative versus seropositive-mange positive foxes, during the second study period, 40:18, compared to the first, 14:18. These findings indicate that the red fox population is adapting to live with the parasite and that low-grade or sub-clinical infections, and even recoveries, occur amongst exposed foxes. Mange positive foxes had significantly poorer body condition than those without sarcoptic mange. No significant difference in body condition was seen between seropositive-mange negative versus seronegative-mange negative foxes. The ELISA sensitivity was found to be 95% and proved a useful tool for investigating the exposure to *S. scabiei* in wild foxes. This study is believed to be the first pointing to a long-term *Sarcoptes*/fox adaptation, combining long-term prevalence studies of clinical sarcoptic mange and serological evidence of exposure to the parasite in the general fox population.

Keywords: ELISA; Epidemic; Immunity; *Sarcoptes scabiei*; Sarcoptic mange; Serodiagnosis; Seroprevalence; Sub-clinical disease; Wildlife

1. Introduction

Sarcoptes scabiei (*De Geer* (*1778*)) is a highly contagious burrowing mite found in the epidermis of a wide range of hosts. It is thought to be a single species with different strains infecting different hosts (Burgess, 1994). *S. scabiei var. vulpes* has been identified in red foxes (*Vulpes vulpes*), considered the primary host, as well as in lynx (*Lynx lynx*), wolves (*Canis lupus*), dogs (*Canis lupus familiaris*) and less frequently in cats (*Felix silvestris catus*) (Bornstein et al., 2004). Transmission of the mites may follow both direct and indirect contact between animals (Borg, 1978; Pence and Ueckermann, 2002). The Fennoscandian red fox populations were naïve to *S. scabiei* prior to the epizootic that started in Finland in the late 1960s and

* Corresponding author. Tel.: +47 23216352.
E-mail address: rebecca.davidson@vetinst.no (R.K. Davidson).

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subsequently swept through the Scandinavian peninsula, during the 1970s and 1980s with dramatic consequences on population levels (Mörner, 1992). The first Norwegian case was diagnosed in 1976. Forty-nine percent of all red foxes (277/566) submitted for post-mortem at the National Veterinary Institute, Oslo, Norway, between 1976 and 1989, were diagnosed with sarcoptic mange (Holt and Berg, 1990). However, the real prevalence of sarcoptic mange in Norway during this period is difficult to ascertain as the animals examined did not represent a random selection from the general red fox population.

Skin lesions in infected red foxes develop with the course of the infection from small localised areas to generalised mange: erythema and seborrhoea progress to matting of the fur, alopecia, crusting and hyperkeratosis (Bornstein et al., 1995; Little et al., 1998). In experimental red foxes the appearance of skin lesions occurred 10–31 days post-infection, dependent on the infection dose (Mörner and Christensson, 1984; Bornstein et al., 1995). The course of *S. scabiei* infection, in experimental fox infections, normally lead to loss of appetite, emaciation, generalised mange and eventually death (Mörner and Christensson, 1984; Bornstein et al., 1995). However, during the course of a long-lasting epidemic in wild animal populations some degree of parasite/host adaptation, with the occurrence of non-fatal, restricted or sub-clinical infections, could be anticipated (Mörner and Christensson, 1984; Pence and Windberg, 1994). One wildlife survey has also suggested that foxes may recover from *S. scabiei* infections (Storm et al., 1976) and the occurrence of localised persistent sarcoptic mange, not progressing to generalised mange, has been observed in a single fox during experimental studies (Bornstein et al., 1995). Recovery from small *S. scabiei* burdens and development of some degree of immunity has been demonstrated in experimentally infected dogs (Arlian et al., 1996). Experimentally infected foxes, on the other hand, failed to exhibit protective immunity when re-infected with high doses of *S. scabiei* (Little et al., 1998).

A definitive diagnosis of sarcoptic mange is achieved by demonstrating *S. scabiei* in skin lesions. However, finding the mites in skin scrapings in canines is notoriously difficult (Griffin, 1993; Beck and Hiepe, 1998) and the identification of subtle lesions is challenging in animals with a thick fur coat, like the fox (Bornstein et al., 1995, 2001). Serodiagnosis, by ELISA, has proved a useful and reliable test in diagnosing experimental infections in red foxes (Bornstein et al., 1995). The ELISA has also recently been evaluated in naturally infected foxes with skin lesions and the sensitivity and specificity of the test were 95% and 100%, respectively (Bornstein et al., 2006). This test could also be valuable in detecting subtle or sub-clinical infections, thus highlighting the general exposure to the parasite in fox populations. Valuable information about possible long-term changes in pathogenicity of the parasite or host/parasite adaptation in fox populations might be gained by combining the ELISA and post-mortem examination of randomly selected foxes, over time.

The aim of this study was to investigate the prevalence of sarcoptic mange, and serologically identified *S. scabiei* exposure in Norwegian red foxes shot by hunters with a 10-year interval; thereby highlighting a possible long-term adaptation between the parasite and the host during this period of time.

2. Materials and methods

2.1. Animals, skin lesions and parasitology

The animals examined were the same as those described by Davidson et al. (2006) reflecting two study periods: during the hunting seasons (December–April) in 1994–1995 and 2002–2005. Hunters, who had supplied red fox pelts to the Oslo Fur Auction House and those that had previously submitted red fox carcasses to the National Veterinary Institute, Oslo, were sent a letter describing the study and requesting participation. Those that participated received a small remuneration for each red fox carcass. Hunters were permitted to retain the pelts and each hunter was permitted to send three foxes per year. The vast majority of hunters that sent in foxes during the first study period also participated in the second study period. During the first study period 65 animals were examined whilst 328 animals were examined during the second period giving a total of 393 animals. Fox carcasses from which blood samples for *S. scabiei* serology could not be obtained were excluded (5 from the first study period and 25 from the second), leaving 363 animals in the study population. The animals originated from throughout the country, with the main bulk coming from Eastern Norway (Fig. 1), consistent with hunting bag statistics (Statistics Norway, www.ssb.no). One hundred and seventy three (47%) of the 363 fox carcasses included in this study were submitted with an intact fur, reflecting 27 (45%) and 146 (48%) of the animals examined during the first and second study periods, respectively. The remaining carcasses were skinned prior to submission. At post-mortem, the general body condi-