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Endoparasites in the endangered Fennoscandian population of arctic foxes (*Vulpes lagopus*)

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Abstract The Fennoscandian arctic fox (*Vulpes lagopus*) population is endangered due to overharvest and competition with the larger red fox (*Vulpes vulpes*). In this study, we have screened the population in Sweden for endoparasites by analysis of non-invasively faecal samples collected at reproductive dens during two summers, one with low food abundance (2008) and the other with high food abundance (2010). Eggs, larvae and oocysts of a total of 14 different endoparasites were identified with a species richness per inhabited den of 3.2 (CI95%±0.48) in 2008 and 2.7 (CI95%±0.72) in 2010. *Capillariidae*-like eggs was identified at 59% of the dens in 2008 and 57% in 2010 and *Toxocara canis* with 7% (2008) and 30% (2010); *Toxascaris leonina* with 93% (2008) and 65% (2010); *Uncinaria stenocephala* 65% (2008) and 39% (2010); *Crenosoma vulpis* 3% (2008) and 4% (2010); *Trichuris* sp. 7% (2008) and 4% (2010); *Cystoisospora canis*-like

oocysts 28% (2008) and 26% (2010); *Cystoisospora ohiensis*-like oocysts 38% (2008) and 4% (2010); *Eimeria* sp. 7% (2008) and 9% (2010); *Sarcocystis* sp. 3% (2008) and 9% (2010); *Taenia* sp. 10% (2008) and 4% (2010); *Mesocestoides* sp. 3% (2008) and 0% (2010); *Balantidium* sp. 0% (2008) and 9% (2010) and *Spiruroidea*-like eggs 0% (2008) and 4% (2010). To our knowledge, *Balantidium* sp., *Sarcocystis* sp. and *Trichuris* sp. has never been described before in wild arctic foxes.

Keywords *Alopex lagopus* · Parasites · Conservation · Wildlife disease · Sweden

Introduction

Endoparasite helminth infections have been found to be an important component in the dynamics of wild mammal populations. Effects on vital demographic parameters such as decreased survival and fecundity have been described (Anderson and May 1978). From a conservation perspective, endoparasite infections might thus hamper population recovery or decrease the efficiency of conservation actions. In Fennoscandia, the arctic fox (*Vulpes lagopus*) population suffered a severe demographic and genetic bottleneck during the twentieth century (Nyström et al. 2006) due to overharvest and increased competition with the larger red fox (*Vulpes vulpes*; Hersteinsson et al. 1989). Since 1998, the conservation project, “Save the Endangered Fennoscandian Alopex”, has conducted conservation actions to increase the viability of the population. The actions include supplementary feeding to increase juvenile survival and red fox culling to decrease interference competition (Angerbjörn et al. 2008). Despite management actions, the juvenile and adult survival in Fennoscandia is lower compared to other small canids

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(Meijer et al. 2008). The arctic fox population in Fennoscandia is highly dependent upon small rodent cycle for reproduction and survival (Angerbjörn et al. 1995). Between the small rodent peaks, food is scarce and endoparasite infections might be one possible factor contributing to the lower survival. In this study, we investigated the species richness of endoparasites in the arctic fox population in Sweden by analysis of non-invasively collected faecal samples during 2 years, one with high small rodent abundance and one with low rodent abundance. Samples were included from two summers since endoparasites can be variable over time and change with food abundance (e.g., Saeed et al. 2006). Approximately, 90% of the recorded arctic fox litters in Sweden were screened for endoparasites in the study.

Materials and methods

The samples were collected in the Swedish part of the mountain tundra in Jämtland, Västerbotten and Norrbotten Counties. Fresh faecal pellets were collected during July–August 2008 and 2010 at reproductive den sites with arctic foxes. The samples originated from both juvenile and adult arctic foxes in order to describe the species richness of endoparasites at den/litter level. In 2008, the small rodent abundance was low, and in 2010, it was high. In total, 29 dens with litters were sampled in 2008 and 23 in 2010; this represents 90% of all litters born in Sweden 2008 and 2010.

Parasitological examinations of the faecal samples were conducted at the National Veterinary Institute, Uppsala, Sweden. Analyses were performed using a flotation

technique with centrifugation according to Thienpont et al. (1986), but with a few modifications. Three grammes of faeces were mixed with 10 ml of saline and sieved into a test tube which was centrifuged. All samples were also analysed with a modified Telemann sedimentation technique (Thienpont et al. 1986), where 3 g of faeces and 10 ml acetic acid solution were mixed and sieved into a test tube before the addition of ether and centrifugation. Parasite eggs and oocysts were identified morphologically according to Thienpont et al. (1986) and Pellérdy (1974). We used Fisher's exact test to detect differences in proportion infected litters/dens between years.

Results

Parasitological analysis of the faecal samples revealed eggs, larvae and oocysts of a total of 14 different endoparasites (Table 1), including seven nematode species: *Capillariidae*-like eggs, *Toxocara canis*, *Toxascaris leonina*, *Uncinaria stenocephala*, *Crenosoma vulpis*, *Trichuris* sp., *Spiruroidea*-like eggs; five protozoan species: *Cystoisospora ohioensis*-like oocysts, *Cystoisospora canis*-like oocysts, *Balantidium* sp., *Eimeria* sp. and *Sarcocystis* sp. and two cestodes: *Taenia* sp. and *Mesocestoides* sp. Species richness per inhabited den was 3.2 (CI95%±0.48) in 2008 and 2.7 (CI95%±0.72) in 2010 ($p=0.21$).

T. leonina was the most frequent parasite species found at 93% of the dens in 2008 and 65% in 2010 (Table 1.). *C. canis*-like oocysts, *U. stenocephala* and *Capillariidae*-like

Table 1 Parasite species and richness (%) at arctic fox (*V. lagopus*) den sites (*n*) with litters in 2008 and 2010

Endoparasite	2008 (<i>n</i> =29)	2010 (<i>n</i> =23)	Trend	Fisher exact test (<i>p</i> value)	1996 (<i>n</i> =3) ^a
<i>Protozoa</i>					
<i>Balantidium</i> sp.	0	9	+	0.19	
<i>Cystoisospora canis</i> -like oocysts	28	26	–	0.57	X
<i>Cystoisospora ohioensis</i> -like oocysts	38	4	---	0.01	X
<i>Eimeria</i> sp.	7	9	+	0.6	X
<i>Sarcocystis</i> sp.	3	9	+	0.41	
<i>Nematoda</i>					
<i>Capillariidae</i> -like eggs	59	57	0	0.51	X
<i>Toxocara canis</i>	7	30	++	0.03	X
<i>Toxascaris leonina</i>	93	65	–	0.01	X
<i>Uncinaria stenocephala</i>	65	39	–	0.05	X
<i>Crenosoma vulpis</i>	3	4	0	0.69	X
<i>Trichuris</i> sp.	7	4	–	0.58	
<i>Spiruroidea</i> -like eggs	0	4	+	0.44	
<i>Cestoda</i>					
<i>Taenia</i> sp.	10	4	–	0.39	
<i>Mesocestoides</i> sp.	3	0	–	0.55	

X indicates that the species was identified

^a from Aguirre et al. (2000), Sweden

eggs were all found in relatively high abundance during both 2008 and 2010 (Table 1). *C. ohioensis*-like oocysts were found at 38% of the den sites in 2008 but only at 4% in 2010. *T. canis* showed the opposite pattern compared to *C. ohioensis*-like oocysts and increased from 7% in 2008 to 30% in 2010. The other parasite species were all found in 10% of the dens or less.

Table 2 Endoparasite species identified in the arctic fox from Sweden (Aguirre et al. 2000, this study), Iceland (Skirnisson et al. 1993), Greenland (Kapel and Nansen 1996; Rausch et al. 1983), Canada (Eaton and Secord 1979) and Svalbard (Stien et al. 2002)

	Sweden	Iceland	Greenland	Canada	Svalbard
<i>Cestoda</i>					
<i>Taenia crassiceps</i>				x	x
<i>Taenia ovis krabbei</i>			x		x
<i>Taenia</i> sp.	x		x		
<i>Taenia polyacantha</i>					x
<i>Mesocestoides canislagopodis</i>		x			x
<i>Mesocestoides lineatus</i>			x		
<i>Mesocestoides</i> sp.	x				
<i>Diphyllobothrium dendriticum</i> and <i>Diphyllobothrium</i> sp.		x	x		x
<i>Schistocephalus solidus</i>		x			
<i>Echinococcus multilocularis</i>				x	x
<i>Nematoda</i>					
Ascarioid nematodes ^a					x
<i>Capillariidae aerophila</i>		x			
<i>Capillariidae</i> -like eggs	x				
<i>Toxascaris leonina</i>	x	x	x	x	
<i>Toxocara canis</i>	x	x			
<i>Uncinaria stenocephala</i>	x	x	x		
<i>Crenosoma vulpis</i>	x				
<i>Trichuris</i> sp.	x				
<i>Spiruroidea</i> -like eggs	x				
<i>Strongyloides stercoralis</i>			x		
<i>Protozoa</i>					
<i>Balantidium</i> sp.	x				
<i>Cystoisospora canis</i> -like oocysts	x				
<i>Eimeria</i> sp.	x	x			
<i>Sarcocystis</i> sp.	x				
<i>Acanthocephala</i>					x
Acanthocephalan ^a					
<i>Corynosoma hadweni</i>		x			
<i>Polymorphus meyeri</i>		x			
<i>Polymorphus</i> sp.			x		
<i>Trematoda</i>					
<i>Tristriata</i> sp.		x			
<i>Spelotrema</i> sp.		x			
<i>Brachylaemus</i> sp.		x			
<i>Plagiorchis elegans</i>		x	x		
<i>Cryptocotyle concavum</i>			x		
<i>Cryptocotyle lingua</i>		x			
<i>Cryptocotyle</i> sp.			x		
<i>Echinoparyphium</i> sp.			x		

^a not specified

Discussion

The species richness identified in this study is similar to previous studies of arctic foxes in Fennoscandia (Aguirre et al. 2000), Greenland (Kapel and Nansen 1996) and Iceland (Skirnisson et al. 1993), even though the species composition differs between the areas (Table 2.). Most notable is the

absence of Acanthocephalans and trematodes in Sweden, Canada and Svalbard compared to Iceland and Greenland (Table 2). This is likely due to dietary differences between coastal foxes and inland foxes where the coastal foxes prey upon marine resources and inland foxes depend on small rodents or birds. In Iceland, no trematodes were found in the inland foxes but were common among coastal foxes (Skirnisson et al. 1993). According to Wilson et al. (2003), low density of host populations may have a negative impact on the parasite species richness. This implies a prediction that the small Fennoscandian arctic fox population with a recent population bottleneck (Nyström et al. 2006) should host fewer species of endoparasites compared to larger populations as in, e.g. Iceland and Greenland. In Fennoscandia, the arctic fox is sympatric with the red fox which might function as an endoparasite reservoir and explains the high number of endoparasites despite the small population size. *Trichuris* sp., *Sarcocystis* sp. and *Balantidium* sp. have to our knowledge, never been described in wild arctic foxes but *Trichuris* sp. and *Sarcocystis* sp. are common in the red fox (Persson and Christensson 1971; Rajkovic-Janje et al. 2004). Except for the *C. ohioensis*-like oocysts and *Balantidium* sp., all the endoparasite species identified in the arctic fox have previously also been described in the red fox (Persson and Christensson 1971; Martínez-Carrasco et al. 2007a; Rajkovic-Janje et al. 2002; Rajkovic-Janje et al. 2004; Rodríguez and Carbonell 1998). In addition, the number of identified endoparasite species in the Fennoscandian arctic fox population is most likely underestimated in this study since analysis of faecal samples only can detect species that sheds eggs during the sampling period. Especially cestodes have been found to be difficult to detect in faecal samples (Martínez-Carrasco et al. 2007b).

Comparisons of the parasite species richness between 2008 and 2010 indicate a stable number of species in the arctic fox population. The most common species in our study was also found in Aguirre et al. (2000) that recorded endoparasites of three litters in Sweden 1996. Even though the species richness seems to be fairly stable over time, the proportion of infected dens is more variable (Table 1). *T. canis* was the only parasite that significantly increased from 7% to 30% between 2008 and 2010 which could be explained by the increase of small rodents, possible function as an indirect paratenic host (Taylor et al. 2007). However, this seems not to be a general phenomenon since *T. leonina*, *U. stenocephala* and *C. ohioensis*-like oocysts all decreased despite that they all can be spread by small rodents (Taylor et al. 2007). Several of the other identified parasite species are likely to be spread by small rodents but they all remained at a stable level between the sampling years. Monitoring over several years would be needed for further conclusions about the endoparasite dynamics in the arctic fox.

The impact of the identified parasites on the population might be variable due to large variations in natural food resources. The parasite burden can have effects on both survival and lactation levels in other mammal species (Gulland 1992; Albon et al. 2002). The most common endoparasite species in this study, *C. ohioensis*-like oocysts, *C. canis*-like oocysts, *Capillariidae*-like eggs, *T. leonina* and *U. stenocephala*, have all been observed to have a negative impact on their host (Taylor et al. 2007). Aguirre et al. (2000) found a negative relationship between hind foot length and infection of *T. leonina* with a possible negative effect on future reproduction. However, in the study population, the foxes have been supplementary fed (Angerbjörn et al. 2008), which might reduce possible negative effects of the endoparasites by the extra energy provided in the food. Only few cases of juvenile mortality due to starvation have been observed in the area where the foxes have received supplementary food (Meijer et al. 2008; Meijer et al. 2010). Earlier studies of arctic foxes showed that non-fed litters were found to suffer from higher mortality due to starvation (Tannerfeldt et al. 1994). In the study area, the juvenile summer mortality has been found to be 27% (Meijer et al. 2010) with an annual mortality of 92% during the first year (Meijer et al. 2008). A large proportion of the summer mortality has been attributed to predation (Meijer et al. 2010), but the cause of mortality after natal dispersal is yet unknown. Endoparasites might contribute to the high mortality rate, especially since the juveniles lose their access to supplementary food after dispersing. The juvenile body weight has been found to be highly variable in the study area but seems to be related to maternal experience and date of birth (Meijer et al. 2010). From a conservation perspective, it is of importance to consider the impacts of endoparasite infections if supplementary feeding is reduced or suspended.

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