Infections with cardiopulmonary and intestinal helminths and sarcoptic mange in red foxes from two different localities in Denmark

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Abstract
Monitoring parasitic infections in the red fox is essential for obtaining baseline knowledge on the spread of diseases of veterinary and medical importance. In this study, screening for cardiopulmonary and intestinal helminths and sarcoptic mange (Sarcoptes scabiei) was done on 118 foxes originating from two distinct localities in Denmark, (Copenhagen) greater area and southern Jutland. Fifteen parasite species were recorded in 116 foxes (98.3%), nine parasitic species are of zoonotic potential. Parasite diversity was greater in foxes of Copenhagen in terms of overall parasite species richness and species richness of all helminth groups individually: trematodes; cestodes; and nematodes. Six parasite species were recovered from foxes of Copenhagen, but not from foxes of Southern Jutland: Echinochasmus perfoliatus; Echinostoma sp.; Pseudamphistomum truncatum; Dipylidium caninum; Angiostrongylus vasorum; and Sarcoptes scabiei, but Toxascaris leonina was only recorded in foxes of southern Jutland. A high prevalence and abundance of A. vasorum in foxes of Copenhagen was observed. The prevalence of four nematode species; Eucoleus (Capillaria) aerophilus, Uncinaria stenocephala, Toxocara canis, and Crenosoma vulpis, in foxes of both localities were comparable and ranging from 22.9% to 89%. The prevalence of Mesocestoides sp. was significantly higher in foxes of Copenhagen. Taenia spp. were detected using morphological and molecular analysis, which revealed the dominance of T. polyacantha in foxes of both localities. Infections with sarcoptic mange were evident only among foxes of Copenhagen (44.9%), which significantly affected the average weight of the infected animals. Further remarks on the zoonotic and veterinary implications of the parasites recovered are given.

Keywords
Red fox, intestinal helminths, cardiopulmonary helminths, sarcoptic mange, Angiostrongylus vasorum, Taenia spp.

Introduction
In Europe several parasite species were recovered from foxes including parasites that are shared with pet animals and humans (Table I). Accordingly, this situation has created concerns of increased transmission of parasites of medical and veterinary importance to urban areas (Deplazes et al. 2004). In Denmark, the proximity of the red fox to people has intensified at the same time as zoonotic parasites have become more prevalent in foxes (Saeed et al. 2006; Al-Sabi et al. 2013a). Monitoring parasitic infections in foxes assists control programmes and increases the awareness of the presence of communicable diseases.

The cardiopulmonary system of foxes in Europe can be infected with several metastrongylid nematodes, among which are Angiostrongylus vasorum, Crenosoma vulpis, Eucoleus aerophilus, and Eucoleus boehmi (Davidson et al. 2006). The red fox plays a major role as reservoir host for canine angiostrongylosis (Bolt et al. 1992). Infection with A. vasorum can cause mild or no clinical signs to highly pathogenic and even deadly consequences depending on the parasite burden (Denk et al. 2009). The geographical distribution of A. vasorum in Europe has increased over the past decades, and expansion is most likely linked to expanding fox populations and/or dog transportation (van Doorn et al. 2009; Al-Sabi et al. 2013b). Since the earliest record of A. vasorum in Denmark in 1983 (Finnerup 1983), clinical and epidemiological studies on dogs and foxes showed increased prevalence on both hosts (Pedersen et al. 1995; Saeed et al. 2006).
Table I. Prevalence of selected intestinal helminth of foxes reported in European countries. R: road-killed, H: hunted, D: found dead, Ns: not specified. *Echinostomatidae, **prevalence of Trematoda: 11.8%, ***prevalence of Trematoda: 1.4%

| Parasite species | Animal source | Reference | Echinochasmus peroliatus | Opisthorchis felinus | Echinostoma sp. | Paraphyllobothrium truncatum | Ariaa alata | Cryptocotyle lingua | Dipylidium caninum | Taenia serialis | Taenia taeniaeformis | Taenia hydatigena | Taenia pisiformis | Taenia polyacantha | Taenia ovisiceps | Taenia spp. | Echinococcus multilocularis | Mesocestodes sp. | Toxocara canis | Toxascaris leonina | Uncinaria stenocephala | Trichuris vulpis |
|------------------|--------------|-----------|--------------------------|---------------------|----------------|-----------------------------|-------------|------------------|-----------------|----------------|------------------------|-----------------|-----------------|----------------------|----------------|----------------|---------------------|----------------|----------------|
| Denmark (1040)   | R, H         | Saeed et al. 2006 | 1.3                      | 2.2                 | 15            | 24                          | 1           | 0.4              | 0.3              | 0.2             | 21.5                    | 0.3              | 36              | 59                   | 69              | 0.6             | 0.5                  |
| Denmark (21)     | R            | Willingham et al. 1996 | 38                      | 24                  | 81            | 86                          | 1           | 2                | 26              | 10              | 49                      | 35              | 70              | 9                    | 1               |                 |                      |
| Denmark (100)    | H, D         | Gluidal and Clausen 1973 | 1                        | 2                   | 26            | 2                           | 3           | 5                | 10              | 49              | 35                      | 70              | 9               | 1                    |                 |                 |                      |
| Lithuania (53–99) | H            | Bruzinskaite-Schmidhalter et al. 2012 | 10.6*                   | 96.5                | 2.2           | 2                           | 9.4         | 8.2              | 30.6            | 17.6            | 98.8                    |                 |                 | 35.8                 |                 |                 |                      |
| Switzerland (228)** | R (>75%)    | Reperant et al. 2007 | 2.2                      | 41.9                | 46.3          | 5.7                         | 44.3        | 78.2             | 37.3            | 8.3             | 3                       |                 |                 |                      |                 |                 |                      |
| Poland (639)     | H            | Borecka et al. 2009 | 0.9                      | 56.7                | 29.7          | 13.9                        | 71.2        | 19.1             | 35.8            |                 |                         |                 |                 |                      |                 |                 |                      |
| Portugal (62)    | H            | Eira et al. 2006     | 3.2                      | 3.2                | 1.6           | 3.2                         | 30.7        | 37.3             | 77.4            | 8.1             |                         |                 |                 |                      |                 |                 |                      |
| Italy (645)**    | H, D         | Di Cerbo et al. 2008 | 3.4                      | 0.3                | 29            | 0.8                         | 27.4        | 54.4             | 51.3            | 0.2             |                         |                 |                 |                      |                 |                 |                      |
| Hungary (68)     | H            | Andras 2001          | 48.5                     | 2.9                | 2.9           | 2.9                         | 33.8        | 4.8              | 26.5            | 11.8            | 11.8                    | 4.4             |                 |                      |                 |                 |                      |
| Spain (399)      | Ns           | Segovia et al. 2004  | 0.2                      | 2                   | 0.2           | 2                           | 10.3        | 4.3              | 28.8            | 29.3            | 71.2                    | 19.3            | 8.3             |                      |                 |                 |                      |
| France (154)     | H            | Deblock et al. 1988  | 1.3                      | 11                  | 23.4          | 14.9                        | 26.1        | 51.3             | 58.4            | 25.3            | 16.2                    |                 |                 |                      |                 |                 |                      |
| Netherlands (139)| Ns           | Borgsteede 1984      | 10.9                     | 3.6                | 53.3          | 73.7                        | 59.9        |                 |                 | 73.7            | 59.9                    |                 |                 |                      |                 |                 |                      |
| Croatia (85)     | H            | Rajkovic-Janje et al. 2002 | 4.7                     | 24.7               | 4.7           | 28.2                        | 25.9        |                 |                 |                 |                         |                 |                 |                      |                 |                 |                      |
| Austria (516)    | H            | Lassing et al. 1998  | 0.2                      | 6.8                | 14.6          | 17.4                        | 3.6         | 15.6             | 46.8            | 43              | 0.6                      | 0.2             |                 |                      |                 |                 |                      |
| Germany (3573)   | H, R         | Loos-Frank and Zeyle 1982 | 0.5                     | 0.6                | 8             | 24                          | 20.2        | 32               | 26              | 3               |                         |                 |                 |                      |                 |                 |                      |
No further updates on the prevalence of *A. vasorum* were reported among Danish foxes.

The red fox can host many species of *Taenia* (Table I) that can cause severe disease in intermediate and aberrant hosts (Jones and Pybus 2001), including humans (OIE 2005). Differential diagnosis of taeniid worms is not always feasible due to loss of characteristic morphological features as a result of cadaver preservation methods (Borgsteede 1984; Wolfe et al. 2001). Alternatively, differential diagnosis of taeniid worms can be achieved by molecular typing (Trachsel et al. 2007; Al-Sabi et al. 2011; Armua-Fernandez et al. 2011), but this has not been practiced in epidemiological studies on fox taeniids yet.

Before 1996, fox infections with sarcoptic mange was never reported from the island of Zealand, but occurred in other regions in Denmark (Bak et al. 1997; Forchhammer and Asferg 2000). Later to that date, an outbreak of sarcoptic mange was evident in the island Zealand, and highly reduced the fox population in that area (Danish Nature Agency 2012). Outbreaks of scabies in foxes of Fennoscandinavia were previously linked to the reduction of the fox population, sometime by over 70% (Forchhammer and Asferg 2000). These structural changes in the fox population may have influence on the behaviour of foxes (Overskaug 1994) and potentially influenced the spread, transmission, and distribution of parasites.

Monitoring parasite infections in foxes is usually done by collecting road kills and/or hunted animals (Table I). Foxes killed by speeding vehicles can be found year-round in urban and rural areas, while hunting might be restricted, according to local legislations, to specific seasons and is usually not allowed in urban localities. Therefore, analyzing samples collected by a single method in one locality might not represent the true parasite prevalence in the whole population (Loos-Frank and Zehyle, 1982), especially if studies utilize small sample sizes. Another important factor that might bias the use of road kills is that parasitic infections might induce behavioral changes (Rammuth 2009) that could increase or reduce the vulnerability of infected hosts to be killed in the road, but to our knowledge this has not been studied yet. The aims of this report are to study the prevalence of cardiopulmonary, intestinal and external parasites of foxes originated from two distinct localities in Denmark, (Copenhagen) greater area and southern Jutland.

### Materials and Methods

**Locality of study and post mortem examination**

Foxes were collected from two different localities in Denmark. The first was the densely populated locality of Copenhagen in north-east Zealand, from which 70 foxes were road-killed in highways and streets during the period from October 2006 to March 2008. The second locality was the southern part of the peninsula Jutland that links Denmark to mainland Europe via Germany. In that locality, small cities are located and the main activities there are related to agriculture. Foxes from southern Jutland (n = 48) were hunted during the hunting season from January to March 2007. Because we used two different methodologies to collect foxes from two different localities, we will not apply the terms ‘urban’ or ‘rural’ to indicate the origin of the collected foxes.

The skin of foxes was visually inspected and sarcoptic mange was recorded based on pathognomonic clinical signs and presentation of causative agent by microscopy (Davidson et al. 2008). The small intestine of sampled animals were frozen for at least four days at –80°C to deactivate eggs of *E. multilocularis*, and then thawed and dissected. The mucosa of the small intestine was scraped and the intestinal contents were washed with lukewarm water into a 500 µm and a 212 µm sieve by means of a water jet. An initial diagnosis of taeniid worms was based on the shape, size and number of rostellar hooks (Verster 1969) and followed by multiplex PCR analysis for differentiating species of *Taenia* (Al-Sabi et al. 2011). If foxes harboured less than five worms then all worms were examined, whereas at higher worm burden up to ten worms per host were examined with priority given to worms that had retained rostellar hooks, for morphological comparison and confirmation. In either case, all worms were analyzed individually. Hearts were opened with scissors and lung tissue was dissected using a metallic needle to free the adult worms. The dissected lung tissue was then placed over a 212 µm sieve and was washed with lukewarm water by means of a water jet. Collected worms from cardiopulmonary and intestinal tracts were collected in Petri dishes for morphological identification after examination under a dissection stereomicroscope (40×–100× magnifications) (Soulsby 1982).

### Statistical analysis

Summaries of parasites prevalence, mean intensity of infection, and abundance were estimated according to Bush et al. (1997) and data were presented as mean values ± 95% confidence intervals (95% CI) fitted using the binomial distribution.

The association between the presence of the cardiopulmonary nematodes: *C. vulpis* and *E. aerophilus*; *C. vulpis* and *A. vasorum*; and *E. aerophilus* and *A. vasorum*, was investigated, adjusted for the effect of the area where the animal was obtained (Area), using logistic regression according to the following equation:

\[
Y = \beta_0 + \beta_1 \times \text{Parasite} + \beta_2 \times \text{Area} + \beta_3 \times \text{Parasite} \times \text{Area} \quad (1)
\]

Y was a nominal variable representing the presence of the parasite of concern in an animal. Parasite was also a nominal variable representing the presence of the other parasite of concern in an animal. \(\beta_0\), \(\beta_1\), \(\beta_2\), and \(\beta_3\) represented the intercept and the coefficient of parasite, area and the interaction term between parasite and area, respectively. Area was a dichotomous variable representing the sampled locality.

Data on animal age and gender was only available for foxes of Copenhagen, therefore were not included in the statistical analysis. The association between parasite presence and area
and the weight of the animal (Weight) was investigated using logistic regression according to the following equation:

\[ Y = \beta_0 + \beta_1 \times \text{Weight} + \beta_2 \times \text{Area} + \beta_3 \times \text{Area} \times \text{Weight} \]  

(2)

\( Y \) was a nominal variable representing the presence of the parasite of concern in an animal. \( \beta_0, \beta_1, \beta_2, \) and \( \beta_3 \) represented the intercept and the coefficient of weight (kg), area and the interaction term between area and weight, respectively.

The statistical analysis was carried out using the freeware R version 2.15 (R core team, 2012).

## Results

Parasites were recovered from 116 foxes (98.3%; 94–99.8, 95% CI). Fifteen parasite species were isolated from foxes of both localities, nine of which are of zoonotic potential (Table II). The overall parasite species richness in foxes of Copenhagen (average 5.4 helminth species/fox) was significantly greater \((p<0.001)\) than that of foxes of southern Jutland (average 3 helminth species/fox) (Fig. 1). Almost half of the 70 foxes of Copenhagen \((n = 33; 47.1\%)\) harbored at least six different parasite species, whereas none of the foxes of southern Jutland harbored more than five different parasite species. Foxes from both localities did not differ in terms of overall presence of nematode infections (Fig. 2), but foxes from Copenhagen had significantly more cestode and trematode infections than foxes from Jutland \((p<0.001, \text{Fig. 2})\). For all parasite type groups: trematodes; cestodes; and nematodes, the parasite species richness in foxes of both localities showed significantly different pattern \((p<0.01, \text{Fig. 3})\). Most of the recovered helminths from both localities were nematodes (Table II). The prevalence of four nematode species; \(E. aerophilus\), \(U. stenocephala\), \(T. canis\), and \(C. vulpis\), in foxes of both localities were comparable, ranging in total from 22.9% to 89%. On the other hand, five parasite species were recovered from foxes of Copenhagen, but not from foxes of southern Jutland; \(E. perfoliatus\), \(E. \) sp., \(P. truncatum\), \(D. caninum\), \(A. vasorum\) and infection with \(S. scabiei\), while infections with \(T. leonina\) were only recorded in foxes of southern Jutland. The prevalence of \(M. \) sp. was higher in foxes of Copenhagen. Trematodes were almost exclusively recovered from foxes of Copenhagen that harbored five different trematode species with prevalence ranging from 5.7 for \(E. \) sp. to 34.3% for \(C. lingua\), while only two individual cases of \(A. alata\) and \(C. lingua\) were recorded in foxes of southern Jutland. The results of the univariate analysis showed significant negative association between prevalence of \(P. truncatum\) and animal weight \((p<0.01)\).

### Cardiopulmonary helminthes

The majority of the foxes from the two sampled localities harbored helminthes in its cardiopulmonary system. Only three

![Fig. 1. Bar graph showing the frequency percentage of parasite species (Y axis) recovered from foxes (X axis) originating from Copenhagen greater area and southern Jutland](image-url)
out of 70 foxes from Copenhagen (4.3%) and also three out of 48 foxes from southern Jutland (6.3%) were free of nematode infections in the cardiopulmonary system (Fig. 4). All foxes infected with *C. vulpis* were also infected with at least another cardiopulmonary nematode. The majority of infections with *A. vasorum* (50/64; 78.1%) were also infected with *E. aerophilus*. Foxes from both localities had a similar percentage (22.9%) of *C. vulpis* and *E. aerophilus* co-infections. No evidence of associations between cardiopulmonary parasites could be demonstrated statistically.

Infections with *A. vasorum* were only recorded among foxes of Copenhagen, which harboured a total of 976 *A. vasorum* worms, giving a mean abundance of 17.4 worms per infected fox and abundance per all foxes was 13.9 worms. The minimum parasite count in individual host was one worm, and the maximum parasite count in individual host was 88 worms. The biomass distribution of *A. vasorum* recovered from infected foxes highly fitted the binomial distribution ($R^2 = 0.964$). Most of the foxes infected with *A. vasorum* (64%) were juveniles less than one year of age.

Intestinal helminthes

*Taenia* spp. were recovered from 35 foxes in total from both localities with comparable prevalence (Table II). The biomass distribution of *Taenia* spp. recovered from infected foxes

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**Table II.** Prevalence (95% CI) of parasitic infections in foxes in (Copenhagen) greater area and southern Jutland, Denmark, based on *post mortem* analysis. Parasites of zoonotic potential are presented in italic bold

<table>
<thead>
<tr>
<th>Parasite group</th>
<th>Parasite species or disease</th>
<th>Copenhagen (n = 70)</th>
<th>Southern Jutland (n = 48)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trematodes</td>
<td><em>Echinococcus perfoliatus</em></td>
<td>1.4 (0.0–7.7)</td>
<td>0 (0.0–7.4)</td>
</tr>
<tr>
<td></td>
<td><em>Echinostomatidae</em> spp.</td>
<td>5.7 (1.6–14.0)</td>
<td>0 (0.0–7.4)</td>
</tr>
<tr>
<td></td>
<td><em>Pseudophistomum truncatum</em></td>
<td>10.0 (4.1–19.5)</td>
<td>0 (0.0–7.4)</td>
</tr>
<tr>
<td></td>
<td><em>Alaria alata</em></td>
<td>20.0 (11.4–31.3)</td>
<td>2.1 (0.1–11.7)</td>
</tr>
<tr>
<td></td>
<td><em>Cryptocotyle lingua</em></td>
<td>34.3 (23.4–46.6)</td>
<td>2.1 (0.1–11.7)</td>
</tr>
<tr>
<td>Cestodes</td>
<td><em>Dipylidium caninum</em></td>
<td>1.4 (0.0–7.7)</td>
<td>0 (0.0–7.4)</td>
</tr>
<tr>
<td></td>
<td><em>Taenia</em> spp.</td>
<td>22.9 (13.7–34.5)</td>
<td>39.6 (25.8–54.7)</td>
</tr>
<tr>
<td></td>
<td><em>Mesocestoides</em> sp.</td>
<td>78.6 (67.1–87.5)</td>
<td>8.3 (2.3–20.0)</td>
</tr>
<tr>
<td>Nematodes</td>
<td><em>Crenosoma vulpis</em></td>
<td>22.9 (13.7–34.5)</td>
<td>22.9 (12.0–37.3)</td>
</tr>
<tr>
<td></td>
<td><em>Toxocara canis</em></td>
<td>48.6 (36.4–60.8)</td>
<td>64.6 (49.5–77.8)</td>
</tr>
<tr>
<td></td>
<td><em>Angiostrongylus vasorum</em></td>
<td>80.0 (68.7–88.6)</td>
<td>0 (0.0–7.4)</td>
</tr>
<tr>
<td></td>
<td><em>Uncinaria stenocephala</em></td>
<td>84.3 (73.6–91.9)</td>
<td>60.4 (45.3–74.2)</td>
</tr>
<tr>
<td></td>
<td><em>Eucoleus</em> (Capillaria) <em>aerophilus</em></td>
<td>87.1 (77–94)</td>
<td>93.8 (82.8–98.7)</td>
</tr>
<tr>
<td></td>
<td><em>Toxascaris leonine</em></td>
<td>0 (0.0–5.3)</td>
<td>6.3 (1.3–17.2)</td>
</tr>
<tr>
<td>Ectoparasite</td>
<td><em>Sarcoptes scabiei</em></td>
<td>44.9 (32.4–56.7)</td>
<td>0 (0.0–7.4)</td>
</tr>
</tbody>
</table>
highly fitted the binomial distribution ($R^2 = 0.919$). The mean intensity of infection in foxes from Copenhagen was 13, with a worm range of one to 63 worms, with a mean abundance of 2.6 worms/fox. The mean intensity of infection in foxes from Jutland was 5.6, with a worm range of 1 to 33 worms, with a mean abundance of 2.9 worms/fox. Out of the recovered

![Fig. 3. Bar graph showing parasite species richness (based on parasite group) in foxes originating from two localities in Denmark: Copenhagen greater area, and southern Jutland](image)

**Fig. 3.** Bar graph showing parasite species richness (based on parasite group) in foxes originating from two localities in Denmark: Copenhagen greater area, and southern Jutland

![Fig. 4. Venn diagram representing prevalence (in percentage and count) and composition of cardiopulmonary nematode infecting red foxes collected from: Copenhagen greater area, and southern Jutland during a post mortem investigation carried out in Denmark from October 2006 to March 2008](image)

**Fig. 4.** Venn diagram representing prevalence (in percentage and count) and composition of cardiopulmonary nematode infecting red foxes collected from: Copenhagen greater area, and southern Jutland during a post mortem investigation carried out in Denmark from October 2006 to March 2008
worns of *Taenia* spp. (*n* = 263), mature/gravid segments were present in only 68 worms (25.9%), scoleces in 244 worms (92.8%) and rostellar hooks in 55 worms (20.9%), but none of the scoleces had more than 20 small and/or large hooks in rostellum. Analysis of 110 worms collected from the 35 infected foxes from both localities showed that 41 worms were identified to the species level by morphology (37.3%; ± 95% CI: 28.2–47%), whereas multiplex-PCR specifically identify 91 *Taenia* worms (82.7%; ± 95% CI: 74.4–89.3%). No mixed infections with more than one species of *Taenia* were detected. *Taenia polyacantha* was detected in 34 foxes from both localities (28.8%; 95% CI: 21–38%) and one *T. crassiceps* worm was detected in a fox (2.9%; 95% CI: 0.1–14.9%) originated from southern Jutland. None of the examined carnivores carried worms that could be referred as *E. multilocularis*.

Sarcoptic mange

Sarcoptic mange (*Sarcoptes scabiei*) was wide spread among foxes of Copenhagen (44.9%; 56/70), while none of the foxes from southern Jutland were infected with sarcoptic mange. Fox infections with sarcoptic mange had statistically strong negative association with body weight (*p* < 0.00075), as shown by the logistic regression. Most of the foxes infected with sarcoptic mange (79%) were juveniles less than one year of age.

**Discussion**

The current results show a marked difference in the prevalence of most of the recovered parasites from foxes collected from different localities, with marked higher level of parasite species richness among foxes of Copenhagen. Such phenomenon could be attributed to several behavioral and ecological reasons, including the ample presence of anthropogenic food in urban areas (Contesse *et al.* 2004), suitable intermediate host, appropriate condition for survival of highly resistant parasite eggs and larvae (Gortazar *et al.* 1998) and host feeding habits (Saeed *et al.* 2006). Nonetheless, the sampled foxes in southern Denmark might represent a mixed population of native and migrating foxes that usually exhibit reduced parasite species richness (Torchin *et al.* 2003).

Previous studies on road killed mammals linked animals’ vulnerability to road accidents to its species, age, gender and life history trait (Grilo *et al.* 2009), but no indication was given to its general health status or the presence of specific disease/s. It is commonly acknowledged that parasites induce various behavioral changes on its hosts to enhance parasite transmission (Ramnath 2009), but on the other hand hosts developed several strategies to avoid or reduce the effect of parasitic infections (Hart 1990). In this study, foxes from the area of Copenhagen were sampled year-round by collecting road-kills, while foxes from southern Jutland were sampled by hunters during winter. Such differences in the sampling methodology restrict the ability to generalize the results obtained here to the whole population of foxes in the corresponding localities, and as well restrict the ability to compare parasite prevalence rates reported here as if it originated from urban or rural areas.

Cardiopulmonary helminthes

*A. vasorum* were recovered from foxes of Copenhagen only, while the overall prevalence of *C. vulpis* and *E. aerophilus* did not differ between foxes of Copenhagen and southern Jutland. The majority of the examined foxes in this study (94.8% of 116) and in Norway (95.4% of 174; Davidson *et al.* 2006) were infected with cardiopulmonary nematodes, whereas lower prevalence of cardiopulmonary nematodes were reported in other European countries, for example 73.7% in Catalonia (Manas 2005) and 7.3% in Great Britain (Morgan *et al.* 2008). Most of the currently recovered cardiopulmonary nematodes are transmitted via invertebrate hosts, which are highly dependent on optimum environmental conditions (Gortazar *et al.* 1998; Ferdushy *et al.* 2010), host feeding habits, season and host aggregation (Rajkovic-Janje *et al.* 2002; Davidson *et al.* 2006; Saeed *et al.* 2006) for its development and ability to transmit infective larvae to the final host. The currently observed increase in the prevalence and abundance of *A. vasorum* among foxes compared to previous studies in Denmark (Guildal and Clausen 1973; Bolt *et al.* 1992; Willingham *et al.* 1996; Saeed *et al.* 2006) might be related to the increase in the abundance of snails in the currently studied area (Ferdushy *et al.* 2009). The increased prevalence of *A. vasorum* in foxes might enhance higher transmission rates to dogs (Jefferies *et al.* 2010), unless adequate preventive measurements are implemented.

Intestinal helminthes

In this study implementing a molecular typing of taeniid worms by a single step multiplex-PCR assay (Al-Sabi *et al.* 2011) facilitated species-specific detection of worms that could not be specifically diagnosed using morphology. Variations in prevalence rates of taeniids could be attributed to intrinsic variations in the ecological components of the studied localities, which mainly affect host feeding habits (Martinez-Moreno *et al.* 2007). Higher prevalence of *Taenia* spp. was reported in rural foxes in Denmark (Saeed *et al.* 2006) and Switzerland (Reperant *et al.* 2007). Most of the recovered *Taenia* spp. from foxes in the present and previous studies (Table 1) are transmitted via rodents. A previous study in Denmark showed that rodents make up a major portion of a fox diet (up to 67%) (Jensen and Sequeira 1978). The high prevalence of vole-transmitted *T. polyacantha* in foxes could be explained by the presence and close proximity to the intermediate host (Stien *et al.* 2010).

In Europe, the fox is the main definitive host for *Echinococcus multilocularis*, the causative agent of the po-
tentially lethal alveolar echinococcosis in humans (Deplazes et al. 2004). Fox infections with *E. multilocularis* in Denmark was reported for the first time in Copenhagen in 2000 (Kapel and Saeed 2000), and recently a small locality in southern Jutland, Højter, was reported highly endemic for *E. multilocularis* during a nation-wide surveillance program on parasites of wildlife (Enemark et al. 2013). In this study, none of the examined foxes that originated from these two areas had worms of *E. multilocularis*, probably because of limited sample size, because of sampling of animals from non-endemic foci or because of limitations related to helminth isolation technique. It is very likely that minute worms such as *Pygidiopsis* spp. might pass through the pores of the currently used mesh (212 µm), but relatively bigger worms such as *Echinococcus* spp. are most likely retained by the sieve. A recent study demonstrated that the use of a 150 µm mesh for collecting worms of *Echinococcus* spp. resulted in the retaining of more than 300,000 scoleces except for one scolex (Gesy et al. 2013). The later study demonstrated that using the 150 µm mesh for sieving the sediments of intestinal contents increased the sensitivity of the sedimentation and counting technique, with an additional advantage of significantly reducing time spent on sample examination (Gesy et al. 2013). We do not know if the currently used mesh of a slightly bigger pore size (220 µm) would have been less sensitive than using sedimentation and counting technique for recovering *E. multilocularis*, but this is yet to be confirmed using a well designed study.

The high prevalence of *T. canis* reported here confirms the wide spread distribution of this parasite among foxes in Europe (Table 1). *Toxascaris leonina* was recovered in this study from foxes of southern Jutland only, with relatively higher prevalence than what previously been reported from the same area in Denmark; 0.6% (Saeed 2005). A recent study showed that the prevalence of *T. leonina* decreased in rural foxes compared to urban foxes, but urbanization unlikely affects the distribution of *T. canis* (Reperant et al. 2007). On the other hand, the direct life cycle of *U. stenocephala* together with optimum environmental conditions makes it one of the most successful parasites transmitted between carnivores (Saeed et al. 2006).

The prevalence and abundance of *A. alata* in Denmark was generally higher in foxes from Zealand than foxes from other localities in Denmark (Saeed et al. 2006). The zoonotic potential of this parasite is well documented (Möhl et al. 2009). Infections with *C. lingua* were previously reported in foxes of Copenhagen with a similar prevalence of 23%, but the prevalence was previously higher in southern Jutland (17%) (Saeed et al. 2006). Willingham et al. (1996) on the other hand did not report the presence of *C. lingua* in 68 examined foxes of Copenhagen. There is a zoonotic potential of this parasite (Chai et al. 2009), and it is not commonly found in foxes in Europe (Table 1). Other less prevalent trematodes, such as *P. trunca-tum* and *E. perfoliatus*, were also previously isolated from foxes of Copenhagen (Saeed 2005), while *Echinostoma* sp. was once reported by Guildal and Calusen (1973). Among the key factors for higher prevalence of trematodes in general is the abundance of amphibians and snails and its proximity to fresh water lakes and coastlines (Eira et al. 2006; Saeed et al. 2006).

### Sarcoptic mange

Sarcoptic mange has only recently infected foxes in the region of Zealand (Bak et al. 1997; Forchhammer and Asfgero 2000). Scabby foxes exhibited significant loss of body weight especially in juvenile foxes, which might subsequently expose the infected foxes to other infections. The presence of such outbreaks among foxes close to urban areas might raise concern about the possible transmission to domestic animals (Bornstein et al. 2001; Penge and Ueckermann 2002). However, a recent country-wide study in Denmark that included 384 fox (Al-Sabi et al. 2013a) showed no evidence of sarcoptic mange in any of the examined foxes, which might indicate that the reported outbreak in this study has currently reduced to negligible level, probably as a result of host-parasite adaptation (Davidson et al. 2008).

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