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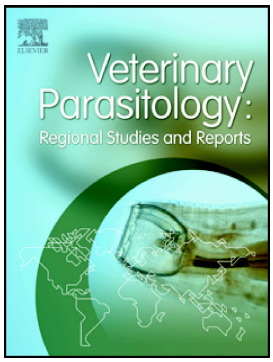

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Gastrointestinal parasites in reindeer (*Rangifer tarandus tarandus*) calves from Fennoscandia: an epidemiological study

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Abstract

Reindeer (*Rangifer tarandus tarandus*) host numerous parasites. Although there is a general knowledge about parasite diversity in reindeer, detailed baseline information about parasitic infections is limited. Detailed knowledge of parasite prevalence and diversity provide a pathway for more targeted parasite control, an increasing need expected in the future. The main aim of our cross-sectional study was to estimate the prevalence of gastrointestinal parasites in semidomesticated reindeer calves. The 480 reindeer calves included in our study were aged 6–7 months, originated from 9 reindeer herding cooperatives in Finland and 1 in Norway, and were slaughtered during September-November 2015 in 10 reindeer slaughterhouses. All the reindeer calves passed meat inspection, and the detected parasitic infections were subclinical. As the reindeer included in this study were young animals intended for slaughter, they had never been administrated any antiparasitic treatment. Assessments of gastrointestinal parasitism among these reindeer calves were based on fecal examination and morphological identification of coccidian oocysts or helminth eggs. Individual fecal samples collected from the rectum of each of the reindeer were examined using a modified McMaster method. Most (78.3%) of the reindeer calves had eggs or oocysts of at least one parasite species in their feces, and more than half (53.5%) had a mixed infection. Strongylid eggs were detected in 75.6%, *Eimeria* sp. oocysts in 50.6%, *Moniezia* sp. eggs in 28.1%, *Nematodirus* sp. eggs in 22.1%, *Capillaria* sp. eggs in 9.4%, and *Trichuris* sp. eggs in 0.6% of the samples. The prevalence of gastrointestinal parasites was similar or higher relative to previous estimates from the region; the proportion of reindeer calves shedding strongylid eggs and the proportion of reindeer calves shedding *Moniezia* sp. eggs had increased. Prevalence varied by geographical region, which may reflect different herding practices or environmental parameters. Higher reindeer density was a risk factor for testing positive for *Eimeria* sp. oocysts, and the odds of testing positive for *Nematodirus* sp. eggs were

higher if a peroral route was used for antiparasitic treatment in the reindeer herding cooperative. The mean proportion of reindeer estimated to receive antiparasitic treatment in Finland was 86% in 2004–2005 and 91% in 2014–2015. During the historical time frames of current management practices, this routine annual antiparasitic treatment of breeding reindeer has not decreased the prevalence of gastrointestinal parasites in reindeer calves, which can be seen as sentinels or indicators of the infection pressure.

Keywords: reindeer; gastrointestinal parasites; eggs; oocysts; Finland; Norway

1. Introduction

Reindeer (*Rangifer tarandus tarandus*) are semidomesticated animals in northern Fennoscandia, which comprises parts of Finland, Sweden, Norway, and Russia. In Finland, there were about 280,000 reindeer before slaughter season in the reindeer herding year 2014–2015, distributed among 54 cooperatives (Paliskuntain yhdistys, 2016). Each reindeer herding cooperative has defined geographical borders. The relatively stationary husbandry in Finland (Horstkotte and Aikio, 2017) contrasts with that circumscribed by the seasonal migrations between summer and winter grazing grounds in Sweden and Norway.

Reindeer graze freely on natural pastures for most of the year. In winter, supplementary feeding of reindeer in corrals or on the pastures is common in Finland (Laaksonen, 2016), leading to higher reindeer density and increased frequency of close animal-to-animal contacts. There are usually two major annual roundups: the mid-summer earmarking of calves and the late-autumn cull when approximately 80% of the calf population and older reindeer which are removed from breeding are selected for slaughter (Laaksonen, 2016).

Reindeer are hosts for numerous parasite species, and high prevalence of subclinical, low-intensity mixed infections of parasites appears typical (Halvorsen, 1986; Hoberg et al., 2001; Hrabok, 2006; Oksanen, 1999; Josefsen et al., 2014; Laaksonen et al., 2008; Laaksonen, 2016; Laaksonen et al., 2017; Tryland and Kutz, 2018). Gastrointestinal parasites may cause reduction in growth rate, whereas mortality attributed to helminths and protozoans has not been a concern (Halvorsen, 1986; Hrabok, 2006; Oksanen, 1999; Josefsen et al., 2014). Although reindeer and their parasites have a long history together, the balance between them is constantly subject to changes determined by interactions among hosts and their environments. Baseline data are

needed to evaluate the effects of climate change and changes in reindeer husbandry practices, as well as evolving regimes for antiparasitic treatment and potential emergence of resistance against antiparasitics. In typical Finnish reindeer husbandry, routine antiparasitic treatment (most often ivermectin) is administrated annually to the majority of breeding reindeer. Because the routine use of ivermectin is widespread and has been continued for a long time, the potential for development of resistance is a concern, and a need for more targeted parasite control is expected.

In the present study we report the results of a cross-sectional epidemiological study that aimed to estimate the prevalence of shedding eggs and oocysts of gastrointestinal parasites among reindeer calves from the Finnish reindeer herding area and northern Norway (Fig. 1) in 2015. Moreover, we evaluated associations of plausible risk factors (geographical area, reindeer density, level of domestication, and antiparasitic treatment practices) with presence of eggs and oocysts of the parasites in the feces of the reindeer calves.

2. Materials and methods

2.1 Ethical statement

The fecal samples were collected post mortem at slaughter. The reindeer were slaughtered for human consumption.

2.2 Study design

The study was a cross-sectional epidemiological study of naturally-acquired infections with gastrointestinal parasites in reindeer calves. Our target population was Eurasian tundra reindeer calves from northern Fennoscandia. Specifically, the study area encompassed northern Finland

and the adjacent region in Norway (Fig. 1). The climatic conditions vary considerably across the study area (Kivinen et al., 2017). In the northernmost Regions (Fig. 1), the mean annual temperature is below –1.5 °C, the mean temperature of the warmest quarter of the year is below 10 °C, and annual precipitation is below 450 mm. These indicators increase towards the south being –1.5 °C to 1.5 °C, 12 °C to 14 °C, and 500–700 mm, respectively, in the southernmost Regions.

A multi-slaughterhouse study design was selected to obtain a geographically representative sample. The study population comprised reindeer calves aged 6–7 months that were slaughtered between 30th September and 2nd November 2015 at ten reindeer slaughterhouses (Fig. 1).

2.3 Samples and laboratory analysis

The fecal samples were collected at slaughter, immediately following ligation and removal of the digestive tract. A fecal sample from each reindeer calf was “milked” from the rectum to an individual sealable plastic bag. The samples were cooled and transported to the laboratory within 48 hours.

Care was taken that the fecal samples did not freeze before examination. The samples were processed using a modified McMaster method (a concentration McMaster technique) proposed by Roepstorff and Nansen (1998). A saturated sugar solution (1.25 g/ml) was used as the flotation medium, and the chambers were read with a light microscope at x100 magnification. The results were given as eggs per gram of feces (epg) or oocysts per gram of feces (opg); each egg counted represented 20 epg (Roepstorff and Nansen, 1998). If the fecal sample was smaller than 3 g, the method was modified accordingly.

The identification of the parasite eggs and oocysts was done based on their key morphologic features up to the genus level (Oksanen, 1999; Taylor et al., 2016). The nematode eggs were identified as strongylids, encompassing a range of largely indistinguishable forms of the suborder Strongylida, in this case primarily representing genera and species of Trichostrongyloidea, especially ostertagiines. Strongyle eggs are generally oval or ellipsoid, not markedly asymmetrical, thin-shelled, and relatively small, not exceeding 60 to 100 µm in length (*Marshallagia* contrasts with these in being exceptionally large). Other strongyles include the Nematodirinae, with *Nematodirus* and *Nematodirella,* characterized by large eggs > 150 µm in length with a thin shell and 2–8 large dark blastomeres. Eggs of *Capillaria* are rough-shelled, about 50 µm in length, dark-stained, of barrel shape, and with slightly protruding polar plugs. Eggs of *Trichuris* are rough-shelled, about 70 µm in length, with an oval-lemon shape, and two extruding polar plugs. Eggs attributed to *Skrjabinema* were typical to this genus of oxyurids, about 50 to 70 µm long, thin-shelled, and markedly asymmetrical (rather like an orange section).

2.4 Sources of data

The reindeer originated from nine geographically defined reindeer herding cooperatives in Finland and one in Norway. The study area was divided into five Regions for geographical comparison (Fig. 1). Meat inspection outcomes for each of the animals sampled were documented and available from the slaughterhouses.

Data documenting reindeer density over the previous decade was available from the Finnish Reindeer Herders' Association for three cooperatives located in Region 1 and two located in each

of the Regions 2–4. The reindeer density of Region 5, located in Norway, was available from the literature (Pentha et al., 2014).

A questionnaire was designed to survey the use of antiparasitic treatment (percentage of reindeer being administered antiparasitic treatment, proportion of parenteral and peroral treatment) and reindeer management practices (fencing, corralling, supplementary feeding) in 2004–2015. The questionnaire survey was performed by personal interviews of the chiefs of the nine reindeer herding cooperatives in Finland. From the area in Norway, Region 5, information was available as personal communication (Helene Weydahl Guttorm, personal communication).

2.5 Statistical analyses

Confidence intervals (CI) for the prevalence estimates were calculated using Mid-P exact of open source software OpenEpi (Dean et al., 2018). Further statistical analyses, including descriptive analyses and logistic regression models, were performed using Stata software, version 13.1 (Stata Corporation, TX, USA). P values < 0.05 were considered statistically significant.

If at least one parasite egg or oocyst was detected in a sample, it was defined positive. We built logistic regression models for each parasite separately. The outcome was dichotomous: parasite eggs or oocysts were either absent or present. The variables investigated using logistic regression models were the Regions (included as dummy variables; the southernmost Region 1 was used as the reference region), reindeer density (included as a continuous variable), level of domestication (included as a dichotomous variable; < 70% vs. at least 70% of reindeer supplementary fed in corrals), and using peroral antiparasitic treatment (included as a dichotomous variable; no peroral treatment vs. > 0% peroral treatment). Univariable (crude) and multivariable analyses were

conducted to identify the statistically significant predictors and any confounders. In addition, we evaluated whether being from a specific cooperative 'A' in eastern part of Region 3 was a risk factor for parasitic infections. The husbandry of reindeer in this cooperative 'A' has been different from the others for decades: in this cooperative, reindeer do not receive supplementary feeding and they are not kept in corrals during winter.

3. Results

Fecal samples from 480 reindeer calves, which all passed meat inspection without condemnations, were included in this study. Altogether 376 (78.3%, 95% CI 74.5-81.9) of the 480 reindeer had eggs or oocysts of at least one parasite species in their feces, and 257 (53.5%, 95% CI 49.1-58.0) of the 480 reindeer had a mixed infection with 2–5 different gastrointestinal parasites. Strongylid eggs and *Eimeria* oocysts were the most common findings, followed by eggs of *Moniezia*, *Nematodirus* and *Capillaria* (Table 1). The distribution of epg and opg among these commonly observed parasites and by Region are shown in Table 2. A strong positive correlation (Pearson correlation coefficient 0.81, P = 0.0000) was observed between epg of strongylid nematodes and *Moniezia* sp. tapeworms. Observations of other parasites in these samples were rare: Eggs of *Trichuris* sp. were detected in two reindeer (40 epg, 60 epg) from Region 1 and in one reindeer (100 epg) from Region 3, and eggs of *Skrjabinema* sp. were observed in one reindeer (820 epg) from Region 3.

Univariable models confirmed that there were geographical differences (Table 2) and identified higher reindeer density and peroral antiparasitic treatment as risk factors. None of the tested variables were significant predictors for detecting eggs or oocysts of any of the parasites when

examined in multivariable models. The options for model building were limited due to correlation between Regions, reindeer density, and level of domestication, which could not be retained together in a model.

According to univariable models, reindeer calves from Region 5, located in Norway, had higher odds to have *Nematodirus* sp. eggs, *Moniezia* sp. eggs, and *Eimeria* sp. oocysts than reindeer calves from the southernmost Region 1 (Table 2). By contrast, the odds of having strongylid, *Nematodirus* sp., and *Moniezia* sp. eggs were lower in reindeer calves from Region 4 than in reindeer calves from Region 1 (Table 2). In addition, the odds of having strongylid eggs were lower in reindeer calves from Region 2 when compared with reindeer calves from Region 1 (Table 2).

Our sample included 46 reindeer calves from the cooperative 'A' in eastern part of Region 3. Based on univariable analyses, being from this cooperative was a significant risk factor for testing positive for strongylid eggs (OR 3.7, 95% CI 1.3–10.5), *Eimeria* sp. oocysts (OR 3.1, 95% CI 1.5–6.0), *Nematodirus* sp. eggs (OR 2.5, 95% CI 1.3–4.8), and *Moniezia* sp. eggs (OR 2.1, 95% CI 1.1–4.0).

The mean reindeer density was 1.23 reindeer/km^2 in Region 1 (calculated based on data from three reindeer herding cooperatives), 1.43 reindeer/km^2 in Region 2, 1.32 reindeer/km^2 in Region 3, 2.42 reindeer/km^2 in Region 4 (calculated based on data from two reindeer herding cooperatives per Region), and 2.7 reindeer/km^2 in Region 5 (Pentha et al., 2014). According to univariable models, higher reindeer density was a risk factor for reindeer calves having *Moniezia*

sp. eggs and *Eimeria* sp. oocysts (reindeer density as continuous variable; OR 1.4, 95% CI > 1.0–2.0 and OR 1.4, 95% CI > 1.0–1.9, respectively).

The husbandry practices differed by Region. Three reindeer cooperatives reported that all the reindeer receive supplementary feeding and six reported that 20–80% of the reindeer received supplementary feeding; the mean proportion was 84%. In six cooperatives (all three cooperatives from Region 1, both cooperatives from Region 2, and one of the two cooperatives from Region 3), at least 70% of the reindeer received supplementary forage in corrals. This indicator of a higher level of domestication was not a significant factor in univariable logistic regression analysis for any of the investigated parasites. In two cooperatives, located in Region 4, at least 90% of the reindeer received supplementary forage on pastures to facilitate herding. Three cooperatives, located in Regions 1 and 2, reported 5–15% of reindeer also received supplementary forage on pastures. The cooperative, located in Region 3, that was reportedly feeding 20% of the reindeer, reported using both methods of feeding. Some cooperatives mentioned that there was further local variation in the feeding practices. The two cooperatives located in Region 4 reported that they did not use summer roundups. Most of the reindeer herders, in particular those from Regions 1–3, mentioned that moose (*Alces alces*) or roe deer (*Capreolus capreolus*) visited the feeding sites. The cooperatives in Regions 3 and 4 are enclosed by fences and they also reported using fences to separate winter and summer pastures. The cooperatives from Regions 1 and 2 are not enclosed by fences and seasonal partitioning of pastures is not practiced, mainly because reindeer spend winter time in corrals and are fed there.

According to univariable models, the odds of a reindeer calf having *Nematodirus* sp. eggs and *Moniezia* sp. eggs were higher if peroral antiparasitic treatment was used in the reindeer herding

cooperative (OR 2.4, 95% CI 1.4–4.2 and OR 2.1, 95% CI 1.2–3.5, respectively). According to the questionnaire data, the mean proportion of the reindeer estimated to receive antiparasitic treatment in Regions located in Finland (Regions 1–4) was 86% in 2004–2005, 87% in 2005–2006, 86% in 2006–2007 and 2007–2008, 89% in 2008–2009 and 2009–2010, 90% in 2010–2011, 89% in 2011–2012, 90% in 2012–2013 and 2013–2014, and 91% in 2014–2015. In one cooperative from Region 1, the proportion increased from 55% to 85%, while in the others, the proportion was constantly at least 80%. The majority of the treatments were administered at autumn round-ups (70–98%, mean 85%), while 0–15% (mean 4%) of the treatments took place at round-ups and 0–30% (mean 10%) in corrals in the beginning of the year. Two reindeer cooperatives from Region 1 reported using a peroral route for antiparasitic treatment, for 20% and 100% of the reindeer.

4. Discussion

The main finding of our study was that subclinical infections with gastrointestinal parasites were common in reindeer calves. The results of our study add to the knowledge about reindeer parasites under current practices of husbandry, establish an initial baseline, and set the stage for understanding and addressing the effect of changes that are unfolding in Fennoscandia. The challenges include changing climate, changes in management of reindeer, and potentially development of antiparasitic resistance.

As the reindeer included in this study were young animals and intended for slaughter They had spent all their life free-ranging on natural pastures and thus they had never been administrated any antiparasitic treatment. The results of our cross-sectional study represent the infection

pressure for reindeer calves during their first 6–7 months of life, including the warmest season (summer), on natural pastures and in the summer roundup corrals. The majority of the reindeer calves were shedding eggs or oocysts of at least one parasite species in their feces, and mixed infections were common. The results are consistent with earlier observations and conclusions that semidomesticated reindeer harbor a high prevalence of subclinical, low-intensity mixed infections of gastrointestinal parasites (Halvorsen, 1986; Hoberg et al., 2001; Hrabok, 2006; Oksanen, 1999; Josefsen et al., 2014; Laaksonen et al., 2008; Laaksonen, 2016). The results also confirm that gastrointestinal parasites maintain their life cycles in the study area on an annual basis, and that reindeer calves contribute to the environmental reservoir of eggs and oocysts (Oksanen et al., 1990; Hrabok, 2006; Laaksonen et al., 2008; Manninen et al., 2014) under the currently established practices for management of reindeer herds in the study area. For example, strongylid eggs were shed by over 75% of the reindeer calves, and *Eimeria* sp. oocysts by half of the reindeer calves (Table 1), indicating that the life cycles are well maintained. It should be emphasized that the egg count method used in the current study has a diagnostic sensitivity of 20 epg (Roepstorff and Nansen, 1998). The median strongylid egg counts by the Regions varied between 40 and 100 epg, and it is likely that some infected animals were not detected. Prevalence estimates derived from our study may thus be an underestimate of the actual distribution of the parasites.

The sampling was at slaughter, which was ethically sound and practically feasible. Although a multi-slaughterhouse study design was labor intensive, it enabled us to have good geographical coverage of the study area. The sample size was sufficiently large for estimating the overall prevalence, and the sample well represents the reindeer calves slaughtered in 2015. We focused on obtaining samples of good quality, while a classical methodology was selected to yield results

that are easily comparable with those that may be derived from prior and future studies. The detection of the parasite eggs and oocysts was based on morphology only, and the findings were not confirmed at the species-level by culture of larvae or molecular methods. As the samples used in the present study were feces, the apparent almost total absence of *Skrjabinema* eggs may be explained by the egg deposition on the perianal skin (Sapozhnikov, 1969) and not in the intestinal content.

Our sample comprised reindeer calves that all passed meat inspection; based on this, the reindeer calves were all apparently healthy and the parasitic infections detected were all considered to be subclinical. That is, the presence of parasites at the levels observed is probably of relatively little relevance to the health status and welfare of reindeer calves. Most of the epg and opg were near the low end of the observed ranges (Table 1), but few reindeer calves had epg or opg counts that appeared high. In particular, infections by *Eimeria* sp. and *Trichuris* sp. might merit more attention from the clinical veterinary point of view.

The positive correlation between strongylid epg and *Moniezia* sp. epg was an interesting observation, as their life cycles are different. It needs to be emphasized that this observation should be interpreted with caution: for *Moniezia* sp., the epg should not be considered to indicate worm burden, however, it may be regarded as a measure of parasite activity. Nevertheless, the observation might represent the mixed nature of gastrointestinal parasitic infections in natural scenarios. The explanation for the correlation could be on the host side, perhaps immunological; for example, it could be that some reindeer are high-shedders and others are low-shedders. It is also possible that the observation reflects common environmental controls (e.g., temperature and

humidity) on the distribution of infective stages that facilitate transmission at particular landscape scales.

Our prevalence estimates of gastrointestinal parasites were similar or higher than those derived from samples collected over a decade earlier (Laaksonen et al., 2008) in the same regional setting. Our prevalence estimates for *Eimeria* sp., *Capillaria* sp., and *Nematodirus* sp. were not statistically significantly different from the previous estimates. The proportion of reindeer shedding strongylid eggs and the proportion of reindeer shedding *Moniezia* sp. eggs, however, were significantly higher ($P < 0.01$ and $P < 0.05$, respectively). These observations merit further monitoring.

It is probable that annual routine antiparasitic treatment of reindeer that are largely free-ranging does not have a substantial long-term effect on the prevalence of gastrointestinal parasites. In Fennoscandia, routinely administrated comprehensive antiparasitic treatment over many decades (Oksanen, 1999; Laaksonen et al., 2008) has not decreased the prevalence of gastrointestinal parasites in reindeer calves (Laaksonen et al., 2008; this study). Reindeer calves can be considered sentinels or indicators of the infection pressure on the natural pastures. The routine antiparasitic treatment practice has not been shown to increase slaughter weight of reindeer either (Oksanen et al., 1998; Laaksonen et al., 2008). While the main targets of this treatment as well as the timing recommendations have changed in the past and by region, as the parasites of major importance have changed (Laaksonen et al., 2008; Laaksonen, 2016), the annual routine use and the main drug used (ivermectin) have remained unchanged. The proportion of reindeer treated is high and appears to have increased; in 2002–2004, about 80% of Finnish reindeer were treated (Laaksonen et al., 2008) and the results of this study indicate an increase over the past decade: the

mean proportion was over 90% in 2014–2015. Taken together, perhaps it would be time to evaluate the treatment practice as a whole, including its aims, economical aspects and logistics, effectiveness and impacts, targeting and extent, and timing. For example, a modeling approach indicated that to efficiently prevent outbreaks of the vector-borne *Setaria tundra*, an unrelated filarioid nematode, all infected reindeer should be treated once a year, during winter (Haider et al., 2018).

The odds of a reindeer having *Nematodirus* sp. eggs and *Moniezia* sp. eggs were higher if a peroral route was used for antiparasitic treatment in the cooperative. A peroral administration route is not recommended for reindeer due to probable adherence to ingesta leading to low systemic absorption (Oksanen et al., 1995; 2014). This route of administration could be expected, however, to be beneficial against intestinal worms, such as *Nematodirus*. As ivermectin is not expected to have any direct effect against *Moniezia* sp., that association might have an indirect explanation and needs to be confirmed by other studies.

Our observations confirm that the circulation and transmission of gastrointestinal parasites is efficient in the Fennoscandian reindeer herding area irrespective of geographical partitions, current and contemporary climatic conditions, and current conditions of husbandry and management. The geographical differences observed (Table 2) could be explained by climatic variation or by different management, which could not be separated in this study because specific herding practices are typical for the Regions.

A higher level of domestication, exemplified by high proportion of reindeer receiving supplementary feeding in corrals, was not a significant factor for any of the investigated parasites

in this study. However, being from the cooperative in eastern part of Region 3, where supplementary feeding and corrals have not been used for decades, appeared as a risk factor for several parasitic infections. Further comparative studies could elucidate the practices that could explain the differences, and our observations can help in designing such studies. Based on univariable analysis, higher reindeer density was a risk factor for reindeer calves testing positive for *Moniezia* sp. eggs and *Eimeria* sp. oocysts in feces. *Eimeria* sp. could perhaps serve as indicators for monitoring, especially when making changes to reindeer husbandry practices that affect reindeer density. Management practices where reindeer are gathered together for shorter time periods would also merit further research. Not using midsummer roundups, which was reported in Region 4, could be an approach to lower the infection pressure of several types of parasites (Table 2).

In summary, our prevalence estimates of gastrointestinal parasites in reindeer calves were similar or higher in relation to previous estimates. In particular, the proportion of reindeer calves shedding strongylid eggs was high and had increased from the previous estimate (Laaksonen et al., 2008). This is a noteworthy observation that requires further monitoring, especially together with the insight that routine annual antiparasitic mass-treatments of breeding reindeer over many years has not decreased the prevalence of gastrointestinal parasites, as measured by testing reindeer calves as sentinels or indicators. Our results can serve as the baseline data to evaluate the effects of climate change and changes in reindeer husbandry practices, in particular more modern regimes for antiparasitic treatment. Because routine annual use of ivermectin has been widespread for decades, the potential for resistance is a concern, and establishing a more targeted parasite control in reindeer would be welcomed.

Conflict of interest

None.

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References

Dean, A.G., Sullivan, K.M., Soe, M.M., 2018. OpenEpi: Open Source Epidemiologic Statistics for Public Health. Version 3.01. http://www.openepi.com (accessed February 2019).

Haider, N., Laaksonen, S., Kjær, L.J., Oksanen, A., Bødker, R., 2018. The annual, temporal and spatial pattern of *Setaria tundra* outbreaks in Finnish reindeer: a mechanistic transmission model approach. Parasit Vectors, 11, 565.

Halvorsen, O., 1986. Epidemiology of reindeer parasites. Parasitol. Today 2, 334–339.

Hoberg, E.P., Kocan, A.A., Rickard, L.G., 2001. Gastrointestinal strongyles in wild ruminants. In: Samuel, W.M., Pybus, M.J., Kocan, A.A. (Eds.), Parasitic Diseases of Wild Mammals. Iowa State University Press, Ames, pp. 193–220.

Horstkotte, T., Aikio A., 2017. Reindeer husbandry under global change in the tundra region of northern Fennoscandia. In: Käyhkö, J., Horstkotte, T. (Eds.), Publications from the department of geography and geology, University of Turku. No 1. University of Turku, Turku, pp. 19–28.

Hrabok, J.T., Oksanen, A., Nieminen, M., Waller, P.J., 2006. Population dynamics of nematode parasites of reindeer in the sub-arctic. Vet. Parasitol. 142, 301–311.

Hrabok, J.T., 2006. Nematode Parasites of Reindeer in Fennoscandia, Population Dynamics, Anthelmintic Control and its Environmental Impact. Doctoral thesis. Swedish University of Agricultural Sciences, Uppsala, 52 pp.

Josefsen, T.D., Oksanen, A., Gjerde, B., 2014. Parasitter hos rein I Fennoskandia – en oversikt. Norsk veterinærtidsskrift, 2, 185–201.

Kivinen, A., Johansen B., Käyhkö J., 2017. Reindeer husbandry under global change in the tundra region of Northern Fennoscandia. In: Käyhkö, J., Horstkotte, T. (Eds.),

Publications from the Department of Geography and Geology, University of Turku. No 1. University of Turku, Turku, pp. 29–35.

Laaksonen, S., 2016. Tunne poro – poron sairaudet ja terveydenhuolto. Livonia print, Riga, 375 pp.

Laaksonen, S., Oksanen, A., Orro, T., Norberg, H., Nieminen, M., Sukura, A., 2008. Efficacy of different treatment regimes against setariosis (*Setaria tundra*, Nematoda: Filarioidea) and associated peritonitis in reindeer. Acta Vet. Scand. 50, 49.

Laaksonen, S., Oksanen, A., Kutz, S., Jokelainen, P., Holma-Suutari, A., Hoberg, E., 2017. Filarioid nematodes, threat to arctic food safety and security. In: Paulsen, P., Bauer, A., Smulders, F.J.M. (Eds.), Game meat hygiene: Food safety and security. Wageningen Academic Publishers, Wageningen, pp. 101–120.

Manninen, S.M., Thamsborg, S.M., Laaksonen, S., Oksanen, A., 2014. The reindeer abomasal nematode (*Ostertagia gruehneri*) is naturally transmitted to sheep when sharing pastures. Parasitol. Res. 113, 4033–4038.

Oksanen, A., 1999. Endectocide treatment of the reindeer. Thesis. Rangifer, Special Issue 11, 118 pp.

Oksanen, A., Nieminen, M., Soveri, T., Kumpula, K., Heiskari, U., Kuloharju, V., 1990. The establishment of parasites in reindeer calves. Rangifer, Special Issue 5, 20–22.

Oksanen, A., Norberg, H., Nieminen, M., Bernstad, S., 1995. Influence of route of administration on the plasma concentrations of ivermectin in reindeer. Res.Vet. Sci. 58, 286–287.

Oksanen, A., Norberg, H., Nieminen, M., 1998. Ivermectin treatment did not increase slaughter weight of first-year reindeer calves. Prev. Vet. Med. 35, 209–217.

Oksanen, A., Åsbakk, K., Raekallio, M., Nieminen, M., 2014. The relative plasma availabilities of ivermectin in reindeer (*Rangifer tarandus tarandus*) following subcutaneous and two different oral formulation applications. Acta Vet. Scand. 56, 76.

Paliskuntain yhdistys, 2016. Tilastoja 2014-2015. Paliskuntien poromäärät ja talous poronhoitovuonna 2014-2015. Poromies 2/2016, 36–46.

Pentha, S.M., Myklevold, M., Voje Skorge L.T., Solberg, A., 2014. Reindriftsnæringen i Norge. Norsk veterinærtidsskrift, 2, 89–93.

Roepstorff A., Nansen, P., 1998. Epidemiology, diagnosis and control of helminth parasites of swine. FAO Animal Health Manual No. 3. Food and Agriculture Organization of the United Nations, Rome, 51–56 pp.

Sapozhnikov, G.I., 1969. The life-cycle of *Skrjabinema ovis* (Skryabin, 1915). Trudy vsesoyuznogo Instituta Gel'mintologii 15, 267–274.

Taylor, M.A., Coop, R.L., Wall, R.L., 2016. Veterinary Parasitology. Fourth Edition. Wiley-Blackwell, Oxford, 1032 pp.

Tryland M., Kutz, S.J. (Eds.), 2018. Reindeer and Caribou: Health and Disease. First Edition. CRC Press, Boca Raton, 534 pp.

Figure legends

Figure 1. Map showing the distribution of reindeer (*Rangifer tarandus tarandus*) included in this study (large gray dots) and location of the slaughterhouses where sampling occurred (red dots). Representative sampling occurred across Regions 1–4 in Finland and Region 5 in Norway, north from Finland. Area in black is the Finnish reindeer herding area, and the dotted areas show the Finnish wild forest deer (WFR; *Rangifer tarandus fennicus*) populations.

Table 1. Eggs and oocysts of gastrointestinal parasites in 480 reindeer (*Rangifer tarandus tarandus*) calves from Finland and one Region in Norway.

	n positive	% positive	95% CI	Mean epg/opg	Median epg/opg	Range of epg/opg
Strongylid	363	75.6	71.6–79.3	81	60	20–800
Nematodirus sp.	106	22.1	18.5–26.0	53	20	20–520
Capillaria sp.	45	9.4	7.0–12.2	46	20	20–200
Moniezia sp.	135	28.1	24.2–32.3	734	420	20–11160
Eimeria sp.	243	50.6	46.2–55.1	3814	180	20–360000

CI = confidence interval, Mid-P exact.

epg = eggs per gram feces, opg = oocysts per gram feces.

Table 2. Eggs and oocysts of gastrointestinal parasites in 480 reindeer (*Rangifer tarandus tarandus*) calves from Finland and Norway, by Region (Fig. 1). Prevalence, mean number of eggs per gram (epg) or oocysts per gram (opg), median epg or opg, range of epg or opg, and odds ratio from univariable (crude) model for testing positive, comparing with Region 1, are shown for each parasite, with 95% confidence intervals.

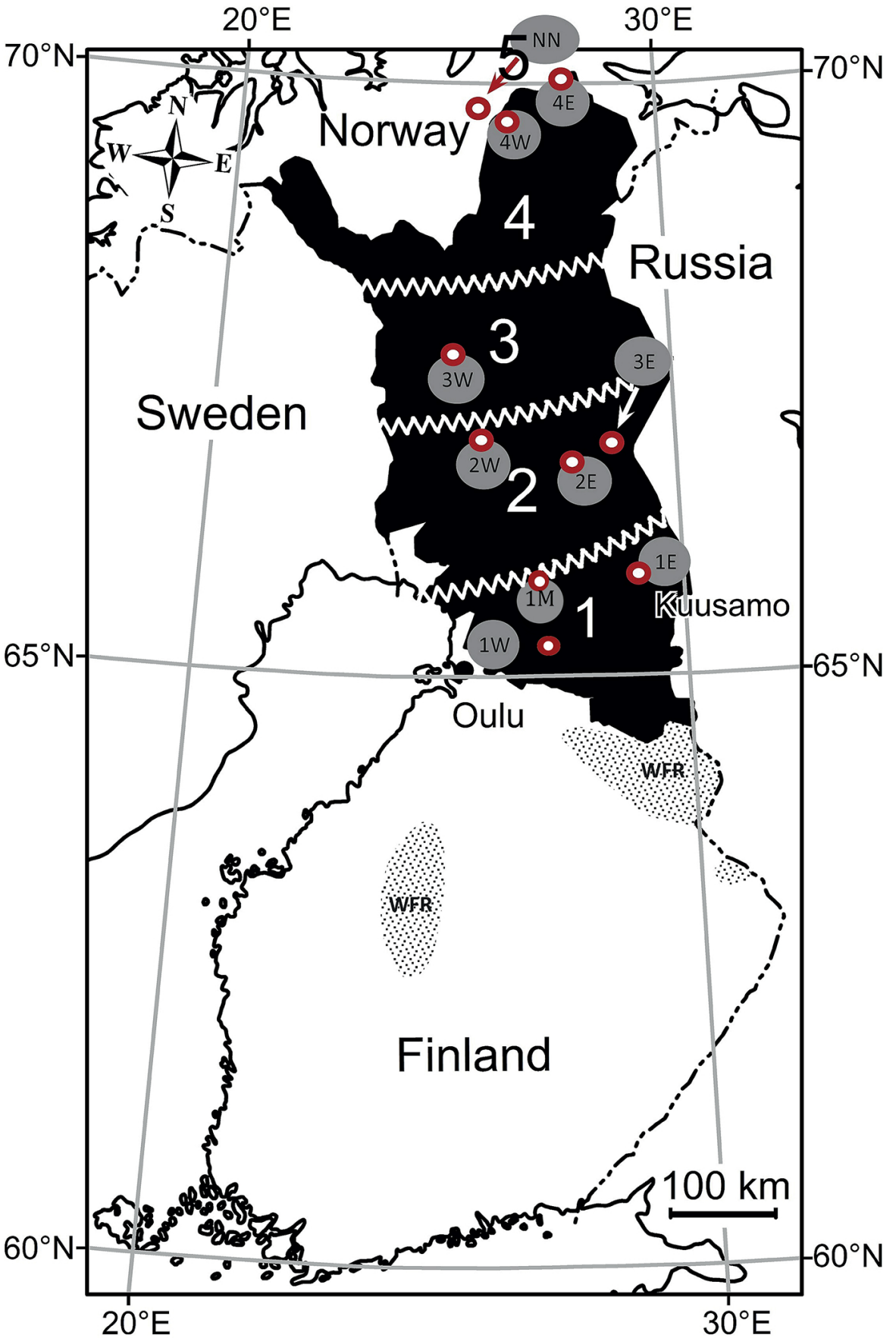
	Region 1 N = 165	Region 2 N = 77	Region 3 N = 90	Region 4 N = 87	Region 5 N = 61
Strongylid n % mean median range odds ratio	 134 81.2% (74.7–86.6) 77 epg 60 epg 20–540 epg Reference	 50 64.9% (53.8–75.0) 84 epg 60 epg 20–760 epg 0.4 (0.2–0.8)	 68 75.6% (65.9–83.6) 74 epg 60 epg 20–280 epg 0.7 (0.4–1.3)	 50 57.5% (46.9–67.5) 45 epg 40 epg 20–340 epg 0.3 (0.2–0.6)	 61 100.0% (95.2–100.0) 124 epg 100 epg 20–800 epg (all positive)
Nematodirus sp. n % mean median range odds ratio	 37 22.4% (16.6–29.3) 48 epg 20 epg 20–340 epg Reference	 10 13.0% (6.8–21.9) 94 epg 20 epg 20–340 epg 0.5 (0.2–1.1)	 21 23.3% (15.5–32.9) 33 epg 20 epg 20–80 epg 1.1 (0.6–1.9)	 3 3.4% (0.9–9.1) 53 epg 20 epg 20–120 epg 0.1 (0.0–0.4)	 35 57.4% (44.8–69.3) 58 epg 40 epg 20–520 epg 4.7 (2.5–8.7)

Capillaria sp.					
n	16	4	4	16	5
%	9.7% (5.8–15.0)	5.2% (1.7–12.1)	4.4% (1.4–10.4)	18.4% (11.3–27.6)	8.2% (3.1–17.2)
mean	44 epg	50 epg	20 epg	58 epg	32 epg
median	20 epg	40 epg	20 epg	40 epg	20 epg
range	20–200 epg	20–100 epg	20–20 epg	20–160 epg	20–60 epg
odds ratio	Reference	0.5 (0.2–1.6)	0.4 (0.1–1.3)	2.1 (< 1.0–4.4)	0.8 (0.3–2.4)
Moniezia sp.					
n	47	14	24	6	44
%	28.5% (22.0–35.7)	18.2% (10.7–28.0)	26.7% (18.3–36.5)	6.9% (2.8–13.8)	72.1% (59.9–82.3)
mean	653 epg	1460 epg	598 epg	613 epg	680 epg
median	400 epg	240 epg	480 epg	230 epg	580 epg
range	40–4740 epg	100–11160 epg	120–1580 epg	20–2760 epg	20–2760 epg
odds ratio	Reference	0.6 (0.3–1.1)	0.9 (0.5–1.6)	0.2 (0.1–0.5)	6.5 (3.4–12.5)

Eimeria sp.					
n	74	39	46	30	54
%	44.8% (37.4–52.5)	50.6% (39.6–61.7)	51.1% (40.8–61.3)	34.5% (25.1–44.9)	88.5% (78.6–94.8)
mean	3186 opg	5053 opg	632 opg	626 opg	8259 opg
median	240 opg	100 opg	240 opg	40 opg	470 opg
range	60–150000 opg	20–150000 opg	20–4760 opg	40–15840 opg	40–360000 opg
odds ratio	Reference	1.3 (0.7–2.2)	1.3 (0.8–2.2)	0.6 (0.4–1.1)	9.5 (4.1–22.1)

Highlights

- Subclinical infections with gastrointestinal parasites were common in reindeer calves
- Higher reindeer density was a risk factor for reindeer calves to shed *Eimeria* sp.
- Annual routine antiparasitic treatments of breeding reindeer are a common practice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Kuusamo
1W
Oulu
WFR
WFR
Finland
100 km

Figure 1