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Short communication

Severe impact of sarcoptic mange on the movements and space use for one of its most important vector species, the raccoon dog

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ABSTRACT

Sarcoptic mange is a highly contagious zoonotic skin disease that can have severe effect on population dynamics of many wild mammals. However, very little is known about its effect on the activity and space use of infected animals. In this study we equipped two raccoon dogs (*Nyctereutes procyonoides*) in a mange outbreak area with radio-collars and observed the spatial and temporal effects of sarcoptic mange to these individuals. Initially, the raccoon dogs had no external symptoms of mange infection, but developed these during the study period. One of the raccoon dogs died just 32 and the other 52 days after collaring. During a relatively short period before their death, there was an abrupt and drastic decline in their home range size. For one of the animals it started about 1 month before its death and the home range size reduced > 1000×, whereas for the other raccoon dog it took place within the last week, decreasing > 200×. The daily covered distances also declined considerably. These results indicate that at the later stage sarcoptic mange affected the physiological state of the diseased animals so forcefully that made them almost immobile. Our results show for the first time how rapid and severe could the impact of sarcoptic mange be for one of its most important reservoir and vector species.

1. Introduction

Sarcoptic mange, caused by the burrowing mite *Sarcoptes scabiei*, is a highly contagious disease affecting numerous mammalian species (Micali et al., 2016). The burrowing and feeding activity of *S. scabiei*, as well as hypersensitivity to mite antigens, causes cutaneous inflammation and intense pruritus, leading to excoriation, exudation and often to severe alopecia (Colebrook and Wall, 2004). Since transmission of the disease is by direct or indirect contact, it is deemed density-dependent (Kolodziej-Sobocinska et al., 2014). Not surprisingly, Chronert et al. (2007) found that during an outbreak of sarcoptic mange, infected coyotes *Canis latrans* located within home ranges of healthy coyotes contributed to the spread of the disease.

Sarcoptic mange and other zoonotic diseases such as rabies, trichinellosis and echinococcosis, are effectively spread by raccoon dogs, causing considerable ecological, economic and health problems (Kauhala and Kowalczyk, 2011; Laurimaa et al., 2015, 2016a; Marcinkute et al., 2015). Sarcoptic mange can be transferred indirectly by visiting or sharing dens and passage sites (Kraabøl et al., 2015). This kind of disease transmission is likely common in the populations of European red foxes (*Vulpes vulpes*) and raccoon dogs. Both species have been shown to be amongst the main reservoirs and carriers of the sarcoptic mange in European wildlife (Kauhala and Kowalczyk, 2011; Laurimaa et al., 2016b). While there have been numerous studies about the impact of sarcoptic mange to red fox populations, corresponding information about raccoon dog − one of the most successful mammalian alien species in Eu

rope − is scarce (Kauhala and Kowalczyk, 2011; Kolodziej-Sobocinska et al., 2014). After its introduction from Far East of Russia to Europe from 1920s to 1950s, the species rapidly became well established in eastern and northern regions of Europe and is still spreading, also towards west and south of the continent (Drygala et al., 2016). The recent increase in the number and range of raccoon dogs in Europe and the relatively high number of zoonotic parasite taxa it harbours (Laurimaa et al., 2016a), suggests that this species should be considered an important source of environmental contamination with zoonotic agents in Europe.

Although several studies have described the physiological course of sarcoptic mange or effect of the disease to population dynamics of wild carnivore hosts (e.g. Little et al., 1998; Kołodziej-Sobocinska et al., 2014), very little is known about the impact of mange on the activity and space use of infected species, including raccoon dog. However, knowledge of such changes is crucial to understand potential effects of sarcoptic mange on wild and domestic animals, as well as for effective management of the disease. In this study we attempted to fill this gap by analysing the space use of raccoon dogs in the study area with severe

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mange outbreak. We equipped two raccoon dogs with radio-collars and observed the spatial and temporal effects of sarcoptic mange to these individuals. We hypothesized that (i) mange can cause gradual decline in raccoon dog movements and home range size, affecting animals more severely during the later phase of the disease, and (ii) infected individuals will remain close to supplementary feeding sites (created for wild boar *Sus scrofa*) that provide easy access to food at minimum energy expenditure.

2. Materials and methods

The study was carried out in an intensively managed area in southern Estonia nearby Ilmatsalu borough (58°24′N, 26°32′E). About 35% of the area is in agricultural use, while the remaining area is covered with forests (39%), transitional woodlands (scrubs and woodland shrubs; 19%) and waterbodies (ponds, drainage ditches; 6%). There were also many dwellings with adjacent buildings scattered over the study area where domestic dogs as guards or companions were common. Two adult raccoon dogs (female and male) without any visual symptoms of sarcoptic mange were captured with wire box traps and suited with MiniTrack210 GPS-collars (LOTEK Wireless Inc.). A three-element flexible Yagi-antenna (AN-3FX 172), SIKA receiver (SIKARX4) and handheld VHF Command Unit (GPS-CMD VHF) were used to follow their movements on the area of severe outbreak of sarcoptic mange. Captured animals were collared without drug immobilisation and collars were scheduled to collect the location points in accordance with the daily activity dynamics of raccoon dogs (Kauhala and Holmala, 2008; also our own observations): in 1 h interval from 6 p.m. to 6 a.m. and in 3 h interval from 6 a.m. to 6 p.m.

To ascertain any changes in the raccoon dogs' spatiotemporal movement dynamics during the outbreak of mange, we determined alterations in their home range sizes and activity. We calculated the changes in the size of the area used by the raccoon dogs in 7 day intervals. Home range sizes were calculated by using 100% minimum convex polygons (MCP100). For activity rates we calculated the daily distances plotted using *ts* and *lowess* functions in program R. We also determined if there were any differences in habitat use between periods when raccoon dogs were active (animals moved actively around) and passive (animals stayed put in one place). For that we compared frequencies of location points in different habitats (arable land, forest, shrub, waterside) between active and passive periods in seven day intervals within raccoon dogs' home ranges. Distribution of location points in different habitats were determined by using CORINE Land Cover 2006 map and program Biotas.

3. Results

We were able to radio-track the female raccoon dog for five weeks (32 days) and male raccoon dog for nine weeks (59 days) before their death. Carcasses of both animals had severe symptoms of sarcoptic mange: extensive skin crusting and alopecia all over the body. The home range sizes for both animals declined noticeably before their death. For the male raccoon dog, the abrupt decrease in home range size − more than 200× (from 81.0 ha to 0.35 ha) − took place during its last week alive (Table 1, Fig. 1b and c). For the female it started about a month before its death; while on the fifth tracking week the home range was 301 ha, by the sixth week it was 2.1 ha and by the week prior to its death had diminished to 0.3 ha, reducing thus > 1000× during the study period (Table 1, Fig. 1e and f).

The daily distances covered by raccoon dogs also shortened considerably. The abrupt decline of the average distance covered in 24 h started six days before the male raccoon dog's death, being 2986 m/day before the 26th tracking day and 276 m/day after (Fig. 1a). For the female raccoon dog, the notable decline in movement activity took place 25 days before its death and was on average 3406 m/day before the 31st tracking day and 283 m/day after (Fig. 1d). Thus, both animals reduced their daily movements more than 10-fold.

Table 1
Home range sizes (ha; MCP100) of radiocollared raccoon dogs during the tracking period.

Week	Female	Male
1	278.4	63.3
2	161.8	144.6
3	141.8	133.7
4	175.8	81.0
5	301.4	0.35
6	2.1	
7	1.2	
8	0.3	
9	0.04	

There was also a significant difference between usage of habitats in active and passive periods for both raccoon dogs (female raccoon dog: chi-square = 454.57, df = 7, $p < 0.0001$; male raccoon dog chi-square = 747.55, df = 7, $p < 0.0001$). In active period, the raccoon dogs did not exhibit any preference towards certain habitat, as there were less than 40% of location points in each habitat during each tracking week. However, in passive period the female spent most of the time in forest habitat (53% of the location points) and the male preferred shrubs (83% of the location points).

4. Discussion

Opportunities to radio collar animals who are without symptoms of sarcoptic mange, but develop these during the study, are rare and although we were able to follow the impact of sarcoptic mange only on two raccoon dogs, this study, to the best of our knowledge, is the first one providing insights into the impact of this disease on raccoon dog movements and habitat choice in spatial and temporal scale. Our results demonstrate severe and rapid impact of sarcoptic mange on life expectancy: one of the raccoon dogs died just 32 and the other 52 days after collaring. Comparably rapid impact has been recorded also for red foxes: death of infected individuals occurred in 23–271 days after capture (Newman et al., 2002).

Abrupt decline (not gradual as we hypothesized) in home range size and in daily covered distances indicates that at some stage the impact of mange started to affect the physiological state of infected animals so forcefully that made them almost immobile. While raccoon dogs usually spend most of their time searching for food, preferably in wet open habitats rich of various food objects (Kauhala and Kowalczyk, 2011; Süld et al., 2017), the health condition of the diseased individuals in our study deteriorated to an extent that their movements almost stopped. It has also been shown in wombats (*Vombatus ursinus*) that individuals with severe mange spend only a fraction of time walking, and it was proposed that this may result from an attempt to reduce energy expenditure associated with movements as a trade off against fighting infection (Simpson et al., 2016). Epizootics of sarcoptic mange have also been shown to alter the movements and territoriality of the red fox (Potts et al., 2013).

The abrupt decline in movements was most probably caused by severe sepsis leading to organ failure. In the study of Nakagawa et al. (2009), the predominant causes of death in 43 studied raccoon dogs with mange were sepsis and pneumonia. Kido et al. (2011) showed in their study that infected animals developed malnutrition and severe dehydration, which also led to sepsis and insufficient renal perfusion. Poor health condition could also explain why in the passive period raccoon dogs spent most of their time either in forest or in shrubs that apparently provided them suitable hiding and resting places to avoid contact with predators.

Various human activities have, at least to some extent, contributed to the spread of sarcoptic mange. Anthropogenic food, including cereals