13 Health and diseases of semi-domesticated reindeer in a climate change perspective

Morten Tryland, Birgitta Åhman and Javier Sánchez Romano

Introduction

Climate change, in combination with loss of land, has increased the need for supplementary winter feeding of semi-domesticated reindeer in Fennoscandia (Chapter 12). Feeding a reindeer requires that sufficient good quality feed is provided, while also keeping the right timing and conditions to avoid health and disease problems. Even though reindeer are gregarious, feeding may contribute to even higher animal density and more nose-to-nose contact between animals, thus facilitating transmission of infectious agents that may cause disease in reindeer. Poor hygienic conditions in feeding corrals may further increase exposure to pathogens, especially for newborn calves and other immunologically naïve animals.

Climate change affects all life in an ecosystem, including insects and other arthropod populations. Some are associated with reindeer as ectoparasites, with the subsequent harassment and stress, and may cause diseases and secondary infections. Other arthropods are temporary blood-sucking parasites that may also act as vectors for parasites, bacteria and viruses that can cause disease in reindeer.

In this chapter, we present some common conditions directly related to feed and feeding regimes, as well as the most relevant infectious agents and insect vectors that may cause or contribute to disease in semi-domesticated reindeer in Fennoscandia; we also address how they may be affected by climate change.

Health challenges and diseases associated with feeding

Disease conditions related to feed and feeding regimes

Several of the health problems associated with feeding are related to the change of diet and the fact that the rumen microorganisms need time to adapt to the new diet. Other problems are associated with unsuitable feedstuffs and poor hygienic quality of the feed.

DOI: 10.4324/9781003118565-18

Ruminal acidosis

In ruminal acidosis, digestion stops because the rumen content has become too acidic. It is a serious and relatively common condition when reindeer are shifted from natural pasture to grain-based commercial pelleted feed.

In a well-functioning reindeer rumen, the pH varies between 6 and 7 (Nilsson et al. 2006). Grain-based feeds for reindeer contain easily digestible carbohydrates (primarily starch) that lower the rumen pH when fed in large amounts. This affects the rumen microorganism population and may result in the growth of lactic acid-producing bacteria such as lactobacilli, making the rumen pH drop to 4–5 (Åhman et al. 2018). This can cause metabolic and life-threatening acidosis. Ruminal acidosis usually occurs within three weeks of the start of feeding (Åhman et al. 2018). Reindeer with ruminal acidosis are often lethargic, having poor appetite, increased thirst, decreased or ceased rumen contractions and sometimes diarrhoea (Rehbinder & Nikander 1999). The rumen content becomes liquid, which causes a typical sloshing sound from the stomach, thus the common name "*skvalpmage*" or "rippling belly".

It is difficult to treat severe cases of rumen acidosis, while early or milder cases may be cured by changing to a lichen diet or by providing a liquid energy mix with bicarbonate that can neutralize the rumen content.

Diarrhoea

Diarrhoea in reindeer is relatively common at the onset of feeding with grain-based pellets but has also been observed in reindeer that have been fed high-fibre diets (e.g., Josefsen et al. 2007). Diarrhoea may be only transient, but severe cases must be treated. Diarrhoea can also be caused by bacterial infections in the digestive tract, discussed later in this chapter.

Wet belly

A seemingly unique condition in reindeer that is associated with feeding is wet belly syndrome. Affected reindeer start to perspire, making the haircoat wet under the belly and often down the legs (Figure 13.1), sometimes also in the neck region (Åhman et al. 2002). Additional signs may be that the reindeer have an extraordinary appetite and that they get cold and curl up when lying down. The condition has been reported since the 1960s, when feeding experiments with reindeer started (e.g., Persson 1967).

The reason for wet belly is unknown. Hay or high-fibre diets containing straw have been suggested as causes of wet belly (Jacobsen & Skjenneberg 1977). However, Åhman et al. (2002) showed that wet belly may also occur when reindeer are fed a "natural" diet (e.g., lichens, bilberry shrubs and willow leaves) with no grass forage. Thus, although linked to feeding, wet belly seems not to be associated with any special feedstuff. Nonetheless, it is usually effective to change the feed.

Figure 13.1 Reindeer with wet belly. The condition is characterized by wet fur under the belly and down the hind legs and by an extraordinarily strong appetite.

Photo: Svenska Samernas Riksförbund/Gård & Djurhälsans bildarkiv för renens hälsa.

Bloat

Bloat, or ruminal tympany, occasionally affects reindeer during feeding (Åhman et al. 2018). It happens when the rumen is filled with gas or foam, and the animal is unable to burp up the gas. This causes a high and rapidly increasing pressure in the abdomen that may obstruct breathing and blood circulation, and the animal can die. The probable reason is the intake of large amounts of concentrates.

Accumulation of grass

The digestive system of reindeer is not adapted to handling large amounts of fibre (Hofmann 1989). Accumulation of undigested grass in the rumen is thus a well-known condition in reindeer that are fed mainly with hay or grass silage (Åhman et al. 2018). When grass is not digested, the reindeer do not get enough energy, remains hungry and continues to eat, but may die from emaciation although its rumen is full of forage. In most cases, the condition can be reversed if the animal is provided with more easily digested feed.

Infections and diseases associated with increased animal density and hygienic conditions

Feeding of reindeer will increase animal-to-animal contact and may also contribute to unfavourable hygienic conditions facilitating transmission of reindeer pathogens, especially in corrals and when the animals are fed over extended periods of time. Wet conditions and accumulation of faeces and mud may create a situation that results in infections affecting young calves (Foster 2010; Wikström 2014). Reindeer are sometimes infected with opportunistic bacteria, such as staphylococci, streptococci, *Escherichia coli* and *Trueperella pyogenes*, which may cause localized or generalized infectious diseases, but also with specific bacterial pathogens, such as *Salmonella* sp., *Moraxella* sp., *Listeria* sp., *Mycoplasma* sp. and others (Josefsen et al. 2019). Some selected infectious diseases in reindeer that may be associated with feeding are discussed below.

Infectious keratoconjunctivitis: Alphaherpesvirus and secondary bacterial infections

The eye disease infectious keratoconjunctivitis (IKC) was first thoroughly described in Scandinavian reindeer in Sweden (Bergman 1912). IKC in reindeer has been described as a multi-factorial disease, and a plethora of microorganisms have been identified in the eyes of affected reindeer, including the alphaherpesvirus cervid herpesvirus 2 (CvHV2), *Chlamydia* spp. and *Moraxella* spp. (Sánchez Romano et al. 2018; 2019; Tryland et al. 2009). CvHV2 is enzootic in most reindeer populations in Fennoscandia (das Neves et al. 2010), and a clinical trial with this virus demonstrated that it had the capacity to cause severe IKC in reindeer with no previous exposure and immunity to the virus (Tryland et al. 2017). However, this finding does not exclude the possibility of other pathogens being involved in the pathogenesis of IKC in reindeer (Sánchez Romano et al. 2018; 2019).

IKC may be seen in single animals in a herd but can also appear as large outbreaks, affecting tens or hundreds of animals, primarily calves and yearlings. Such outbreaks have been associated with stress and supplementary feeding (Tryland et al. 2009; Sánchez Romano et al. 2019). IKC can affect one or both eyes, and it often starts with increased lacrimation and fur discoloration under the eyes that can rapidly progress to purulent secretions, corneal and periorbital oedema, conjunctivitis and keratitis. The most severe cases may result in corneal ulcers, eye ruptures and permanent blindness (Tryland et al. 2009; 2017).

The lack of an effective treatment for CvHV2 together with its enzootic status make it difficult to control viral IKC outbreaks, but broad-spectrum antibiotics have been used to control secondary bacterial infections (Sánchez Romano et al. 2019; Tryland et al. 2009). Single cases are often slaughtered at an early stage by the herders, whereas outbreaks are often dealt with by a veterinarian.

Parapoxvirus (contagious ecthyma)

Contagious ecthyma (CE) is a disease caused by viruses from the genus *Parapoxvirus* (family *Poxviridae*). The disease has been diagnosed in semi-domesticated reindeer under natural herding conditions in Sweden, Finland and Norway (Tryland et al. 2019). The parapoxvirus Orf (ORFV) is distributed worldwide and affects small ruminants and a wide range of wild ruminant species; it may also cause painful cutaneous lesions in people handling infected animals. Another parapoxvirus, Pseudocowpoxvirus (PCPV), which has cattle as its main reservoir, has been associated with several CE outbreaks in Finland (Tryland et al. 2019).

Contagious ecthyma in reindeer is usually characterized by proliferative "cauliflower-like" lesions in the skin around the mouth and nostrils, as well as in the oral mucosa (Tryland et al. 2019). CE starts with the entry of the virus through small skin or mucosal lesions. The initially small and pink proliferative lesions develop to larger masses, often covered by thick, black crusts. Animals in the later stages of the disease may be unable to eat, and reduced body condition and emaciation can be observed. Currently, there is no specific treatment against CE, but supportive therapy and antibiotics can be used to control secondary bacterial infections.

Necrobacillosis

Necrobacillosis is caused by the bacterium *Fusobacterium necrophorum*, which is an obligate anaerobic rod that is part of the normal ruminal microbiota of ruminants, including reindeer (Aagnes et al. 1995). It is thus present in the environment but not able to penetrate intact skin or mucosal membranes. Abrasions and lesions, caused by external factors, viral infections or the eruption of new teeth in young animals, may pave the way for opportunistic infection by this bacterium. Although *F. necrophorum* is regarded as the primary pathogen, other opportunistic bacteria may contribute to the disease, such as *Trueperella pyogenes* and *Staphylococcus aureus* (Josefsen et al. 2019). In the past, necrobacillosis was mainly recorded as an infection of the feet, but also of the oral mucosa (Skjenneberg & Slagsvold 1968; Rehbinder & Nikander 1999). During recent disease outbreaks in semi-domesticated reindeer, the oral form has dominated, being associated with corralling and supplementary feeding (Wikström 2014; Tryland et al. 2019b). However, necrobacillosis may also affect the rumen and cause severe lesions, disease and mortality in animals showing no clinical signs in the mouth (Figure 13.2).

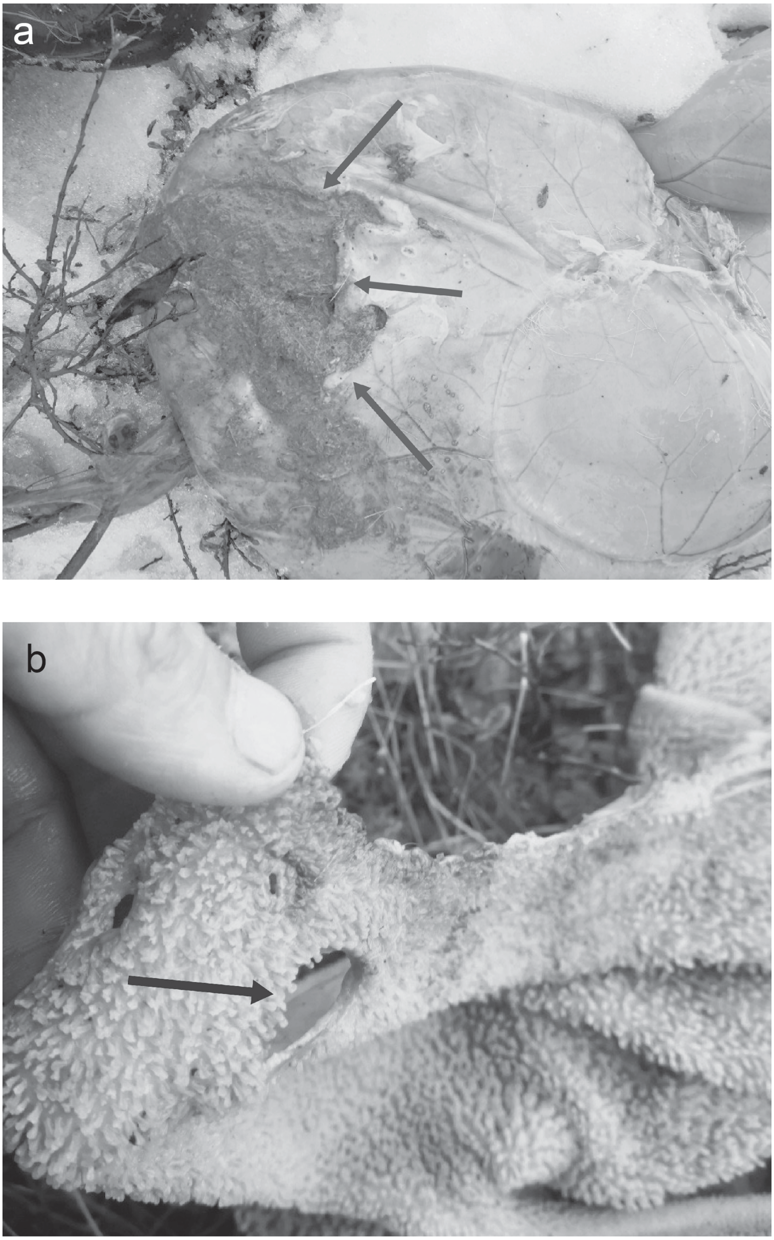

Figure 13.2 Necrobacillosis in reindeer can usually be identified as affecting the distal part of the legs (digital necrobacillosis) or the oral mucosa (oral necrobacillosis). However, the infection may also affect internal organs such as the rumen or liver, with no visible necrotic lesion on the oral mucosa. (a) the outside (serosa) of the rumen was necrotized and rumen content was leaking out in the abdomen. (b) An inspection of the inside of the rumen (mucosa) confirmed necrotic lesions.

Photo: Svenska Samernas Riksförbund/Gård & Djurhälsans bildarkiv för renens hälsa.

Pasteurellosis

Pasteurellosis in reindeer refers to a disease caused by the bacterium *Pasteurella multocida* (Josefsen et al. 2019), which is found as a commensal organism in the throat and the upper respiratory tract of many animal species. The potential pathogen is transmitted via direct contact between animals and is known to cause disease when associated with stress, such as heat, drought, insect harassment and animal transport, especially affecting young animals (Nordkvist & Karlsson 1962). In reindeer, pasteurellosis is usually characterized by per-acute haemorrhagic septicaemia, and animals can be found dead with no previously recorded clinical signs. With a more prolonged disease course, nasal discharge and coughing are common, and the calves display weakness and apathy and often die (Josefsen et al. 2019). Pasteurellosis in reindeer was first described to appear as large epizootics among semi-domesticated reindeer in Norway and Sweden in 1912–1914 (Horne 1915). Several outbreaks of pasteurellosis have been reported in Fennoscandia during the past century. An outbreak in a slaughter corral in Norway in 2010 caused septicaemia and killed 44 reindeer calves (Mørk et al. 2014).

Altered distribution of arthropods, arthropod vectors and associated reindeer pathogens

Some arthropods such as ticks, mosquitoes and midges feed on reindeer as temporary blood-sucking parasites. Through this blood-sucking activity, arthropods may act as vectors and transmit parasites, bacteria and viruses between hosts. The development and activity of arthropods depend on climatic conditions, such as wind, precipitation and temperature, which are factors that are expected to change in the northern regions (IPCC 2021). Thus, climate change may impact the epidemiology of vector-borne diseases (Wittmann & Baylis 2000; Ogden & Lindsay 2016). The generally low temperatures in Arctic regions are, in fact, close to minimum requirements for insect locomotion, and thus largely determine their activity patterns (Strathdee & Bale 1998). Snow cover, bird migration and plant flowering have a great effect on the seasonal development of insects and other arthropods (Strathdee & Bale 1998; Høye et al. 2007). They may also be quick responders to climatic conditions, having a short generation time, which also affects their role as vectors for infectious diseases for *Rangifer* (Boggs 2016).

Deer ked (Lipoptena cervi)

The deer ked (*Lipoptena cervi*) is a blood-sucking ectoparasite that is mainly associated with moose (*Alces alces*) and roe deer (*Capreolus capreolus*) in Fennoscandia (Välimäki et al. 2010). It has, however, expanded its range northwards during the last five years and is now affecting the reindeer herding area in Finland (Kynkäänniemi et al. 2020). The adults feed on the host's blood and reproduce in its fur, potentially causing hair breakage and heat loss (Härkönen et al. 2010). Even though the potential impact of deer ked in semi-domesticated reindeer has still not been thoroughly studied, there are indications of acute behavioural disturbances and an increase in potential stress due to deer ked infestation, which may pave the way for the appearance of several of the infectious diseases mentioned above (Kynkäänniemi et al. 2014).

Reindeer pathogens transmitted by ticks

The tick (arthropod, class Arachnida) *Ixodes ricinus* is the primary arthropod vector of zoonotic diseases in Europe (Gilbert 2010; Heyman et al. 2010). This species mainly feeds on rodents, hares and cervids, but also on birds, livestock, pets and humans. The distribution of *I. ricinus* is expanding towards higher latitudes and upwards in elevation from coastal to inland areas (Medlock et al. 2013; Jore et al. 2014; Mysterud et al. 2017). The conditions for ticks in higher altitudes may improve with predicted climate change scenarios, increasing the impact of ticks as disease vectors (Gilbert 2010). In Norway, ticks are now emerging on reindeer in Nordland county, sometimes combined with undiagnosed diseases. A recent study (2018–2019) indicated that ticks are now present in almost all the northern municipalities in Sweden, and not only in coastal regions (Jaenson et al. 2012).

Anaplasmosis (Tick-borne fever)

Anaplasma phagocytophilum is a worldwide tick-borne bacterium that causes tick-borne fever in sheep, cattle and wildlife; in humans the disease is called anaplasmosis (Stuen et al., 2013). In general, the clinical symptoms of tick-borne fever are high fever, anorexia and dullness. Anti-anaplasma antibodies have recently been detected among reindeer in Nordland county, Norway, suggesting exposure and disease in the population (unpublished data). An experimental inoculation of reindeer with blood from infected sheep caused fever five days post inoculation, followed by dullness and anorexia, as well as a severe reduction of white blood cells by 40–85%, demonstrating that reindeer are susceptible to *A. phagocytophilum*.

Borreliosis (Lyme's disease)

Borreliosis (Lyme's disease) is caused by bacteria of the *Borrelia burgdorferi* sensu lato complex, which, in Eurasia, is transmitted by *I. ricinus* and *I. persulcatus*. Borreliosis is estimated to affect 65,000 people in Europe annually (Berger 2014). A study of ticks in Nordland county, Norway, revealed that 21% of the nymphs and 46% of adult ticks contained *B. burgdorferi* bacteria, suggesting that reindeer are most probably exposed (Hvidsten et al. 2015).

Babesiosis

The disease babesiosis is caused by a group of protozooans. Babesiosis is characterized by high fever and blood in the urine (haematuria), and high mortality. Studies in southern Sweden revealed that 4% of the ticks carried *Babesia* spp. (Karlsson & Andersson 2016), and 53% of the cattle were exposed to *B. divergens* (Andersson et al. 2017). Babesiosis is only rarely reported from Norway and Finland. Reindeer have been shown to be susceptible to babesiosis (Langton et al. 2003; Wiegman et al. 2015).

Reindeer pathogens transmitted by mosquitoes and midges

Setaria tundra

Setaria tundra (*Filarioidea*; *Onchocercidae*) is a mosquito-borne filaroid nematode of which there have been several outbreaks in semi-domesticated reindeer in Finland, characterized by peritonitis and decreased body condition (Kutz et al. 2019). Adult forms of *S. tundra* live in the peritoneal cavity of reindeer (definitive host). A larval stage (L1) is released into the bloodstream and ingested by mosquitoes, in which they develop into stage L3 infective larvae in a temperature-dependent process, taking approximately two weeks at 21 °C (Laaksonen et al., 2009), before being transmitted to new hosts during mosquito feeding.

Bluetongue virus (BTV)

Bluetongue virus (BTV; genus *Orbivirus*, family *Reoviridae*) is transmitted by biting midges (*Culicoides* spp.) but can also have oral and transplacental transmission (Backx et al. 2009). BTV causes an acute disease in naïve sheep, with fever, excessive salivation, oedema of the face and cyanosis of the tongue and lips (hence the name "bluetongue"). BTV also infects other domestic animals and most species of wild ruminants, although frequently with no clinical symptoms. Increased ambient temperatures may shorten the time from the uptake of the virus in a vector to when it is infective (Wittman et al. 2002) and facilitate virus replication, contributing to a longer season with infective vectors (Mullens et al. 1995). BTV recently expanded its distribution, appearing in Denmark in 2007, Sweden in 2008 and Norway in 2009, but never seemed to reach the reindeer populations in these countries (Tryland et al. 2019).

Schmallenberg virus (SBV)

Schmallenberg virus (SBV; genus *Orthobunyavirus*, family *Bunyaviridae*) was first reported in dairy cattle in 2011 in Germany and the Netherlands, where it caused fever, diarrhoea and reduced milk production. This virus may also cause congenital malformations in newborn lambs, goat kids and calves, as well as premature birth, stillbirth or the birth of mummified foetuses (Wernike et al. 2014). SBV is transmitted by biting midges (*Culicoides* spp.) or mosquitoes. In Sweden, a serological screening of roe deer, red deer, moose and fallow deer (*Dama dama*) revealed SBV-antibodies in samples obtained after the vector season of 2012, but no such antibodies were detected in 2015. A possible explanation for why SBV did not become established among wild cervids in

Sweden, in contrast to more southern parts of Europe, is the occurrence of a vector-free season during winter (Malmsten et al. 2017). Serological screenings of wild and semi-domesticated reindeer in Norway and Finland did not demonstrate exposure of reindeer to SBV (Tryland et al. 2019).

Reindeer pathogens transmitted by other insect vectors

Rumenfilaria andersoni

Rumenfilaria andersoni (*Splendidofilariinae*; *Onchocercidae*) is a lymphatic-dwelling filaroid nematode that can be found in the lymphatic vessels of reindeer and other cervids, and as microfilariae larvae in peripheral blood. This parasite is transmitted by blood-sucking insects, but the actual vector, geographical distribution and health impact in reindeer remain unknown (Grunenwald et al. 2016; Laaksonen et al. 2015).

Onchocerca spp.

The parasite *Onchocerca skrjabini* (=*Onchocerca tarsicola*) is transmitted by blackflies (*Simuliidae*) and biting midges (*Ceratopogonidae*), which transport the subcutaneous microfilaria from one host to another. The infection has been described in reindeer in Sweden and Finland (Kutz et al. 2019; Laaksonen et al. 2017). The adult parasites are often found in connective tissues surrounding the tendons of the tibio-tarsal and radio-carpal joints (Rehbinder et al. 1979) and severe infections have been associated with granulomatous nodules in most organs and severe haemorrhagic tarsitis in Finnish reindeer (Kutz et al. 2018).

Concluding remarks

In this chapter, we have described selected health conditions, diseases and infections in semi-domesticated reindeer that, directly or indirectly, will or may be affected by climate change. Climate change will affect ecosystems and may change reindeer herding. To track these changes and their potential impact on reindeer health, it is necessary to gather data on health and disease parameters from reindeer continuously, to be able to support the reindeer herding industry in the future.

References

Aagnes, T.H., Sørmo, W. & Mathiesen, S.D. (1995). Ruminal microbial digestion in free-living, in captive lichen-fed, and in starved reindeer (*Rangifer tarandus tarandus*) in winter. *Applied and Environmental Microbiology*. 61(2), 583–591.

Åhman, B., Finstad, G.L. & Josefsen, T.D. (2018). Feeding and associated health problems. In: Tryland, M. & Kutz, S.J. (eds) *Reindeer and caribou: Health and disease*. Boca Raton: Taylor & Francis. 135–156.

Åhman, B., Nilsson, A., Eloranta, E. & Olsson, K. (2002). Wet-belly in reindeer (*Rangifer tarandus tarandus*) in relation to body condition, body temperature and blood constituents. *Acta Veterinaria Scandinavica.* 43, 85–97.

Andersson, M.O., Vichová, B., Tolf, C., Krzyanowska, S., Waldenström, J. & Karlsson, M.E. (2017). Co-infection with *Babesia divergens* and *Anaplasma phagocytophilum* in cattle (Bos taurus), Sweden. *Ticks and Tick-borne Diseases.* 8, 933–935.

Backx, A., Heutink, R., van Rooij, E. & van Rijn, P. (2009). Transplacental and oral transmission of wild-type bluetongue virus serotype 8 in cattle after experimental infection. *Veterinary Microbiology*. 138(3–4), 235–243.

Berger, S. (2014). *Lyme disease: Global status. 2014 edition*. Los Angeles, CA: GIDEON Informatics Inc. P.

Bergman, A.M. (1912). Smittosam hornhinneinflammation, dermatitis infectiosa, hos ren. *Skand Vet Tidskr*. 2, 145–177.

Boggs, C.L. (2016). The fingerprints of global climate change on insect populations. *Current Opinion in Insect Science.* 17, 69–73.

das Neves C.G., Roth S., Rimstad E., Thiry E. & Tryland M. (2010). Cervid herpesvirus 2 infection in reindeer: a review. *Veterinary Microbiology.* 143(1), 70–80.

Fernández-Pacheco, P., Fernández-Pinero, J., Agüero, M. & Jiménez-Clavero, M.A. (2008). Bluetongue virus serotype 1 in wild mouflons in Spain. *The Veterinary Record*. 162(20), 659–660.

Foster, A. (2010). Common conditions of reindeer. *In Practice*. 32(10), 462–467.

Gilbert, L. (2010). Altitudinal patterns of tick and host abundance: a potential role for climate change in regulating tick-borne diseases?. *Oecologia.* 162, 217–225.

Grunenwald, C.M., Carstensen, M., Hildebrand, E., Elam, J., Laaksonen, S., Oksanen, A. & Gerhold, R.W. (2016). Epidemiology of the lymphatic-dwelling filarioid nematode Rumenfilaria andersoni in free-ranging moose (*Alces alces*) and other cervids of North America. *Parasites & Vectors*. 9, 450.

Härkönen, L., Härkönen, S., Kaitala, A., Kaunisto, S., Kortet, R., Laaksonen, S. & Ylönen, H. (2010). Predicting range expansion of an ectoparasite – the effect of spring and summer temperatures on deer ked (*Lipoptena cervi*) performance along a latitudinal gradient. *Ecography*. 33, 906–912.

Heyman, P., Cochez, C., Hofhuis, A., Van Der Giessen, J., Sprong, H., Porter, S.R., Losson, B., Saegerman, C., Donoso-Mantke, O., Niedrig, M. & Papa, A. (2010). A clear and present danger: tick-borne diseases in Europe. *Expert Review of Anti-infective Therapy*. 8(1), 33–50.

Hofmann, R.R. (1989). Evolutionary steps of ecophysiological adaptation and diversification of ruminants: a comparative view of their digestive system. *Oecologia*. 78, 443–457.

Horne, H. (1915). Rensyke (Hæmorrhagisk septikæmi hos ren). *Norsk Veterinærtidsskrift*. 27, 41–47, 73–84, 105–119.

Høye, T.T., Post, E., Meltofte, H., Schmidt, N.M. & Forchhammer, M.C. (2007). Rapid advancement of spring in the High Arctic. *Current Biology*. 17(12), R449–R451.

Hvidsten, D., Stordal, F., Lager, M., Rognerud, B., Kristiansen, B.E., Matussek, A., Gray, J. & Stuen, S. (2015). Borrelia burgdorferi sensu lato-infected *Ixodes ricinus* collected from vegetation near the Arctic Circle. *Ticks and Tick-Borne Diseases*. 6(6), 768–773.

IPCC (2021). *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press.

Jacobsen, E. & Skjenneberg, S. (1977). Resultater og erfaringer fa foring av rein med høy, surfor, "sauenøtt" og "komplettfor m/halm". *Forskning og forsøk i landbruket.* 28, 651–660.

Jaenson, T.G.T., Jaenson, D.G.E., Eisen, L., Peterson, E. & Lindgren, E. (2012). Changes in the geographical distribution and abundance of the tick Ixodes ricinus during the past 30 years in Sweden. *Parasites & Vectors*. 5, 8.

Jore, S., Vanwambeke, S.O., Viljugrein, H., Isaksen, K., Kristoffersen, A.B., Woldehiwet, Z., Johansen, B., Brun, E., Brun-Hansen, H., Westermann, S., Larsen, I.L., Ytrehus, B. & Hofshagen, M. (2014). Climate and environmental change drives *Ixodes ricinus* geographical expansion at the northern range margin. *Parasites & Vectors*. 7, 11.

Josefsen, T.D., Sørensen, K.K., Mørk, T., Mathiesen, S.D & Ryeng, K.A. (2007). Fatal inanition in reindeer (*Rangifer tarandus tarandus*): Pathological findings in completely emaciated carcasses. *Acta Veterinaria Scandinavica.* 49, 27.

Josefsen, T.D., Oksanen, A. & Gjerde, B. (2014). Parasitter hos rein i Fennoskandia, en oversikt. *Norsk Veterinærtidskrift.* 126, 185–201.

Josefsen, T., Mørk, T., Nymo, I.H. (2019). Bacterial infections and diseases. In: Tryland, M. & Kutz, S.J. (eds) *Reindeer and caribou: Health and disease*. Boca Raton: Taylor & Francis. 237–271.

Karlsson M.E. & Andersson, M.O. (2016). Babesia species in questing *Ixodes ricinus*, Sweden. *Ticks and Tick-borne Diseases*. 8, 10–12.

Kutz, S., Laaksonen, S. Åsbakk, K. & Nilssen, A.C. (2019). Parasitic infections and diseases. In: Tryland, M. & Kutz, S.J. (eds) *Reindeer and caribou: Health and disease*. Boca Raton: Taylor & Francis. 177–235.

Kynkäänniemi, S.M., Kettu, M., Kortet, R., Härkönen, L., Kaitala, A., Paakkonen, T., Mustonen, A.M., Nieminen, P., Härkönen, S., Ylönen, H. & Laaksonen, S. (2014). Acute impacts of the deer ked (*Lipoptena cervi*) infestation on reindeer (*Rangifer tarandus tarandus*) behavior. *Parasitology Research.* 113(4), 1489–1497.

Kynkäänniemi, S.M., Kortet, R. & Laaksonen, S. (2020). Range expansion and reproduction of the ectoparasitic deer ked (*Lipoptena cervi*) in its novel host, the Arctic reindeer (*Rangifer tarandus tarandus*), in Finland. *Parasitology Research.* 119, 3113–3117.

Laaksonen, S., Solismaa, M., Kortet, R., Kuusela, J. & Oksanen, A. (2009). Vectors and transmission dynamics for *Setaria tundra* (Filarioidea; Onchocercidae), a parasite of reindeer in Finland. *Parasites & Vectors*. 2(1), 1–10.

Laaksonen, S., Oksanen, A. & Hoberg, E. (2015). A lymphatic dwelling filarioid nematode, *Rumenfilaria andersoni* (Filarioidea; Splendidofilariinae), is an emerging parasite in Finnish cervids. *Parasites and Vectors.* 8, 228.

Laaksonen, S., Oksanen, A., Kutz, S., Jokelainen, P., Holma-Suutari, A. & Hoberg, E. (2017). Filarioid nematodes, threat to arctic food safety and security. *Game Meat Hygiene: Food Safety and Security*. 2, 213–223.

Langton, C., Gray, J., Waters, P.F. & Holman, P.J. (2003). Naturally acquired babesiosis in a reindeer (*Rangifer tarandus tarandus*) herd in Great Britain. *Parasitology Research.* 89, 194–198.

Malmsten, A., Malmsten, J., Blomqvist, G., Näslund, K., Vernersson, C., Hägglund, S., Dalin, A.M., Ågren, E.O. & Valarcher, J.F. (2017). Serological testing of Schmallenberg virus in Swedish wild cervids from 2012 to 2016. *BMC Veterinary Research.* 13(1), 84.

Medlock, J, Hansford, K, Bormane, A, Derdakova, M, Estrada-Peña, A, George, J-C, Golovljova, I, Jaenson, T, Jensen, J-K, Jensen, P, Kazimirova, M, Oteo, JA, Papa, A, Pfister, K, Plantard, O, Randolph, S, Rizzoli, A, Santos-Silva, MM, Sprong, H, Bortel, W. (2013). Driving forces for changes in geographical distribution of *Ixodes ricinus* ticks in Europe. *Parasites & Vectors*. 6(1), 1–11.

Mørk, T., Sunde, M., Josefsen, T.D. (2014). Bakterieinfeksjoner hos rein [Bacterial infections in reindeer]. *Norsk Veterinærtidsskrift*. 126(2), 222–228.

Mullens, B.A., Tabachnick, W.J. Holbrook, F.R. & Thompson, L.H. (1995). Effects of temperature on virogenesis of bluetongue virus, serotype 11 in Culicoides variipennis sonorensis. *Medical and Veterinary Entomology*. 9(1), 71–76.

Mysterud, A., Jore, S., Østerås, O. & Viljugrein, H. (2017). Emergence of tick-borne diseases at northern latitudes in Europe: a comparative approach. *Scientific Reports.* 7, 16316.

Nilsson, A., Åhman, B., Murphy, M. & Soveri, T. (2006). Rumen function in reindeer (*Rangifer tarandus tarandus*) after sub-maintenance feed intake and subsequent feeding. *Rangifer.* 26, 73–83.

Nordkvist, M. & Karlsson, K.A. (1962). Epizootisk förlöpande infektion med *Pasteurella multocida* hos ren. *Nordisk veterinaermedicin*. 14, 1–15.

Ogden, N.H. & Lindsay, L.R. (2016). Effects of climate and climate change on vectors and vector-borne diseases: ticks are different. *Trends in Parasitology.* 32(8), 646–656.

Persson, S. (1967). Studier av renarnas energibehov. *Kungliga Lantbruksstyrelsen, Meddelanden – Serie B. Lantbruksavdelningen. Rennäringen.* (75), 23.

Rehbinder, C., Christensson, D. & Forssell, I. (1979). Investigations on parasitic visceral granulomas in reindeer. *Nordisk veterinaermedicin*. 31(6), 282–283.

Rehbinder C. & S. Nikander. (1999). *Ren och rensjukdomar*. Uppsala: Studentlitteratur.

Sánchez Romano, J., Mørk, T., Laaksonen, S., Ågren, E., Nymo, I.H., Sunde, M. & Tryland, M. (2018). Infectious keratoconjunctivitis in semi-domesticated Eurasian tundra reindeer (*Rangifer tarandus tarandus*): microbiological study of clinically affected and unaffected animals with special reference to cervid herpesvirus 2. *BMC Veterinary Research*. 14(1), 15.

Sánchez Romano, J., Leijon, M., Hagström, Å., Jinnerot, T., Rockström, U.K. & Tryland, M. (2019). Chlamydia pecorum associated with an outbreak of infectious keratoconjunctivitis in semi-domesticated reindeer in Sweden. *Frontiers in Veterinary Science*. 6, 14.

Skjenneberg, S. & Slagsvold, L. (1968). *Reindriften og dens naturgrunnlag*. Oslo: Universitetsforlaget. (In Norwegian. English translation: Anderson, C.M. & Luick, J.R. eds. (1979). *Reindeer husbandry and its ecological principles*. Juneau, Alaska: U.S. Department of the Interior Bureau of Indian Affairs.

Strathdee, A.T. & Bale, J.S. (1998). Life on the edge: insect ecology in arctic environments. *Annual Review of Entomology*. 43(1), 85–106.

Stuen, S., Granquist, E.G. & Silaghi, C. (2013). *Anaplasma phagocytophilum* – a widespread multi-host pathogen with highly adaptive strategies. *Frontiers in Cellular and Infection Microbiology*. 3, 31.

Tryland, M., Das Neves, C.G., Sunde, M. & Mørk, T. (2009). Cervid herpesvirus 2, the primary agent in an outbreak of infectious keratoconjunctivitis in semi-domesticated reindeer. *Journal of Clinical Microbiology.* 47(11), 3707–3713.

Tryland, M., Sánchez Romano, J., Marcin, N., Nymo, I.H., Josefsen, T.D., Sørensen, K.K. & Mørk, T. (2017). Cervid herpesvirus 2 and not Moraxella bovoculi caused keratoconjunctivitis in experimentally inoculated semi-domesticated Eurasian tundra reindeer. *Acta Veterinaria Scandinavica*. 59(1), 23.

Tryland, M., Das Neves, C.G., Klein, J., Mørk, T., Hautaniemi, M. & Wensman, J. (2018). Viral infections and diseases. In: Tryland, M. & Kutz, S.J. (eds) *Reindeer and Caribou – Health and Disease*. Boca Raton: CRC Press. 273–303.

Tryland, M., Nymo, I.H., Sánchez Romano, J., Mørk, T., Klein, J. & Rockström, U. (2019). Infectious disease outbreak associated with supplementary feeding of semi-domesticated reindeer. *Frontiers in Veterinary Science*. 6, 126.

Välimäki, P., Madslien, K., Malmsten, J., Härkönen, L., Härkönen, S., Kaitala, A., Kortet, R., Laaksonen, S., Mehl, R., Redford, L., Ylönen, H. & Ytrehus, B. (2010). Fennoscandian distribution of an important parasite of cervids, the deer ked (*Lipoptena cervi*), revisited. *Parasitology Research*. 107(1), 117–125.

Wernike, K., Conraths, F., Zanella, G., Granzow, H., Gache, K., Schirrmeier, H., Valas, S., Staubach, C., Marianneau, P., Kraatz, F., Höreth-Böntgen, D., Reimann, I., Zientara, S. & Beer, M. (2014). Schmallenberg virus – two years of experiences. *Preventive Veterinary Medicine*. 116(4), 423–434.

Wiegmann, L., Silaghi, C., Obiegala, A., Karnath, C., Langer, S., Ternes, K., Kämmerling, J., Osmann, C. & Pfeffer, M. (2015). Occurrence of Babesia species in captive reindeer (*Rangifer tarandus*) in Germany. *Veterinary Parasitology*. 211(1–2), 16–22.

Wikström, E. (2014). Dödlighet hos renkalvar vid kalvning i hägn. SLU, Fakulteten för veterinärmedicin och husdjur, Inst. f. husdjurens utfodring och vård, Uppsala. Master thesis available at https://stud.epsilon.slu.se/6615/.

Wittmann, E.J. & Baylis, M. (2000). Climate change: effects on culicoides-transmitted viruses and implications for the UK. *The Veterinary Journal*. 160(2), 107–117.

Wittmann, E.J., Mello, P.S. & Baylis, M. (2002). Effect of temperature on the transmission of orbiviruses by the biting midge, Culicoides sonorensis. *Medical and Veterinary Entomology*. 16(2), 147–156.