# Are we facing new health challenges and diseases in reindeer in Fennoscandia?

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*Abstract*: A large number of semi-domesticated reindeer is lost every year. Predators are the single most important factor for these losses, whereas restrictions on food availability some years also may cause high mortality. In the past, reindeer herding was challenged by severe infectious diseases, killing hundreds and thousands of animals, and having huge economic and social impact on reindeer herding in Fennoscandia. The general zoo-sanitary situation in Fennoscandia is very favourable for the time being, but reindeer herding is sometimes challenged by disease outbreaks, and diseases play an important role for survival and fitness of reindeer. Reindeer herding is also facing changes and challenges, which also may impact reindeer health and the disease status. Introduction of infectious agents not commonly present in the reindeer population may take place through import of animals, as well as by contact between reindeer, livestock and wildlife. Further, changes in the herding, such as increased feeding, transport, size of herds, animal density and stress load on the animals, may affect the animals ability to cope with infectious diseases. Also changes in weather conditions and climate, such as increased precipitation and mean temperature, may over time lead to restricted availability of pastures, changes in vegetation and changed conditions for parasites and insect vectors. These changes might be especially important for the reproductive success, including fitness of the calves during their first winter. To be able to cope with these changes and their potential impact on reindeer health, increased efforts should be made to gather reference data on health and disease parameters from the different reindeer herding districts, along with epidemiological risk factor analysis. This would increase the ability for the reindeer herding to cope with changes and to continue to produce quality meat products for the market.

**Key words**: climate change; health; infectious disease; livestock; management; reindeer; wildlife.

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## Introduction

A total of 251 019 semi-domesticated reindeer (*Rangifer tarandus tarandus*) was registered in Norway in 2010, with 3102 persons directly involved in reindeer herding, being members of defined herding units (siida) (Anonymous, 2011). During the reindeer herding year 2009-10, 19% of all semi-domesticated reindeer were reported lost. Of these, 88% of the calves and 77% of the adults were lost due to protected predator species (Anonymous, 2011), of which lynx (*Lynx lynx*), wolverine (*Gulo gulo*) and eagle are the most important. Other known causes of death are starvation, due to restricted availability of pastures, trauma and diseases. Although semi-domesticated reindeer have not experienced large and severe pests in recent times, some infectious diseases still cause larger outbreaks and mortalities, representing animal welfare challenges and economical loss for the reindeer herders.

*Reindeer diseases and pests described in the past*

Reindeer is susceptible to a range of infectious agents, such as parasites, bacteria and viruses. Some of these infections may be transmissible between reindeer and other ungulates, both wild animals such as moose (*Alces alces*), red deer (*Cervus elaphus*) and roe deer (*Capreolus capreolus*), and livestock (sheep, goat and cattle), and some infectious agents can be transferred to humans (zoonoses).

Older reports on disease outbreaks in semi-domesticated reindeer describe severe pests that over years caused mass mortality of reindeer and poverty for the reindeer herding societies. One such disease was the reindeer pest (*Pestis tarandi*), an extremely contagious and acute or peracute disease with high mortality, especially in calves and young animals. It was caused by a Gram positive rod-shaped bacterium, most likely *Clostridium septicum* (Horne, 1897a; Skjenneberg & Slagsvold, 1968). Large outbreaks ravaged the northern reindeer herding regions of Sweden and Finland during the 1700 and 1800 centuries, especially during 1850-1900, with thousands of animals dying (Lundgren, 1897; Skjenneberg & Slagsvold, 1968), but there is no solid evidence that this disease have appeared in a similar way in Norway.

Another bacterial pest, necrobacillosis, called "slubbo" in Sami, was characterized as a highly contagious and severe hoof infection, appearing in larger outbreaks and with high mortality. This disease was not uncommon in Norway some decades ago (Horne, 1897b; Skjenneberg & Slagsvold, 1968), but has not recently been registered in the reindeer herding. In wild reindeer in Norway, however, necrobacillosis appeared in 2008 and 2009 (Handeland *et al.*, 2010).

Foot and mouth disease (FMD; *Apthae epizooticae*) is caused by a virus of the *Picornaviridae* family, a fact that was discovered in 1897 by the German bacteriologist Friedrich Loeffler (1852-1915). The disease affects domestic and wild ungulates. It is extremely transmissible, and the virus can be transported long distances by wind, in contaminated clothes and vehicles, and even by predators. FMD has appeared in reindeer herds in Russia, causing massive outbreaks, and it was reported that 246 000 animals were afflicted during the period 1886 – 1897, and that approximately 150 000 animals died (Syroechkovskii, 1995). Experimental infections in reindeer have been conducted in Russia (Dewell, Eckert, 1901) and Sweden (Magnusson, 1927), demonstrating that reindeer, as many other cloven-hoofed animals, indeed is susceptible to this virus infection. FMD caused a severe outbreak among livestock in UK in 2001. The disease was last reported in Norway in cattle in 1952 and Sweden in 1966 (Anonymous 2005), but there is no evidence that FMD has appeared in reindeer in Fennoscandia.

Another disease that has appeared as regular outbreaks among reindeer is pasteurellosis, caused by the bacterium *Pasteurella multocida* (Kummeneje, 1973). Larger outbreaks have been reported in the beginning of the 20$^{th}$ century, both in Sweden and Norway, with hundreds and maybe thousands of dead animals (Brandt, 1914), and smaller outbreaks are also reported today.

Also other infectious diseases may have appeared with severe outbreaks in the past, such as anthrax (*Bacillus anthracis*), brucellosis (*Brucella suis* biovar 4), paratuberculosis (*Mycobacterium avium* subsp. *paratuberculosis*) and infectious keratoconjunctivitis (IKC), of which some will be further discussed below.

*Challenges for reindeer herding*

Although reindeer herding is based on long traditions and knowledge on how to exploit nature resources to produce reindeer meat and other products, reindeer herding is not static, but has rather conducted considerable adaptations during the past decades. In addition to conflicting interests associated to protection of predator populations, one of the most important challenges for reindeer herding is the increase of infrastructure in previously undisturbed reindeer pasture areas. It has been shown that even smaller structures may change the behavioural patterns of animals and herds

(Nellemann *et al.*, 2003). Even if the animals are not physically hindered to cross power lines or roads, they may choose not to approach such constructions, which may restrict the pastures considerably. There is also a trend of increasing herd sizes and increased use of motorized vehicles, to herd animals more efficiently and over longer distances.

The ecological balance between number of animals and available pasture areas remains a great challenge for the reindeer herding industry in some parts of Norway, due to the fact that larger die-offs takes place during winter seasons with unfavourable weather conditions, such as during the winter of 1999-2000. If the predicted results of the climatic change scenarios become reality, we will face more precipitation, higher mean temperatures and more temperature fluctuations in the arctic regions than today (ACIA, 2004). This will have impact on the snow cover, freeze-thaw cycles and ice conditions, which makes the winter pastures unavailable for the animals (Moen, 2008).

This article will address and discuss possible changes in the disease and health conditions of semi-domesticated reindeer in Fennoscandia, due to potential import of infectious agents, changes in the reindeer herding, and climatic changes.

## Infectious agents: increased prevalence and impact on reindeer health?

The general zoo-sanitary situation in Finland and the Scandinavian countries is regarded as favourable compared to continental Europe and many other regions of the world. This is also the situation for reindeer when compared to Russia, Canada and Alaska. However, the presence and prevalence of reindeer pathogens, i.e. parasites, bacteria and viruses causing disease, may change, and infectious diseases may gain increased impact on reindeer herding and economy in the future. Infectious agents can be introduced or have increased distribution and impact on reindeer health via three main mechanisms: through introduction of new pathogens to the reindeer herds in a region, through changes in reindeer herding that may alter the situation for pathogens and diseases, and through climate change which may change the epidemiology of infectious diseases.

### *Introduction of "new" pathogens*

#### Import of animals and animal products

The introduction of potential reindeer pathogens that are not present in Fennoscandia today, can take place through migration of animals across country borders, from regions where such agents are enzootic. New pathogens, or more pathogenic variants of infectious agents already present, may be introduced to an immunologically naïve population. One example is FMD, which has been reported in reindeer in Russia (Syroechkovskii, 1995). Should FMD virus enter the reindeer herds, it will cause major disease outbreaks and reduced production and fitness. Even more seriously, the reindeer herds would most likely be slaughtered as part of a "stamping out" procedure, to hinder the virus to become endemic in reindeer and to spread to livestock. The last outbreak of FMD in UK, Netherlands and France in 2001, cost around 3.1 billion GBP (appr. 30 billion NOK), and about 4.9 million sheep, 700 000 cattle and 400 000 pigs were euthanized and destroyed (Thompson *et al.*, 2002). This outbreak also demonstrated how easily and quickly the virus spread and how difficult it was to stop an outbreak.

We may also be confronted with new pathogens through import of live animals or animal products, from countries or regions were such pathogens are present. One potential threat can be import of reindeer hosting *Brucella*-bacteria, and the most relevant scenario may be import of reindeer from Russia, either directly or via Finland, to Norway (Åsbakk *et al.*, 1999). A disease agent as *Brucella suis* (biovar 4) may readily establish in the reindeer population and become enzootic, causing increased reindeer mortality and reproduction problems, necessitating vaccine regimes and animal transport restrictions. Another threat could be animals infected with mycobacteria, potentially causing tuberculosis in reindeer. Red deer infected with *Mycobacterium bovis* was imported to Sweden in 1987, creating disease problems in farmed deer as well as possible transmission to livestock and humans. After many years of control programs, the deer population now seems to be free from such infections (Wahlström *et al.*, 2010). Import of infected reindeer and contact between reindeer and infected farmed deer may, however, represent threats to the reindeer populations. It is therefore crucial that live animals and products are controlled prior to transport, that no illegal import takes place and that a state of readiness exists to handle diagnostics and management to identify and handle disease outbreaks.

Fig. 1. Many factors related to herding, such as increased herd size, animal density, stress and contact with infected sheep through shared pastures, fences and animal transport vehicles may contribute to the outbreak of contagious ecthyma in reindeer, in Norway caused by a parapox virus common in sheep and goats.
(Photo: Morten Tryland)

### Contact with domestic animals

In Norway, the contact between reindeer and livestock (cattle, sheep and goats) increase during spring and summer. Reindeer are often attracted to coastal farmed fields, from which the snow disappears in early spring, and reindeer and livestock may have close contact on shared mountain pastures. Based on serological screenings, it is obvious that reindeer and caribou throughout the reindeer herding and pasture regions of the world are exposed to alphaherpesvirus and pestivirus (Dieterich, 1981; Ek-Kommonen *et al.*, 1986; Rehbinder *et al.*, 1992; Stuen *et al.*, 1993; Lillehaug *et al.*, 2003; Das Neves *et al.*, 2010). Cattle, and other livestock species, are also infected by closely related viruses, such as bovine herpesvirus 1 (BoHV1), and bovine viral diarrhea virus (BVDV) and border disease virus (BDV), and it has been speculated if reindeer and livestock share the same viruses. Recent findings, however, have concluded that reindeer have their own alphaherpesvirus species, Cervid herpesvirus 2 (CvHV2)(Das Neves *et al.*, 2010), and a specific pestivirus variant was recently isolated from a reindeer in a zoo in Germany (Becher *et al.*, 1999; Avalos-Ramirez *et al.*, 2001). For gammaherpesvirus, it seems that virus causing pathology in moose may share characteristics with similar viruses in sheep (OvHV-2) and goats (CpHV-2), as assessed by PCR and sequence homology (Vikøren *et al.*, 2006). The situation for reindeer is not clear, but anti-gammaherpes antibodies have been detected in reindeer sampled in Finnmark (unpubl. data).

Contagious ecthyma, caused by Orf virus (genus *Parapoxvirus*, family *Poxviridae*), is common in Norwegian sheep and goat farms. Similar disease outbreaks have occurred in semi-domesticated reindeer in Sweden ("Munnvårtsjukan"; Nordkvist, 1973), Finland (Oksanen & Norberg, 1994; Büttner *et al.*, 1995) and Norway (Kummeneje & Krogsrud, 1979; Tryland *et al.*, 2001). Contagious ecthyma has also affected free ranging muskoxen (*Ovibos moschatus*) in Norway (Vikøren *et al.*, 2008). In reindeer, the disease is characterised by lesions and proliferative processes on the lips and in the oral mucosa (Fig. 1). The lesions are easily infected by bacteria, and the situation may in severe cases hinder the animals to eat, and eventually they become emaciated and die. The disease usually affects many animals and generally cause a more severe disease with higher mortality in reindeer, as compared to sheep and goats (Büttner *et al.*, 1995; Tryland *et al.*, 2001). Virus characterization studies concluded that contagious ecthyma outbreaks in reindeer in Norway have been caused by Orf virus, with assumed transmission from sheep (Klein & Tryland, 2005). In Finland, early outbreaks were also caused by Orf virus, whereas more recent outbreaks of contagious ecthyma in Finnish reindeer seem to have been caused by another parapoxvirus, the Pseudocowpoxvirus (Tikkanen *et al.*, 2004; Hautaniemi *et al.*, 2010), which is usually associated to cattle.

Nematodes of the genus *Elaphostrongylus* is represented in reindeer (*E. rangiferi*), red deer (*E. cervi*) and moose (*E. alces*) in Norway. These parasites also cause disease in sheep in western parts of Norway (*E. cervi*) and in goats and sheep in northern parts of Norway (*E. rangiferi*) (Handeland & Sparboe, 1991), through infected pastures, in which snails are intermediate hosts (Skorping & Halvorsen, 1980). Shared pastures between reindeer and sheep may thus contribute to disease in goat herds.

#### Contact with wildlife

Another possibility of introducing new pathogens to semi-domesticated reindeer is through contact with wildlife, such as moose, red deer and roe deer. Although many pathogens have one specific host and cannot infect other animal species, many infectious agents can have a range of possible host species. FMD is one example, for which all cloven-hoofed animals seem to be susceptible, including reindeer and wild ungulates. It is also possible that bacteria belonging to the mycobacterium avium complex, such as *M. a.* subsp. *paratuberculosis*, may be transferred between different species of wild ungulates and reindeer. In Norway, antibodies against such bacteria have been detected in semi-domesticated reindeer (3.4%), moose (1.9%), red deer (3.8%) and roe deer (12.2%), but wild reindeer were all seronegative (Tryland *et al.*, 2004). Since attempts to confirm the serological data by isolation of the bacterium from seropositive moose failed, such findings should, however, be interpreted cautiously, since also other related mycobacteria may be present in the environment and trigger the immune system in similar ways. *Mycobacterium bovis*, causing tuberculosis in cattle, but also in wild animals and man, can also cross species barriers, and probably establish itself in reindeer populations should it be introduced to the ecosystems.

### *Changes in reindeer herding*

#### Increased feeding: herding or farming?

Feeding of semi-domesticated reindeer is a relatively new phenomenon in Norway, conducted on a supplementary basis or as an emergency measure as a response to difficult winters with restricted food availability for the reindeer, usually in late winter towards calving. Some reindeer owners have chosen to feed on a more regular basis, as is quite common in Finland. Climatic changes, with increased precipitation and higher temperatures, might have impact on the availability of reindeer pastures during winter, with more snow and ice covers. This may force reindeer herders to increasingly conduct supplementary feeding during the winter season, or even herd the animals closer all year around and increase the feeding relative to mountain pastures.

With increased corralling and feeding, reindeer will have increased contact with each other (increased animal density) and possibly also with livestock (cattle, sheep and goats), which may facilitate the spread of infectious diseases, both within the reindeer herds and between animal species. Corralling and handling might also increase the general stress load of the animals, which also may contribute to disease outbreaks or other unfavourable health conditions. However, feeding animals that have reached a state of starvation should not only be looked upon as a possible measure to save animal lives and economic interests, but also as a compulsory tool to avoid animal suffering. In this context it is important to remember that reindeer and their microbiological rumen flora are adapted to the plants they usually feed on. Thus, to feed reindeer successfully, both good quality feed and knowledge and experience is vital.

### Increased animal transport and stress

In some reindeer herding regions, the need for animal transport is increasing. This might be due to fragmentation of pasture areas and disruption of migration routes, longer distances to slaughter facilities and increasing herd size, using new areas as reindeer pastures. Further, there is a trend of increased efficiency in the movements of animals, based on motorized vehicles like four-wheelers, snow scooters and helicopters.

Gathering, corralling, long distance herding or vehicle transport of live animals can be very stressful for reindeer. Stress induces an increased release of hormones like glucocorticosteroids to the blood stream, which also has an immunosuppressive effect. As an example, it has been shown experimentally that reindeer having latent alphaherpesvirus infection (CvHV2) and showing no clinical symptoms, developed blisters and lesions in the oral mucosa upon glucocorticosteroid treatment (Das Neves *et al*., 2009a). A stressed animal, especially if the condition last over a period of time, may thus be more prone to become infected and also to develop disease from infections. In addition to stress, these situations also create very high animal density, facilitating the transmission of infectious agents between animals in the herd or between herds if they are mixed.

### Some infectious agents that might be affected by changes in reindeer herding

The disease contagious ecthyma (Orf virus) seems to be more severe in reindeer compared to most outbreaks in sheep and goats. The disease is regarded as multifactorial, and in addition to being exposed to the virus, factors like body condition and food availability, stress and animal density might play important roles for disease outbreaks to take place. Thus, changes in reindeer herding might increase the frequency and severity of contagious ecthyma in reindeer.

In addition to have been described as one of several reindeer pests in the past, pasteurellosis (*Pasteurella multocida*) still occurs as regular outbreaks in reindeer. The latest outbreak recorded in Norway was during fall 2010, when 45 calves (4-5 months old) died after arrival in the slaughterhouse fence in Finnmark County (Pers. comm. Anne Hagen, Norwegian Food Safety Authority, 2010). They were either found dead in the fence without any recorded disease history, or observed ataxic and exhausted prior to death. The epidemiology of pasteurellosis in reindeer is not very well known, and it has been speculated whether warm summer days and dusty conditions, combined with gathering of animals and stress might contribute to disease outbreaks (Kummeneje, 1973), as reported for "shipping fever" in cattle, caused by the bacterium *Mannheimia hemolytica* (previously named *Pasteurella hemolytica*).

Cervid herpesvirus 2 (CvHV2) is enzootic in the reindeer populations in Fennoscandia and probably also in other reindeer and caribou populations (Evans *et al.*, 2012; for a review, see: Das Neves, 2010). Despite its common presence, not much has been known about the impact of this virus infection on reindeer health. Recent reports have revealed that latent infections might be activated by glucocorticosteroids, and that infections are associated to mucosal lesions in the gastro-intestinal tract. Further, CvHV2 can be transferred from mother to the foetus, can cause abortion and also possibly serve as the contagious component in the disease etiology of infectious keratoconjunctivitis (IKC) (Das Neves *et al.*, 2009b; Tryland *et al.*, 2009). CvHV2 infections may gain increased importance if animal density and general stress load of animals increases (Das Neves *et al.*, 2009a).

Antibodies against Pestivirus, a genus within the *Flaviviridae* family, have been detected in semi-domesticated and wild reindeer in Norway (Stuen *et al.*, 1993; Lillehaug *et al.*, 2003), and in semi-domesticated reindeer in Finland 58% (Neuvonen *et al.*, 1983), Sweden 6% (Rehbinder *et al.*, 1992), Canada 60% (Elazhary *et al.*, 1979), and Alaska 3% (Zarnke, 1983). Recent serological studies of reindeer from Finnmark confirmed that a pestivirus seems to be enzootic in many herding districts (unpubl. data). In a study conducted on reindeer found dead on winter pasture in 2000, anti-pestivirus antibodies were detected in 14 of 39 (36%) carcasses (Tryland *et al.*, 2005). According to the necropsies, the cause of death was emaciation (Josefsen *et al.*, 2007), and it was not evident that exposure to pestivirus had any impact on the health of these animals. However, data from an experimental infection of two reindeer calves (8 months of age) with a pestivirus associated to cattle (BVDV), concluded that the virus was capable of replicating in reindeer and cause viremia, nasal discharge and pathological conditions in the respiratory organs (Morton *et al.*, 1990). The epidemiology of pestivirus infections in reindeer is basically unknown, but in cattle, BVDV is transferred to the foetus and the calf is born infected and is shedding virus, but shows no clinical signs. Upon a superinfection with a different biotype of pestivirus, such calves may develop a condition called mucosal disease, with a fatal outcome, following an acute, sub-acute or chronic course. In sheep infected with border disease virus (BDV), adults show no clinical signs, whereas lambs may be still-born, or have low birth weights and poor viability. Whether these characteristics are valid for reindeer pestivirus is not known.

### *Climate change*

Prognoses of climate change impact have pinpointed increased precipitation and mean temperatures, as well as more frequent temperature fluctuations, for the Arctic regions (ACIA, 2004). This may have impact on the vegetation in reindeer pasture areas, such as increased bush vegetation and reduced lichen production, which may negatively impact winter survival. Further, such changes may also have profound effects on the presence and distribution of many infectious agents, on the survival of agents outside the host, and on migration and survival of intermediate hosts and insect vectors.

## Some infectious agents that might be affected by climate change

Animals infected with *Elaphostrongylus rangiferi* are shedding freeze resistant first stage larvae in faeces. The larvae go through a tempera-

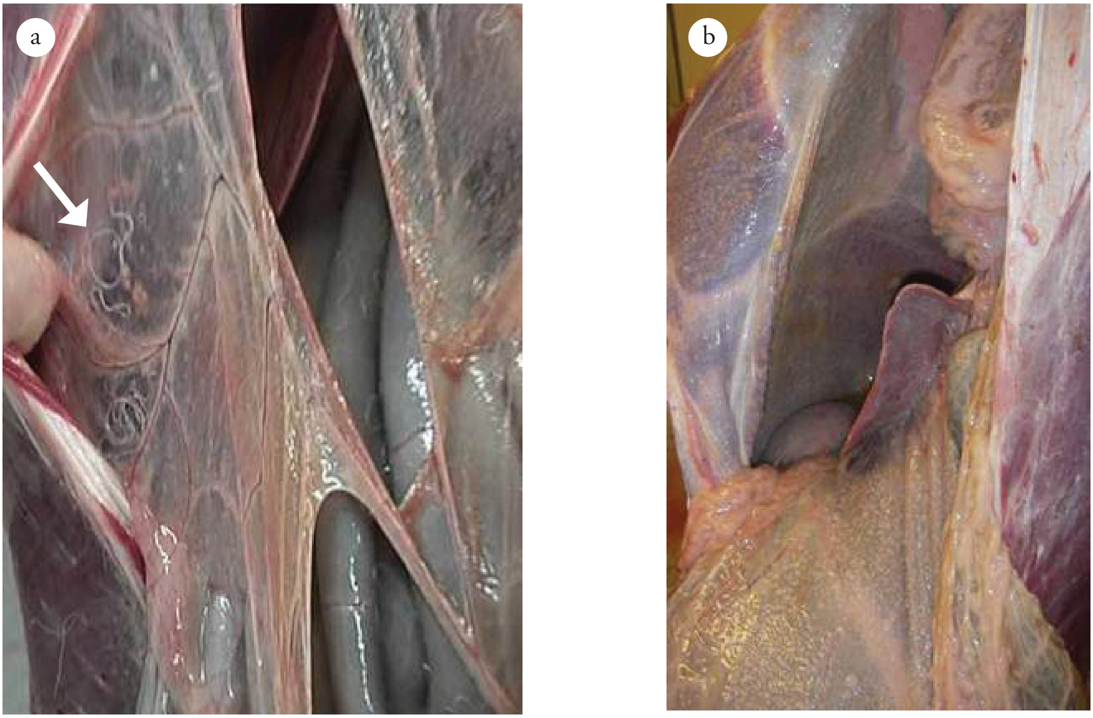


Fig. 2. Presence of the nematode *Setaria tundra* (a; arrow) in the abdomen of a reindeer at slaughter. The larval stage of the parasite is transmitted by mosquitos and may cause severe peritonitis (b), leading to increased mortality and condemnation of carcasses and organs. The development of larvae in the vectors is temperature dependent and climate change may contribute to increased distribution of vectors and the parasite (Photo: Sauli Laaksonen).

ture dependent development to third stage and infective larvae in snails, which accidentally are eaten by new host animals during late summer and autumn. In the reindeer, larvae develop further to adults in the CNS, where they can affect nerve tissue. Clinical symptoms, usually seen in calves during late autumn or early winter, consist of ataxia and paresis, especially in the hind legs, and affected animals have problems to follow the herd. The degree of clinical symptoms and prognosis is dependent on the load of parasites. The minimum temperature for development of *E. rangiferi* in the intermediate hosts is about 10 °C, and the larval development takes 50-75 days at 12 °C, but only 12 days at 24 °C (Halvorsen & Skorping, 1982). These characteristics link this parasite and the disease it cause in reindeer to prospective climatic changes. Thus, an increased mean temperature during the year, may give the parasite a longer season to develop and cause a quicker development, leading to an increase of infective larvae in snails and a higher infection pressure on reindeer and other hosts.

Insect-transmitted filaroid nematodes, *Setaria* spp., are commonly found in the abdominal cavity of ungulates and are usually considered harmless (Urquhart *et al.*, 1996). However, *S. yehi* has been associated to chronic peritonitis in Alaskan reindeer (Dieterich & Luick, 1971), and *S. tundra* has emerged as a sporadic cause of peritonitis, poor body condition, and death in semi-domesticated reindeer in Fennoscandia. In 1973, a severe *Setaria* sp. outbreak caused the death of tens of thousands of semi-domesticated reindeer in northern reindeer herding areas of Finland (Rehbinder *et al*., 1975; Kummeneje, 1980), and wild ungulates were also affected (Laaksonen *et al*., 2010). In 2003, an outbreak of S. tundra caused severe disease in semi-domesticated reindeer in Finland (Fig. 2), starting in reindeer husbandry areas in southern Finland and moving northwards by approximately 100 km/year (Laaksonen, 2007). The development of the parasite in mosquitoes (*Aedes* spp. but also *Anopheles* spp.) is temperature-dependent, and it seems that mean summer temperatures exceeding 14°C result in an increased prevalence of disease in reindeer the following year (Laaksonen *et al*., 2009). *S. tundra* may cause mortality, but also affects the quality of the slaughtered animal, leading to condemnation of carcasses and organs, which represents economic losses for the reindeer industry. Although treatment is possible, it represents a significant economic and labor investment. Climate changes may increase the distribution of insect vectors and also their ability to support development and dissemination of *S. tundra* (Laaksonen *et al*., 2010).

Also tick borne infectious agents can be affected by climate change. The bacterium *Anaplasma phagocytophilum* (formerly *Ehrlichia phagocytophila*) may cause infection in many animal species. The bacterium is prevalent in ticks (*Ixodes ricinus*) in most countries in Europe, and clinical manifestations (anaplasmosis or tick borne fever) have been recorded in sheep, goat, cattle, horse, dog, cat, roe deer, reindeer and man (Stuen, 2007). The infection is usually not fatal, but can cause abortion and also predispose for other infections. Factors as climate, management, body condition and the presence of other infections may impact on the outcome of the infection (Stuen *et al*., 1996, 2007). In Sweden, the geographical distribution of *Ixodes ricinus* corresponds to a vegetation period of approximately 170 days, to an early start of spring and to the distribution of black alder (*Alnus glutinosa*) (Jaenson & Lindgren, 2011). Models based on these parameters and predicted climate change scenarios, leading to a prolonged vegetation period, have indicated an increased range of *Ixodes ricinus*, extending to most of Sweden, Finland and Norway up to 70 °N, with an exception for the mountainous regions (Jaenson & Lindgren, 2011). This may also reflect the distribution of infectious agents hosted by the ticks, such as *Anaplasma phagocytophilum* and *Borrelia burgdorferi*, both being present in ticks in Norway and both infecting many animal species and man (Rosef *et al*., 2009).

Changes in the distribution of insect vectors (mechanical and biological) will be an important and immediate effect of a changing climate, and can have dramatic impact on the distribution of infectious agents. Expanded distribution of a vector may not only introduce viruses to hosts in new regions, but also introduce such viruses into the range of other potential vector species. Bluetongue virus (BTV; genus *Orbivirus*, family *Reoviridae*) causes bluetongue disease in ruminants (Wilson & Melor, 2009). BTV serotype 8 (BTV-8) was discovered in northern Europe in June 2006 at a location approximately 800 km further north than previously recorded. After transmission was interrupted during winter (due to lack of vectors), the virus spread again in 2007 and 2008, causing substantial losses in the animal husbandry industry as well as restrictions on animal movements (Carpenter *et al*., 2009). The change in distribution of the virus was probably due to a combination of mechanisms, including movement of infected livestock but also passive movement of *Culicoides* sp. vectors via winds (Purse *et al*., 2008; Wilson & Mellor, 2009). BTV also appeared in livestock in Norway and Sweden, and has been found in a range of wildlife species in Europe (Ruiz-Fons *et al*., 2008; Linden *et al*., 2010). From a survey conducted on Swedish farms, it was evident that among 33 *Culicoides* species present, *C. obsoletus* and *C. scoticus* represented the largest fraction, both known to be suitable vectors for BTV and being present also in Northern regions of Sweden (Nielsen *et al.*, 2010). Warmer temperatures might promote viral survival and vector longevity, and contribute to a possible introduction of BTV in reindeer herds.

## Discussion

### *Expectations to reindeer meat*

For the reindeer owner, many products from the animals are valuable, but for the society, reindeer meat is the most important outcome and also represents the economical backbone for the herding industry. As for other food items, consumers expect that reindeer meat is safe. A general control of the disease situation, and infectious diseases and zoonoses in particular, is therefore extremely valuable. Consumers also expect reindeer meat to taste reindeer ("game meat"). This implies that a large degree of feeding, at least when approaching the time of slaughter, might reduce the valued taste of reindeer meat and negatively impact the market.

It is also expected that reindeer meat is free of drugs, such as antibiotics, anti-parasitic drugs and hormones. This is based on a restricted need for treatment, which again is possible only if the health and disease situation is favourable. This picture might, however, change dramatically, should other transmissible diseases than present today be introduced to the reindeer population, necessitating routine medication.

Consumers are also increasingly focusing on animal welfare, and generally appreciate meat from healthy animals in good condition that have lived a good life according to their instincts and needs. It is also expected that animals are not exposed to severe diseases or parasitic infestations, pain and high levels of stress during gathering, transport and fencing for slaughter, which may impact the meat quality.

Last but not least, consumers wants reindeer meat for reasonable prices, and the market situation might be a good indicator on what is reasonable to the consumer. In meat quality and taste, reindeer meat can compete with meat from most other animals, and it seems to be a general willingness to pay more for reindeer meat than for cattle meat. This, however, is based upon the idea that reindeer meat have a high quality, tastes reindeer, and is free from zoonotic infectious agents and drugs.

### *Being prepared for the future*

Although reindeer herding in Fennoscandia is, globally speaking, a relatively isolated animal production, we might face new challenges and even pests to the reindeer populations, as has been experienced previously. Although pests and diseases like FMD cause the most acute and dramatic control measures, diseases like tuberculosis and paratuberculosis might represent agents and conditions that may have even stronger impact on reindeer health and herding in the long perspective, due to the severity of the diseases they cause and the restricted potential for eradication.

It has always been necessary for herders to adapt to changing environments, such as restrictions on available land area, extreme weather conditions, as well as predators and diseases. Today, the favourable zoo-sanitary situation in reindeer in Fennoscandia leaves less focus on diseases. It is, however, important to still be aware of these potential threats, since these favourable conditions may change. Feeding will probably become more common and the future zoo-sanitary situation may represent major challenges for reindeer herders and local communities. Investments in research and health management are therefore necessary to be prepared for these challenges and to be able to produce reindeer meat as a valued product also for the future.

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## References

**ACIA** (Arctic Climate Impact Assessment). 2004. *Impacts of a warming Arctic: Arctic Climate Impact Assessment.* Cambridge University Press. (http://www.acia.uaf.edu/pages/overview.html). (21. February 2012).

**Anonymous**. 2005. Norwegian Food Safety Authority (http://www.mattilsynet.no/smittevern_og_bekjempelse/dyr/a-sjukdommer/munn_og_klauvsyke). (21. February 2012).

**Anonymous**. 2011. Ressursregnskap for reindriftsnæringen for reindriftsåret 1. april 2009 – 31. mars 2010. Reindriftsforvaltningen, Alta, Norway.

**Avalos-Ramirez, R., Orlich, M., Thiel, H-J., & Becher, P.** 2001. Evidence for the presence of two novel pestivirus species. – *Virology* **286:** 456–465.

**Becher, P., Orlich, M., Kosmidou, A., König, M., Baroth, M., & Thiel, H. J.** 1999. Genetic diversity of pestiviruses: identification of novel groups and implications for classification. – *Virology* 262: 64-71.

**Büttner, M., von Einem, C., McInnes, C., & Oksanen A.** 1995. Klinik und Diagnostik einer schweren Parapocken-Epidemie beim Rentier in Finland. – *Tierärztliche Praxis* 23: 614-618.

**Brandt, O.** 1914. Pasteurellos hos ren. – *Svensk Veterinärtidning* 19.

**Carpenter, S., Wilson, A., & Mellor, P. S.** 2009. Culicoides and the emergence of bluetongue virus in northern Europe. – *Trends in Microbiology* 17: 172-178.

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

**Das Neves, C. G., Mørk, T., Thiry, J., Godfroid, J., Rimstad, E., Thiry, E., & Tryland, M.** 2009a. Cervid herpesvirus 2 experimentally reactivated in reindeer can produce generalized viremia and abortion. – *Virus Research* 145: 321-8.

**Das Neves, C. G., Mørk, T., Godfroid, J., Sørensen, K. K., Breines, E., Hareide, E., Thiry, J., Rimstad, E., Thiry, E., & Tryland, M.** 2009b. Experimental infection of reindeer with cervid herpesvirus 2. – *Clinical and Vaccine Immunology* 16: 1758-1765.

**Dewell, Ekkert**. 1901. Über die Empfänglichkeit der Renntiere für die Maul- und Klauenseuche. – *Berliner Tierärztliche Wochenschrift* 6: 92-93.

**Dieterich, R. A. & Luick, J. R.** 1971. The occurrence of Setaria in reindeer. – *Journal of Wildlife Diseases* 7: 242–245.

**Dieterich, R. A.** 1981. Respiratory viruses. – *In*: *Alaskan wildlife diseases*. University of Alaska, Fairbanks, USA, pp. 28-29.

**Ek-Kommonen, C., Pelkonen, S., & Nettleton, P. F.** 1986. Isolation of a herpesvirus serologically related to bovine herpesvirus 1 from a reindeer (*Rangifer tarandus*). – *Acta Veterinaria Scandinavica* 27: 299–301.

**Elazhary, M. A. S. Y., Roy, R. S., & Frèchette, J. L.** 1979. Serological evidence of IBR and BVD infection in caribou. – *Veterinary Record* 105: 336.

**Evans, A. L., das Neves, C. G., Finstad, G. F., Beckmen, K. B., Skjerve, E., Nymo, I. H., & Tryland, M.** 2012. Evidence of alphaherpesvirus infections in Alaskan caribou and reindeer. – *BMC Veterinary Research* 8: 5.

**Halvorsen, O. & Skorping, A.** 1982. The influence of temperature on growth and development of the nematode *Elaphostrongylus rangiferi* in the gastropods *Arianta arbustorum* and *Euconulus fulvus*. – *Oikos* 38: 285-290.

**Handeland, K. & Sparboe, O.** 1991. Cerebrospinal elaphostrongylosis in dairy goats in northern Norway. – *Journal of Veterinary Medicine B*, 38: 755-763.

**Handeland, K.** 1994. Experimental studies of *Elaphostrongylus rangiferi* in reindeer (*Rangifer tarandus tarandus*): life cycle, pathogenesis, and pathology. – *Zentralblatt Veterinärmedizin B* 41: 351-365.

**Handeland, K., Boye, M., Bergsjø, B., Bondal, H., Isaksen, K., & Agerholm, J. S.** 2010. Digital necrobacillosis in Norwegian wild tundra reindeer (*Rangifer tarandus tarandus*). – *Journal of Comparative Pathology* 143: 29-38.

**Hautaniemi, M., Ueda, N., Tuimala, J., Mercer, A. A., Lahdenperä, J., & McInnes, C. J.** 2010. The genome of pseudocowpoxvirus: comparison of a reindeer isolate and a reference strain. – *Journal of General Virology* 91: 1560-1576.

**Horne, H.** 1897a. Rensyke. Hæmorrhagisk septikæmi hos ren. – *Norsk veterinærtidsskrift* XXVII.

**Horne, H.** 1897b. Renens klovsyge. – *Norsk veterinærtidsskrift* XXVII.

**Jaenson, T. G. & Lindgren, E.** 2011. The range of *Ixodes ricinus* and the risk of contracting Lyme borreliosis will increase northwards when the vegetation period becomes longer. – *Ticks and Tick Borne Diseases* 2: 44-49.

**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.

**Klein, J. & Tryland, M.** 2005. Characterisation of parapoxviruses isolated from Norwegian semi-domesticated reindeer (*Rangifer tarandus tarandus*). – *Virology Journal* 2: 79.

**Kummeneje, K.** 1973. Pasteurellosis in reindeer in northern Norway – a contribution to its epidemiology. – *Acta Veterinaria Scandinavica* 17: 488-494.

**Kummeneje, K. & Krogsrud, J.** 1979. Contagious ecthyma (orf) in reindeer (*Rangifer t. tarandus*). – *Veterinary Record* 105: 60-61.

**Kummeneje, K.** 1980. Diseases in reindeer in Northern Norway. – *In*: *Proceedings of the Second International Reindeer-Caribou Symposium*, Røros, Norway, pp. 456-458.

**Laaksonen, S., Kuusela, J., Nikander, S., Nylund, M., & Oksanen, A.** 2007. Outbreak of parasitic peritonitis in reindeer in Finland. – *Veterinary Record* 160: 835-841.

**Laaksonen, S., Solismaa, M., Kortet, R., Kuusela, J., & Oksanen, A.** 2009. Vectors and transmission dynamics for *Setaria tundra* (*Filaroidea*; *Onchocercidae*), a parasite of reindeer in Finland. – *Parasite Vector* 2:3 doi: 10.1186/1756-3305-2-3.

**Laaksonen, S., Pusenius, J., Kumpula, J., Venäläinen, A., Kortet, R., Oksanen, A., & Hoberg, E.** 2010. Climate change promotes the emergence of serious disease outbreaks for filaroid nematodes. – *EcoHealth* 7: 7-13.

**Lillehaug, A., Vikøren, T., Larsen, I. L., Åkerstedt, J., Tharaldsen, J., & Handeland, K.** 2003. Antibodies to ruminant alpha-herpesviruses and pestiviruses in Norwegian cervids. – *Journal of Wildlife Diseases* 39: 779-86.

**Linden, A., Gregoire, F., Nahayo, A., Hanrez, D., Mousset, B., Massart, A. L., De Leeuw, I., Vandemeulebroucke, E., Vandenbussche, F., & De Clercq, K.** 2010. Bluetongue virus in wild deer, Belgium, 2005-2008. – *Emerging Infectious Diseases* 16:833-836.

**Lundgren, J.** 1897. Rennthierpest in Lappland. – *Svensk veterinärtidning* (utdrag i Norsk veterinærtidsskrift 1898, h. 10)

**Magnusson, H.** 1927. Er renen mottagelig för mul och klövsjuka? – *Skandinavisk Veterinærtidsskrift I* 17: 49-62.

**Moen, J.** 2008. Climate change: effects on the ecological basis for reindeer husbandry in Sweden. – *Ambio* 37: 304-11.

**Morton, J. K., Evermann, J. F., & Dieterich, R. A.** 1990. Experimental infection of reindeer with bovine viral diarrhoea virus. – *Rangifer* 10: 75-77.

**Nellemann, C., Vistnes, I., Jordhøy, P., Strand, O., & Newton, A.** 2003. Progressive impact of piecemeal infrastructure development on wild reindeer. – *Biological Conservation* 113:307–317.

**Neuvonen, E., Veijalainen, P., Retulainen, S., & Ek-Kommonen, C.** 1983. Onko poroilla virustauteja? – *Poromies* 6: 16-17.

**Nielsen, S. A., Nielsen, B. O., & Chirico, J.** 2010. Monitoring of biting midges (Diptera: Ceratopogonidae: *Culicoides* Latreille) on farms in Sweden during the emergence of the 2008 epidemic of bluetongue. – *Parasitology Research* 106: 1197-1203

**Nordkvist, M.** 1973. Munvårtsjuka - en ny rensjukdom? – *Rennäringsnytt* 8-9: 6-8.

**Oksanen, A. & Norberg H.** 1994. Smittsom munnskurv. – *Reindriftsnytt* 3-4: 13-17.

**Purse, B. V., Brown, H. E., Harrup, L., Mertens, P. P. C., & Rogers, D. J.** 2008. Invasion of bluetongue and other orbivirus infections into Europe: the role of biological and climate processes. – *Revue scientifique et technique (International Office of Epizootics)* 27: 427-442.

**Rehbinder, C., Belak, K., & Nordkvist, M.** 1992. A serological, retrospective study in reindeer on five different viruses. – *Rangifer* 12: 191-195.

**Rehbinder, C., Christensson, D., & Glatthard, V.** 1975. Parasitic granulomas in reindeer. A histopathological, parasitological and bacteriological study. – *Nordisk Veterinærmedisin* 27: 499-507.

**Rosef, O., Paulauskas, A., & Radzijevskaja, J.** 2009. Prevalence of *Borrelia burgdorferi* sensu lato and *Anaplasma phagocytophilium* in questing *Ixodes ricinus* ticks in relation to the density of wild cervids. – *Acta Veterinaria Scandinavica* 51: 47.

**Ruiz-Fons, F., Reyes-Garcia, A. R., Alcaide, V., & Gortázar, C.** 2008. Spatial and temporal evolution of bluetongue virus in wild ruminants, Spain. – *Emerging Infectious Diseases* 14: 951-953.

**Skjenneberg, S. & Slagsvold, L.** 1968. *Reindriften og dens naturgrunnlag*. Universitetsforlaget, Oslo, Norway. 332pp.

**Skorping, A. & Halvorsen, O.** 1980. The susceptibility of terrestrial gastropods to experimental infection with *Elaphostrongylus rangiferi* Mitskevich (Nematoda: *Metastrongyloidea*). – *Zeitschrift für Parasitenkunde* 62: 7-14.

**Stuen, S., Krogsrud, J., Hyllseth B., & Tyler, N. J. C.** 1993. Serosurvey of three virus infections in reindeer in northern Norway and Svalbard. – *Rangifer* 13: 215-219.

**Stuen, S.** 1996. Experimental tick-borne fever infection in reindeer (*Rangifer tarandus tarandus*). – *Veterinary Record* 138: 595-596.

**Stuen, S.** 2007. *Anaplasma phagocytophilum* - the most widespread tick-borne infection in animals in Europe. – *Veterinary Research Communication* 31(Suppl. 1): 79-84.

**Syroechkovskii, E. E.** 1995. Diseases and parasites. – *In*: D. R. Klein (ed.). *Wild Reindeer*. Science Publishers, New Hampshire, USA, pp. 152-167.

**Thompson D., Muriel, P., Russell, D., Osborne, P., Bromley, A., Rowland, M., Creigh-Tyte, S., & Brown, C.** 2002. Economic costs of the foot and mouth disease outbreak in the United Kingdom in 2001. – *Revue scientifique et technique (International Office of Epizootics)* 21: 675-87.

**Tikkanen, M. K., McInnes, C. J., Mercer, A. A., Büttner, M., Tuimala, J., Hirvelä-Koski, V., Neuvonen, E., & Huovilainen, A.** 2004. Recent isolates of parapoxvirus of Finnish reindeer (*Rangifer tarandus tarandus*) are closely related to bovine pseudocowpox virus. – *Journal of General Virology* 85: 1413-8.

**Tryland, M., Josefsen, T. D., Oksanen, A., & Aschfalk A.** 2001. Contagious ecthyma in Norwegian semidomesticated reindeer (*Rangifer tarandus tarandus*). – *Veterinary Record* 149: 394-395.

**Tryland, M., Olsen, I., Vikøren, T., Handeland, K., Arnemo, J. M., Tharaldsen, J., Djønne, B., Josefsen, T. D., & Reitan, L. J.** 2004. Serologic survey for antibodies against *Mycobacterium avium* subsp. *paratuberculosis* in free-ranging cervids from Norway. – *Journal of Wildlife Diseases* 40: 32-41.

**Tryland, M., Mørk, T., Ryeng, K., & Sørensen, K.** 2005. Evidence of parapox-, alphaherpes- and pestivirus infections in carcasses of semi-domesticated reindeer (*Rangifer tarandus tarandus*) from Finnmark, Norway. – *Rangifer* 25: 75-83.

**Tryland, M., Das Neves, C. G., Sunde, M., & Mørk, T.** 2009. Cervid herpesvirus 2, the primary agent in an outbreak of infectious keratoconjunctivitis in semidomesticated reindeer. – *Journal of Clinical Microbiology* 47: 3707-13.

**Urquhart, G. M., Armour, J., Duncan, J. L., Dunn, A. M., & Jennings, F. W.** 1996. *Veterinary parasitology*. 2nd ed. Blackwell Science Ltd., Oxford.

**Vikøren, T., Li, H., Lillehaug, A., Jonassen, C. M., Bökkerman, I., & Handeland, K.** 2006. Malignant catharral fever in free-ranging cervids associated with OvHV-2 and CpHV-2 DNA. – *Journal of Wildlife Diseases* 42: 797-807.

**Vikøren, T., Lillehaug, A., Akerstedt, J., Bretten, T., Haugum, M., & Tryland, M.** 2008. A severe outbreak of contagious ecthyma (orf) in a free-ranging musk ox (*Ovibos moschatus*) population in Norway. – *Veterinary Microbiology* 127: 10-20.

**Wahlström, H., Frössling, J., Lewerin, S. S., Ljung, A., Cedersmyg, M., & Cameron, A.** 2010. Demonstrating freedom from Mycobacterium bovis infection in Swedish farmed deer using non-survey data sources. – *Preventive Veterinary Medicine* 94: 108-18.

**Wilson, A. J. & Mellor, P. S.** 2009. Bluetongue in Europe: past, present and future. – *Philosophical Transactions of the Royal Society B* 364: 2669-2681.

**Zarnke, R. L.** 1983. Serologic survey for selected microbial pathogens in Alaskan wildlife. – *Journal of Wildlife Diseases* 19: 324-329.

**Åsbakk, K., Gall, D., & Stuen, S.** 1999. A screening ELISA for brucellosis in reindeer. – *Zentralblatt Veterinärmedizin B* 46: 649-657.

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Vil vi møte nye helseutfordringer og sykdommer hos reinsdyr i Fennoscandia?

*Abstract in Norwegian / Sammendrag*: Et stort antall reinsdyr rapporteres tapt hvert år. Den viktigste tapsfaktoren er fredet rovvilt, men også nedslitte eller låste beiter kan noen år forårsake høy dødelighet. I tidligere tider var reindrifta plaget med alvorlige infeksjonssykdommer som drepte tusenvis av dyr og som hadde stor innvirkning på reindrifta i Fennoskandia. Den zoo-sanitære situasjonen i reindrifta i Fennoskandia må for tiden kunne sies å være gunstig, men sykdommer spiller fortsatt en stor rolle, både i forhold til sykdom og overlevelsesevne for individer og i flokksammenheng. Reindrifta står imidlertid overfor endringer og nye utfordringer som også vil ha innvirkning på helse og sykdommer hos dyrene. Introduksjon av infeksiøse agens som vi i dag ikke har i reinsdyrpopulasjonen kan foregå ved import av dyr eller dyreprodukter, eller gjennom kontakt med husdyr og ville dyr. Videre kan endringer i driftsrutinene, som økt grad av fôring, flokkstørrelse, dyretetthet og stress for dyra ha innvirkning på dyras evne til å takle sykdommer og infeksjoner. Også endringer i klima, som økte nedbørsmengder og økt gjennomsnittstemperatur, kan over tid føre til begrenset tilgang på beiteressurser, endringer i vegetasjon og endrede forhold for parasitter og insektsvektorer. Slike endringer kan være spesielt viktige i forhold til reproduktiv suksess, også med tanke på overlevelse av kalver første leveår. For å være i stand til å møte disse utfordringene og deres innvirkning på helsetilstanden hos reinsdyr, bør det gjennomføres systematiske undersøkelser og epidemiologiske risikoanalyser for å etablere kunnskap om helse og sykdomsparametere i ulike reinbeitedistrikter. Dette vil øke mulighetene for reindrifta til å tilpasse seg endringene og å fortsatt være i stand til å produsere etterspurte kvalitetsprodukter på en lønnsom måte.