

Critical seasonal conditions in the reindeer-herding year: A synopsis of factors and events in Fennoscandia and northwestern Russia



Roza Laptander^{a,*}, Tim Horstkotte^b, Joachim Otto Habeck^a, Sirpa Rasmus^c, Teresa Komu^c, Heidrun Matthes^d, Hans Tømmervik^e, Kirill Istomin^a, Jussi T. Eronen^f, Bruce C. Forbes^c

^a Universität Hamburg, Institut für Ethnologie, Hamburg, Germany

^b Umeå University, Department of Ecology and Environmental Science, Umeå, Sweden

^c Arctic Centre, University of Lapland, Rovaniemi, Finland

^d Alfred Wegener Institut Helmholtz-Zentrum für Polar- und Meeresforschung, Potsdam, Germany

^e Norwegian Institute for Nature Research, Tromsø, Norway

^f University of Helsinki, Department of Geosciences and Geography, Helsinki, Finland

ARTICLE INFO

Keywords:

Climate change adaptation
Indigenous peoples and local communities
Reindeer
Seasonality and harmful climatic conditions

ABSTRACT

In this article, we identify what herders in Fennoscandia and northwestern Russia see as critical conditions and events in the annual reindeer herding cycle. Indigenous Sámi and Yamal reindeer herders identify eight seasons, each of which has crucial importance in its own way. Differences in perception between Fennoscandian and northwestern Russian reindeer herders about good and bad seasonal conditions are based on the degree of climatic and geographic variation, herd control and the variety of simultaneous pressures on pastures. The scope and speed of ongoing climate change in the Arctic will profoundly modify these conditions, and consequently shape critical events and outcomes in reindeer herding. The resulting challenges need to be assessed in the context of social and economic dynamics. Reindeer herders throughout Fennoscandia and Russia are concerned about future prospects of their livelihood. To adapt to climate change and develop new strategies, reindeer herders must have access to pastures; they must retain their mobility and flexibility; and their participation in land-use decisions must be endorsed.

1. Introduction

Reindeer husbandry [*boazodoallu* (Northern Sami [NS])/*båatsoe* (Southern Sami [SS])/*porotalous* (Finnish [FIN])/*kör vidzöm* (Komi [K])/*ty* *perma* (Tundra Nenets [TN])] is a highly important part of northern Indigenous and local communities' economies, cultures, and ways of life. Reindeer husbandry can be generally described as a form of pastoralism and a sustained human-animal relationship between a herder and their herd (Beach, 1981; Turi, 2002; Jernsletten and Klokov, 2002; Vitebsky and Alekseyev, 2015; Stépanoff, 2017). Across the Arctic, there are different traditions of living and working with semi-domestic reindeer (e.g., Krupnik, 2002; Baskin, 2000; Holand et al., 2022).

We understand the term 'reindeer husbandry' to encompass the whole reindeer herding livelihood and associated culture of local and indigenous Arctic peoples. Contemporary reindeer husbandry is based on traditional skills that have evolved over many centuries and passed down from one generation of reindeer herders to the next, mostly by practical work with the animals. We will use the term "reindeer herding" to refer to the practical aspects of herding and working with reindeer (Paine, 1964; Ingold, 1980; Krupnik, 2000).¹

Reindeer ecology and reindeer herding are very much dependent on the interaction between environmental conditions such as climate, the bio-physical landscape and its biodiversity. All types of reindeer husbandry are strongly dependent on reindeer herders' environmental knowledge. In practicing their livelihood, herders have always had to

* Corresponding author. Universität Hamburg, Institut für Ethnologie, Edmund-Siemers-Allee 1, West 20146, Hamburg, Germany.

E-mail addresses: roza.laptander@uni-hamburg.de (R. Laptander), tim.horstkotte@umu.se (T. Horstkotte), otto.habeck@uni-hamburg.de (J.O. Habeck), sirpa.rasmus@ulapland.fi (S. Rasmus), teresa.komu@ulapland.fi (T. Komu), heidrun.matthes@awi.de (H. Matthes), Hans.Tommervik@nina.no (H. Tømmervik), kirill.istomin@uni-hamburg.de (K. Istomin), jussi.t.eronen@helsinki.fi (J.T. Eronen), bforbes@ulapland.fi (B.C. Forbes).

¹ In this article reindeer herders are defined as individuals or groups owning and tending semi-domesticated reindeer, earning part or most of their income from selling reindeer meat and other reindeer products.

deal with the natural variability and stochasticity of weather and climate phenomena. This entails the skills of observing, interpreting and foreseeing weather events – events that have been variable and yet known to reindeer herders in their very variability (Kitti et al., 2006; Nakashima et al., 2018; Forbes et al., 2014, 2019, 2022; ; Rasmus et al., 2022, Rasmus et al., (in publication)).

However, climate in the Arctic is warming much faster than the global average, causing unprecedented difficulties in northern livelihoods (Fauchald et al., 2017; Myers-Smith et al., 2015; Ksenofontov et al., 2019:37; Rantanen et al., 2022). Here, we explore how reindeer herders' knowledge with regard to variability in weather conditions has shaped their different herding strategies in the Eurasian Arctic, and how their adaptive capacity is challenged by the increasing variability of these conditions.

Our aims are as follows.

- i) to give a description of the most significant (i.e., critical) weather events during the reindeer herding year, following the local seasonal calendars. Compared to the more familiar partition into four seasons, the reindeer-herding year in Fennoscandia and northwestern Russia is split into eight seasons which vary slightly within our focus areas in northwestern Eurasia. We will analyse seasonal critical conditions which affect reindeer herding within each season.
- ii) to discuss the differences in perceived critical conditions between Fennoscandia and northwestern Russia arising from geographical and climatic differences between regions, as well as differences in reindeer herding strategies.
- iii) to identify challenges for reindeer herders' adaptive capacity to respond to the effects of changing weather and climate conditions.

2. Study area, methods, materials and analytical framework

Our focus area consists of the reindeer-herding regions in Fennoscandia and northwestern Russia from Norway to Gydan Peninsula (Fig. 1) with mainly but not exclusively Sámi, Finnish, Nenets, Komi, and Khanty reindeer herders. Data about critical weather conditions are based on reindeer herders' traditional knowledge and seasonal practices collected by the authors and describe what kind of critical conditions, including weather phenomena and other seasonal environmental conditions in interaction with the biophysical environment create critical

events.

2.1. General characteristics of reindeer herding in Fennoscandia and northwestern Russia

The success of the reindeer herding work depends very much on access to grazing areas with different qualities of forage for reindeer during different seasons (Jernsletten and Klokov, 2002). However, there are considerable climatic, geographical, cultural, historical, political and economic differences within the region under study. Thus, different subregions feature different strategies for herding reindeer; hence the purpose of this study, for transregional comparisons have been rare thus far. Although these strategies may vary greatly between different herding communities even within one country, climatic differences justify to distinguish between a Fennoscandian zone and northwestern Russia.

In Fennoscandia, the climate is generally warmer and more humid than in Siberia due to the impact of the Gulf stream. For instance, spring comes almost one month earlier in northern Fennoscandia than in northwestern Siberia, where the climate is colder and drier, resulting in a longer snow season (Hanssen-Bauer et al., 2022).

In Fennoscandia, Sámi and Finnish reindeer herding has gone through mechanization starting approximately in the 1960s, which has resulted in herders today utilizing snowmobiles, helicopters, ATVs, GPS collars and (recently) drones along with traditional herding dogs to control the herds. Mechanization has made it possible to travel longer distances within a day and to control bigger herds with a smaller number of people (Paine, 1994). As a result, for instance, the use of winter pastures in Finnmark, northern Norway, has been extended further south towards the Finnish border since the 1960s (Lyftingsmo, 1965). Each herding community is assigned a maximum number of reindeer, determining the size of each herd after the autumn-winter slaughters and before calving in spring (Paine, 1994; Riseth, 2009; Riseth and Vatn, 2009; Rosqvist et al., 2022).

Reindeer herding in Fennoscandia is greatly affected by competing forms of land use, such as forestry, and also by predation. Nevertheless, it is based on seasonal migrations between different pastures, although in Finland, this pasture rotation may happen at a much smaller scale than in Norway and Sweden (Fig. 1). The intensity of control over the herd fluctuates within and between seasons from intensive herding to letting the reindeer graze freely without human intervention. Moreover, in Finland reindeer get supplementary feeding (Turunen and

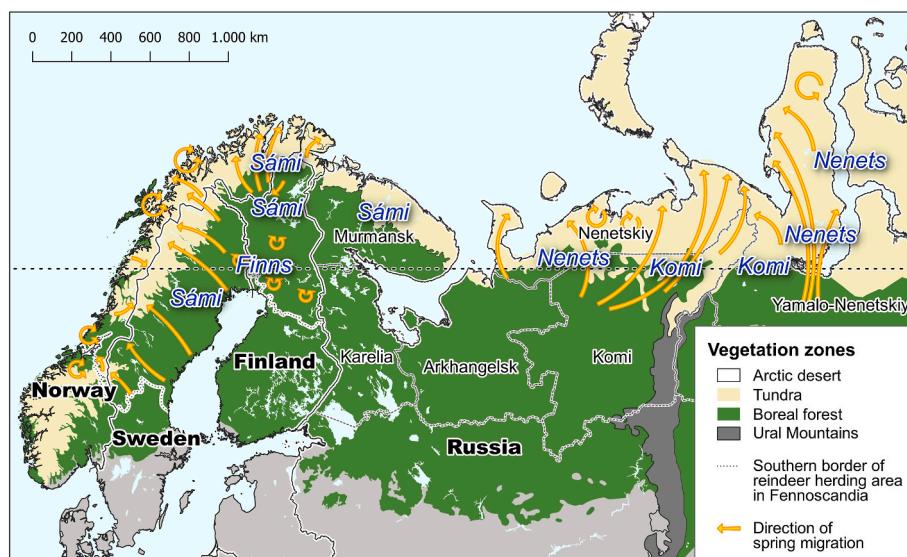


Fig. 1. Approximate outer boundaries of reindeer-herding areas in Fennoscandia and northwestern Russia (including the northeast of European Russia and northwestern Siberia).

Vuojala-Maggia, 2014; Åhman et al., 2022).

Northwestern Russia currently constitutes the largest reindeer herding region in the world as far as the total numbers of reindeer and herders are concerned. About one-third of the global population of semi-domesticated reindeer and about half of all active reindeer herders live in the eastern half of this region, in Gydan and Yamal peninsulas (Istomin, 2020). These territories make up the core area of Nenets reindeer herding. Besides Nenets, reindeer herding in the region outside the core area is practiced by Komi and Khanty. Historically, the latter groups learned reindeer herding practices from Nenets, which explains common traits throughout the region: their reindeer herding is nomadic and intensive in the sense that herds are kept under close observation and control; long periods of free grazing so common in Fennoscandia do not exist there.

In northwestern Russia, reindeer herding is based on the annual long-distance migrations in the tundra with transport reindeer, while keeping the rest of the herd under intensive control. This has been described as *Samoyedic* or Komi-Nenets type of reindeer herding (Klokov and Antonov, 2022; Yuzhakov et al., 2023). Therefore, herds include more male reindeer than in Fennoscandian, and the age composition differs. Roughly 10 per cent of males are castrated and are used as transport reindeer for migrations in the tundra. A large number of reindeer is under intensive everyday control of herders: they move herds from one pasture to another almost every day in summer and once per week or two in winter. Reindeer come or are moved to the camp where their owners live. However, they do not get any supplementary feeding. Reindeer herders control the herd mostly by using snowmobiles.

All reindeer herding groups use similar herding equipment, herding dogs, types of reindeer sledges, nomadic tents, fur clothes, etc. Komi reindeer herders are particularly concerned about 24-h herd control throughout most seasons, whereas Nenets herders conduct permanent herd control mostly during calving and the main mosquito periods. In late autumn and winter, the animals are not constantly observed by both Komi and Nenets. However, the herders check them up regularly, ideally every day.

2.2. Methods, materials and data

This study has evolved as a transdisciplinary exchange between researchers from different sub-fields of biology, geography, social/cultural anthropology, and climate modelling. It is empirically based mainly on reindeer herders' accounts of critical weather conditions during the reindeer-herding year. We combine anthropological fieldwork data (qualitative interviews, participant observation, fieldnotes) with findings presented in publications of the above-mentioned disciplines. The notion of comparison deserves a short excursion into the history of Cultural Anthropology. After publication of the famous essay of Franz Boas (2006 [1896]), the method of comparative research in anthropology was met with particular caution and doubts. However, in our opinion, such comparative studies are important – precisely for the reason that Boas considered them dangerous: the almost unconscious tendency of researchers to overgeneralize certain phenomena taken out of their context. Boas criticized this tendency, as well as the comparative studies that he believed were based on it, but ignored the fact that comparative studies are the only way to demonstrate that the phenomena we take for granted lack coherence and represent overgeneralizations. Thus, it took several decades of comparative research to demonstrate that pastoralism is not a holistic phenomenon but consists of a set of qualitatively different systems of logic and practice (Dyson-Hudson and Dyson-Hudson, 1980). More modern research shows that the same can be said for what we once thought of as components of pastoralism, such as reindeer herding. This means that a standard idiographic study of the Boasian style might tell something about specific cases of reindeer herding, but since we are interested in saying something about reindeer herding in general – for example, about its possible response to global change – we have no choice but to examine

many cases on a comparative basis.

Thus, from the beginning of the article to the conclusions, we will try to find answers to environmental-change related questions based on cultural comparison, assessment of sustainability, and resilience of reindeer herding, using the example of reindeer herders from Fennoscandia and northwest Russia. In the light of the fact that, more often than not, scientific literature on reindeer herding is country-specific, we think that a cross-regional comparison is of particular salience.

Data about critical weather conditions based on Sámi reindeer herders' traditional knowledge and seasonal practices by in Norway and Sweden were provided by Hans Tømmervik and Tim Horstkotte based on their qualitative research (i.e., Riseth et al., 2011, 2020; Hovelsrud et al., 2021; Horstkotte et al., 2014; Horstkotte et al., 2017) and own experience in herding work (Tømmervik et al., 2012; Tømmervik and Forbes, 2020). Data on reindeer herding in Finland and Sweden were provided by Teresa Komu and Sirpa Rasmus. Data by Teresa Komu are based on 11 in-depth, semi-structured interviews with Sámi and Finnish reindeer herders in the spring of 2012 from four reindeer herding communities at the Swedish-Finnish border area: Muonio and Käsivarsi reindeer herding cooperatives (*paliskunta*) in Finland and Muonio and Körkämä herding communities (*sameby*) in Sweden. The material was collected originally for the project CLICHE (Impacts of Climate Change on Arctic Environment, Ecosystem Services and Society). The interviews addressed, among other topics, herders' perceptions of good and bad weather conditions for reindeer herding along the seasonal cycle of the reindeer year. Data by Sirpa Rasmus are based on interviews with and questionnaire surveys to herders within the reindeer management area in Finland about changing snow and seasonal weather conditions (from 2012 to 2017, see Turunen et al., 2016; Rasmus et al., 2020). Data on reindeer herding in the northern part of European Russia (Komi Republic and Nenets Autonomous Okrug) are based on numerous interviews and participant-observation notes collected by Kirill Istomin (from 2000 to date) and J. Otto Habeck (from 1998 to 2005) (Habeck, 2005, 2006; Istomin and Dwyer, 2010; Istomin and Habeck, 2016). Data about reindeer herding in the Yamal-Nenets Autonomous Okrug is based on interviews with Nenets reindeer herders collected by Roza Laptander (from 2006 to date) in the tundra areas of the Yamal Peninsula and the Northern Urals (Laptander and Stammer, 2017; Laptander, 2018, 2020; Serreze et al., 2021).²

2.3. Analytical framework

In this manuscript, we analyse what kind of critical conditions, including weather phenomena and other seasonal environmental conditions in interaction with the biophysical environment create critical events from the perspective of reindeer herders in Fennoscandia and northwest Russia. These events affect the herd and the herding work and thereby influence the outcome – that is, herd well-being, reproductive, and the quality of life and ultimately the livelihood of reindeer herders and their households (Fig. 2). By “condition” we refer to the value or degree of a measurable (often abiotic) variable, most often related to temperature, precipitation, snow conditions on the ground or wind speed that will interact with the biotic environment (i.e., mosquitoes, vegetation, the reindeer themselves) as well as the landscape elements (i.e., rivers, mires, mountains, forest). Informed by the accounts given by herders themselves, we understand “critical” as a quality that describes the importance and impact of outcomes within and across each season for: (i) the animals to survive and be able to produce new offspring; and

² In this work, “Komi” refers to Izhma Komi nomadic reindeer herders migrating in the eastern part of Bol’shezemel’skaya tundra, that is in the sites in where Kirill Istomin and J. Otto Habeck carried out fieldwork. Similarly, the term “Nenets” refers to Nenets reindeer herding nomads living in the tundra areas of the Yamal Peninsula where Roza Laptander and Kirill Istomin carried out fieldwork.

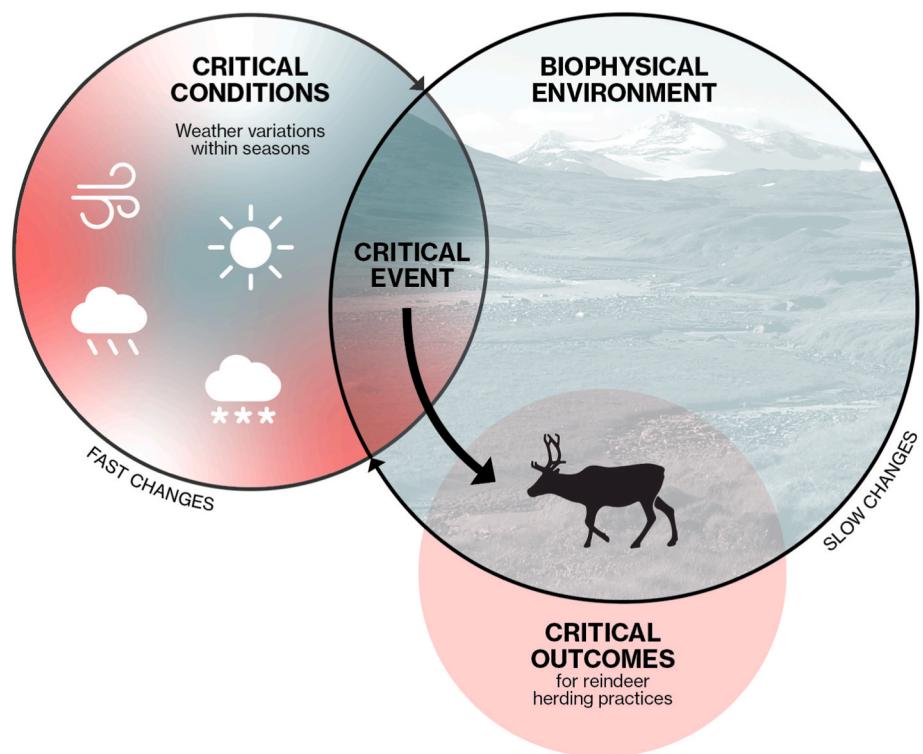


Fig. 2. Conceptual interrelation of 'condition', 'event', 'outcome', and biophysical environment as applied to reindeer-herding practice.

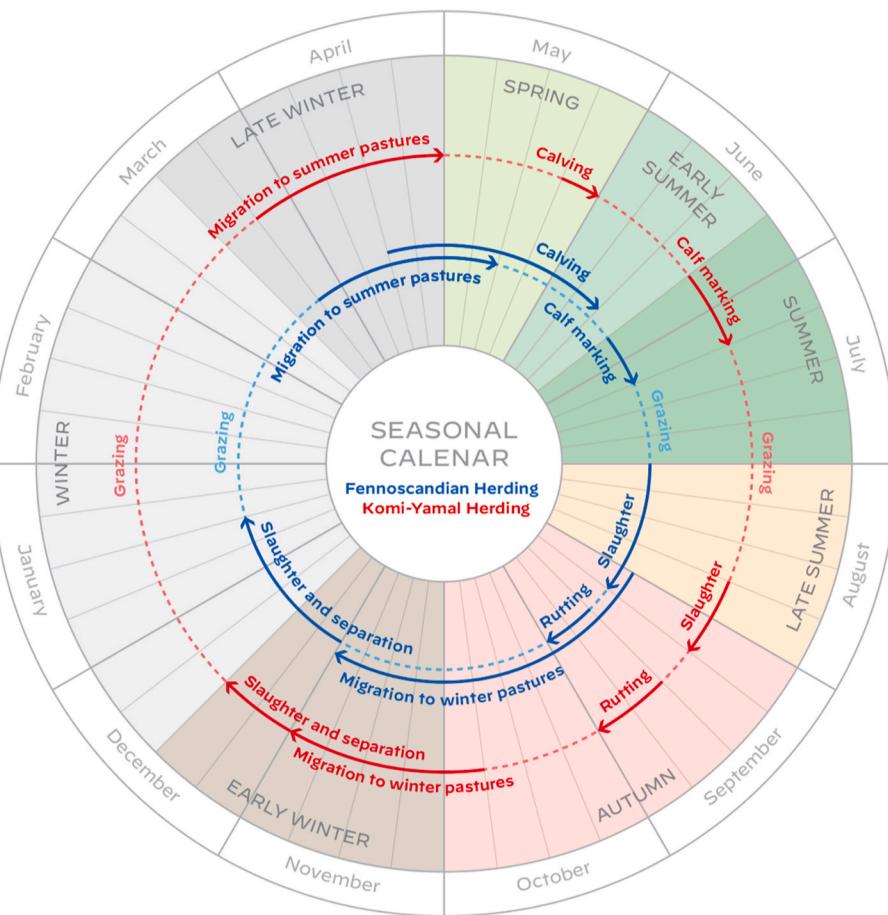


Fig. 3. Division of the reindeer herding year and major strategic moments in Fennoscandia and Russia, with the example of the Yamal Nenets and Sámi seasonal calendars.

(ii) for the herders to successfully carry out their work throughout the entire year, i.e., for the herding year to be successful. Importantly, the word “critical” does not categorize these conditions as good or bad *per se*, but instead as “significant” for both animals and humans.

The interaction between a critical weather condition and the biophysical environment creates an *event*: for instance, the event of rivers freezing or remaining open at a particular point in time that is strategically important for herding operations, such as migration. Temperatures below zero are the *critical condition*: technically speaking, they turn water to ice; thus, they modify physical and biological processes in the landscape; they ultimately turn the surface of the river into a solid state (*critical event*), which, if stable enough, as an *outcome* enables herders and herds to cross the river and thus enhances their mobility.³

Our starting point was observing the commonalities in reindeer herders’ notions of eight seasons or seasonality, along with the qualities attached to them (Manker, 1972). The idea of ‘critical’ came up in what reindeer herders reported themselves. On this basis, we sought to identify critical seasonal conditions. When going through and revisiting the empirical material and published literature, we searched for statements about seasonality, specific seasons, herding operations during the course of the year, weather, along with descriptions of ‘good’ and ‘bad’ years and seasonal phenomena. This qualitative data analysis comprised selective screening and categorising of the material at hand, juxtaposing evidence from different regions of Fennoscandia and northwestern Russia, always focusing on seasonality.

However, in this paper we are not going to give any comprehensive explanation what is known about weather and climate “from the scientific perspective” but rather from the perspective of reindeer herders.

3. The reindeer herding year in Fennoscandia and northwestern Russia

The traditional reindeer herding year in Fennoscandia and northwestern Russia depends largely on the annual cycle of reindeer ecology. The segmentation of the year into sub-seasons reflects the most critical periods in the annual cycle of reindeer ecology and work with reindeer, both in Fennoscandia and northwestern Russia (see Fig. 3).

3.1. Late winter – early spring

The reindeer herding year starts with migrations of reindeer, with or without herders, towards calving grounds and further on to spring and summer pastures. The direction and extent of this migration varies considerably between the different areas in Fennoscandia (Fig. 1). In northwestern Russia, this migration generally occurs from the south towards the north. The sooner spring arrives, the better. In Finland, herders report that snow should start to melt at the end of April or beginning of May, but no later than May 24th, depending on the region. Early formation of snow-free patches offers first available green forage, often on mires or exposed ridges. April is named *Cuojománnu* in Northern Sámi [NS], which means the month with hard crust on the top of the snow. Migration becomes easier when the snow cover surface gets sufficiently hard to bear the weight of reindeer. This type of snow (*hankikeli* in Finnish [FIN]) occurs in April or beginning of May, caused by snow melt during the day and refreezing in the night or from longer melting and freezing periods. However, it requires herders to guard reindeer to keep them gathered. If the snow is too deep and soft for reindeer to walk upon, migration will deplete the energy reserves of pregnant females. On the other hand, a hard snow crust too early and without snow-free patches can be disastrous, causing the reindeer to start wandering long distances looking for food. Even though an early

³ Admittedly, the biophysical environment, including geomorphological features, is constantly undergoing change, but not at the same rate as seasonal and weather conditions.

onset of spring is considered favorable, early snowmelt and unsafe ice cover on lakes and rivers can slow down the migration and make it difficult to guard reindeer against predators. Warm springs with rapid snowmelt also increase the risk for avalanches and floods, increasing the risk of accidents for people and animals.

Herders in Fennoscandia report that an early snowmelt in late winter can necessitate migrating to spring pastures earlier, as reindeer are more difficult to keep gathered when snow is disappearing (Ran Herding Community, 2018). However, as spring pastures often are located at higher elevations, these areas do not show the same trend of early spring onset; snowmelt may even be delayed due to increased winter precipitation (Beniston et al., 2018). This may require herders to provide their reindeer with supplementary feeding for a prolonged period.

In Russia, calving grounds are usually situated at a considerable distance from the winter pasturelands; spring migrations start earlier than in Fennoscandia, typically at the end of March during time of spring with dry snow *nara* in Tundra Nenets [TN]. The need to cross large rivers and other water expanses (e.g., the Ob’ Bay south of Yamal Peninsula), which is generally possible only while they are covered by thick ice, represents one of the main factors influencing the speed of migrations during time of the wet snow *ngay*.

3.2. Late spring/early summer

As the growing season starts and the nights become brighter, reindeer move to summer pastures in forests, bogs, fells, coastal areas and lake and river banks. Snow free patches (*bievla* [NS], *bievle* [SS], *pälv* [FIN]) are important for early calf survival, because they provide access to vegetation and offer dry places where females can give birth. Calves are born from approximately early May to mid-June, with slight regional differences. For example, herders in Finland describe May 18th as *valtakantama*, meaning that calves are typically born on both sides of the date.

Snowmelt only in late May and a hard layer on top of the snow cover without patches of snow-free ground are considered a worst-case scenario for calving. This would prevent lactating reindeer from accessing vegetation, they would start moving long distances and newborn calves would be in danger of freezing to death. Calves are most vulnerable to weather conditions for three days after their birth. In this time, temperatures should stay above 0 °C. Icing events causing hard snow, heavy snowfalls resulting in soft and wet snow cover, or two to three days of continuous rain during calving threatens the survival of calves.

During calving, it is very important that reindeer can be in peace without disturbances from other land users or predation. In Finland, some herders use corrals for calving, which ensures that the calves get enough forage, and they can be earmarked easily in the corral, removing the need for organizing calf marking during summer. Calving in corrals is, however, very expensive, as it increases the period of supplementary feeding, and it does not protect the calves from mesopredators, such as foxes. Also, there are health risks related to enclosure calving (disease and parasite epidemics, Tryland et al., 2022).

In northwestern Russia, during the main calving period in May, male and female reindeer are always separated. Both parts of the herd need to be observed permanently, because males and females who have not yet given birth have to be slowed down so that the slowly moving females with calves can keep pace. On the other hand, females in the process of giving birth and those who just calved should not be disturbed by the herders to prevent them from abandoning newborn calves. Mild weather is optimal for calving. However, in April and May, blizzards, strong winds, and frosts create the biggest problems for reindeer and herders. Among these is *suyu khad* [TN] – a blizzard during calving, during which many newborn calves die, causing serious damage to the herd. The early appearance of the snow-free patches *waryo* [TN] (Fig. 4) is generally considered a good thing, the early break-up of rivers is not. Early calving, like late calving, causes additional difficulties in the herders’ work. Early-born calves often do not survive blizzards and returning



Fig. 4. Snow free patches 'waryo' in the Yamal tundra. Photo Roza Laptander.

colds. Late-born calves do not have sufficient time to get strong enough for winter.

3.3. Early summer

In Fennoscandia, early summer is generally a calm period for both reindeer and herders. For reindeer, it is the critical period to build up body resources for the coming winter. During summer, reindeer feed mainly on different grasses and leaves of shrubs. Summer is also characterized by polar day, warm temperatures, and periods of insect harassment. Calves are marked between mid-June and mid-July. Besides calf marking, reindeer are largely left to graze in peace and the herders wait in anticipation of how many calves will survive the summer till autumn.

Unlike in Fennoscandia, summer in Nenets and Komi reindeer herding is anything but a calm period. Particularly in early summer, the newborn calves create challenges for maintaining herd control and migration. Despite reindeer calves being remarkable runners and rather good swimmers, their stamina does not match that of adult reindeer, and their mothers have to make frequent stops to feed them with their milk. Therefore, the movement of the herd after calving is rather slow and the male part of the herd still has to be kept from running away, which is

particularly difficult in hot weather. While herders prefer to cross large rivers on ice before calving, in recent years it has become more frequent that reindeer need to cross them swimming: calves can drown or get ill after swimming in the cold water (Stammler, 2008; Volkovitsky and Terekhina, 2022).

3.4. Summer

Optimal for reindeer is a summer without any weather extremes. Both cold summers with continuous rain and warm summers with long periods of heat exceeding 25 °C are considered harmful, as well as dry conditions, especially for calves. Hot and dry conditions reduce growth of grasses and herbs, hence they lead to reduced production of milk for the calves, and may lead to deteriorated body condition of calves and adults, which makes winter survival harder. The hot summer of 2018 led to an increase in the loss of calves or a decrease in body weight in some herding groups (*siida*) in South Sápmi (Landbruksdirektoratet, 2019). Sufficient rain and moisture are therefore required for vegetation growth. While an intense period of insects *räkkä* [FIN] during June–July is normal, too many insects can be deadly for young calves or weaken them greatly because of their direct impacts, and also because of herd restlessness, causing small calves to not get enough food.

Hot summers are linked to outbreaks of certain infectious diseases and parasite epidemics, especially if reindeer are kept together closely (Drake, 1918; Skum and Pellijeff, 1955; Riseth et al., 2020; Rantanen et al., 2022). Hot summers may also spark forest fires such as in South Sápmi (Sweden and Norway) in 2018, destroying tundra and pine forest used as winter pastures (Backström, 2021).

Dry weather, with conditions not too dusty, are optimal for calf marking, carried out during the bright and cooler nights. There should be "enough" mosquitoes, so that reindeer gather by themselves into herds, making calf marking easier. During heatwaves, herd handling involves extra stress for the animals and may cause them to die from heat strokes, so it should be avoided. According to herders, calf marking is quite easy to postpone, even as late as till autumn round-ups.

In northwest Russia, the hottest period is called in Nenets *yepdyä*; it usually comprises one or two weeks in July. Komi and Nenets reindeer herders believe that this is a difficult time for reindeer as well as for themselves. During very hot days, stressed and tired animals do not feed well, which diminishes their ability to build up body weight for the winter. The catastrophic icing winter 2013–2014 (when herders in



Fig. 5. Ice- or frost covered (hoar) in the trees 'ritni/bichi' [NS] or 'rijnie' [SS]. Photo: Hans Tømmervik.

Yamal lost c. 60,000 reindeer) was preceded by a hot summer, during which reindeer did not gain much weight. This resembles the situation in Finland in 2019–2020: losses were most probably caused not by just one critical event, but by cumulative impacts during the herding year.

Particularly with the arrival of mosquitoes, the reindeer tend to gather and circle or they rush against the direction of the wind, exhausting themselves in their attempts to get at least a temporary relief from mosquitoes. Reindeer herders reported that during this time, reindeer cannot rest and ruminate properly (while full rumens prevent them from further grazing), they can injure each other, get wounded hooves easily infected and can even die from necrobacteriosis (also see [Riseth et al., 2020](#)). Herd control becomes increasingly difficult. In order to avoid that their reindeer run away and mix with other herds, Nenets reindeer herders permanently observe their herds during the most difficult mosquito weeks (field materials RL). On hot days, packed reindeer can easily get dehydrated and die, something Komi duty herders try to avoid by making their reindeer move around lakes or through shallow swamps *saduku* [K]. This, however, further breaks up the grazing-rumination cycle of the animals. When the tundra ground becomes very dry, there is less food for reindeer. Drying lakes resulting from the same dry periods may however also provide new grazing areas for reindeer. The Nenets name for a new pasture on dried lakes is *khasyro*. In summer, reindeer are very attracted to these places and can feed there for hours. The vegetation succession in these new pasture areas may pose significant dangers to reindeer: when a lake disappears, the place where it was becomes a locus of a very active and abundant vegetation growth for several years. The vegetation is not only abundant and rich, but also very diverse, including plants which rarely grow together in “normal” tundra. Some of the new plant species involve health risks for reindeer: reindeer can get sick after feeding there, they get diarrhea, lose weight and cannot eat for several days. It happens, though rarely, that reindeer even die after feeding there.

Staying near coastal areas where the temperature is lower and mosquitoes are blown away by the sea breeze, is believed to be the best way to spend the mosquito season. Most reindeer herders let their animals have one- or two-weeks rest near the sea; some Nenets herders can stay there even longer.

3.5. Late summer/early autumn

In late summer and early autumn, light decreases and the growing season comes to an end. Reindeer feed on green forage, but gradually change to lichens. Fennoscandian reindeer herders consider mushrooms (e.g. *Boletus* spec., *Amanita* spec., *Suillus* spec., *Leccinum* spec.; [Nieminen and Heiskari, 1989](#); [Inga, 2007](#)) important for reindeer well-being since they help to build up body reserves (fat and vitamins) before the rutting season and winter. Switching to mushrooms is also important to prepare the digestive system to a lichen-dominated diet during winter ([Skjenneberg and Slagsvold, 1979](#); [Inga, 2007](#)). Reindeer are usually not intensively herded during this period, as they spread in search for mushrooms before male reindeer gather the herds for the rutting period ([Skjenneberg and Slagsvold, 1979](#); H. Tømmervik pers. obs.). Sufficient rain for mushroom growth is critical, and if autumn is dry, reindeer will be in worse condition when the winter arrives. Decomposing mushrooms may be eaten until early winter ([Skjenneberg and Slagsvold, 1979](#); [Inga, 2007](#)). During late August and early September, before the rut, reindeer bulls are gathered for slaughter in some areas.

In northwestern Russia, however, the arrival of the mushroom time is viewed as problematic, because reindeer seek mushrooms, which causes increased herd dispersion ([Andreyev, 1977](#)). Both Komi and Yamal Nenets reindeer herders, for whom maintaining control over the herd is essential, indicated the mushroom period as difficult and labour-intensive. Additionally, insect harassment continues well into August (e.g., bot flies place their eggs into the nostrils of the reindeer). Hence why parasite medication is conducted mainly in late summer, both in Fennoscandia and Russia.

3.6. Autumn

Autumn is characterized by first frosts and first snow. Rutting time lasts approximately from late September to mid-October. The rutting period is considered less vulnerable to weather conditions than other periods: herders consider rutting as a predictable event, that happens regardless of weather conditions. Herders did not remember any particularly bad rutting periods. However, Fennoscandian herders have noted that warm autumns can cause late or asynchronous rutting ([Rasmus et al., 2020](#)). During the rut, the bulls will typically gather themselves a small group of females; this alleviates the pending autumn round-ups by herders. Rain and “messy” weather in general, such as slush, are good conditions for rut and important to prevent dehydration of bulls. One herder in Finland said “if there is fog, things are sure to happen”. Early snowfall and freezing temperatures just after the end of rutting are considered harmful.

In Fennoscandian reindeer herding, gathering, round-ups and slaughtering takes place during several weeks from October to November. Ideally, the work should be completed by December 24th at the latest, for the Christmas market, although timing varies, depending on weather conditions. In some regions, it is normal that round-ups last until January, even February. Even though round-ups do not affect the well-being or survival of reindeer, timely round-ups and good-sized calves are important for the success of herding work. The later the round-ups happen, the less money herders will get for their years’ work.

A late rut, absence of snow, or icing of pastures can cause herds to disperse, which makes gathering difficult, and delays round-ups ([Turunen et al., 2016](#); [Rasmus et al., 2020](#)). Without snow, the reindeer “is the master”, according to herders. Depending on the terrain, the herders may use either all-terrain vehicles or snow mobiles for gathering and moving reindeer to round-up sites. In the latter case, the round-ups cannot begin until there is enough snow. Best conditions for round-up time are sufficient snow in November, dry weather, and temperatures well below freezing, between -10°C and -20°C . Lack of snow, late formation of ice covers in rivers and lakes, as well as foggy and rainy conditions delay the work.

In Komi and Nenets reindeer herding, round-ups in the sense of Fennoscandian reindeer herding do not exist; the period after the rut is considered as one of the calmest in the year. Still, the period has its own difficulties. On the one hand, the nights are already long, which makes the 24-h observation of the herd impossible. On the other hand, reindeer are still active, they move around fast in search for the already scarce high-quality forage. Therefore, September and early October constitute a period when herds of different owners mix, which can lead to conflicts between herders. Once the first snow cover forms on the dry ground, however, the speed of spontaneous reindeer movement falls considerably: the herd suddenly becomes calm and easy to control. Therefore, Komi and Nenets reindeer herders consider the early arrival of snow to be positive and important. However, temperatures should fall steadily: wet weather makes it difficult to regularly check and gather the herds and, more importantly, creates the risk of ice forming under the snow. In September, October and November, Komi and Nenets reindeer herders mostly continue to migrate towards their winter pastures in the south and, for the second time during the reindeer year, face the problem of large river crossings. In recent years, reindeer herders reported the late freezing of big rivers. Even in November, the ice is not thick enough to be sufficiently load bearing. Late freezing of lakes and river crossings might delay the migration to the winter pastures to December, even January. Therefore, reindeer herders have made some adjustments in the way of their winter herding, moving reindeer to winter pastures two or three weeks later than they did in previous decades.

3.7. Late autumn/early winter

In the period of the late autumn and early winter, Fennoscandian reindeer are usually gathered for separation into smaller winter groups

(to be moved to their respective winter grazing land). When the polar night starts, active herding and, in some areas particularly in Finland, the period of supplementary feeding starts. In northwestern Russia, the significance of the polar night can be seen in the names of November (in Nenets *Nyudyā pewdey iry* ‘the month of little darkness’) and December (in Nenets *Ngarka pewdey iry* ‘the month of the great darkness’).

Weather conditions during late autumn and early winter determine foraging conditions (digging for terricolous lichen) for the remainder of the winter. Ideally, snow falls on dry, frozen ground at the latest at the end of November and does not melt away before spring. Temperatures should remain below 0 °C. Most reindeer herders in Sweden and Norway want to have a cold autumn with a shallow and dry snow cover also mentioned in [Skum and Pellieff \(1955\)](#), [Manker \(1972\)](#), and [Riseth et al. \(2011\)](#). This facilitates herding because using snowmobiles is possible.

Fennoscandian (but not Russian) reindeer herders believe that a long autumn itself is good for the well-being of reindeer. However, prolonged rainy periods between October–November and temperatures fluctuating around 0 °C increase the risks for rain-on-snow or ice formation on the ground (*bodnevhki* [NS], *suevie* [SS]), encapsulating terricolous lichens ([Riseth et al., 2011](#)). If permanent snow cover forms early on unfrozen and wet ground, in addition to ice-locked pastures, mycotoxin-producing microfungi (moulds) can grow below the snow, ruining the forage even for the whole winter ([Kumpula et al., 2011](#)). This can lead to difficult foraging conditions for the rest of the winter. Catastrophic winters have often started in the end of autumn and before Christmas. Icy lichens are difficult for reindeer to digest – the ice takes a lot of energy to melt in the body, and too much water intake might make reindeer sick. In extreme cases, even arboreal lichens can become ice- or frost covered (hoar) in the trees (*ritni/bichi* [NS] or *rijnie* [SS], *Cuoddalat* ([NS] wet snow) or icy fog can cause thick rime ice (*ritni/skilzun/bihci* [NS] and *tykky* [FIN] on the vegetation and trees ([Riseth et al., 2011](#)) (see [Fig. 5](#)), and this may harm herding or migration of the reindeer ([NBR/RSR, 1986](#)).

In northwestern Russia, December is the month when reindeer herders usually arrive to winter pasturelands in the forest-tundra areas. In the Bol'shezemel'skaya tundra (the northeastern part of European Russia), deep-freeze meat-storage facilities are still quite rare, which means that the commercial slaughter of reindeer can start only after the temperature falls permanently below –15 °C, allowing for a quick self-freezing of reindeer corpses. Usually, this occurs in late November or early December, signaling the start of the slaughter period. In Yamal, several deep-freeze plants have been recently constructed, which permits an earlier slaughter. The construction was decided by Yamal authorities after the catastrophic winter in 2013–14 ([Forbes et al., 2016, 2022](#)).

3.8. Winter

Winter is considered the limiting factor in reindeer herding. Winter is characterized by polar night, low temperatures, and snow cover. During winter, the reindeer mainly graze in the coniferous forest (Sweden, Finland), the tundra of Finnmark (Norway) by the coast, or on some islands of northern Norway ([Vorren, 1986](#); [Hovelsrud et al., 2021](#)). Generally, herds are closely surveyed, but left undisturbed to the largest degree possible. In Fennoscandia, supplementary feeding is increasingly used to battle bad foraging conditions.

If available, reindeer also feed on arboreal lichen in old-growth forests, especially when snow is deep or icy. In general, in the best winter conditions there are not much snow (less than 50 cm) and snow that is easy to dig through. A thick, hard snow cover becomes useful during late winter/early spring when the reindeer need to reach arboreal lichens. [Voere](#) [SS] describes deep snow where reindeer do neither dig nor move ([Bergsland and Magga, 1993](#)).

Short, stable and sufficiently cold winters are usually considered positive. The quality of snow (depth, hardness and compactness of snow;

ice layers in the snow cover) determines the foraging conditions through the snow cover, and thus the energy need and energy intake of reindeer ([Forbes et al., 2022](#)). Deep snow in the forest can force herders in some districts to either not leave the autumn/spring pastures or return back to them (too) early – which might deplete grazing resources that should be used in spring and the calving period. Different forest types can buffer various winter weather events, i.e. the interaction between canopy density, snow interception and winter weather such as warm spells ([Horstkotte and Roturier, 2013](#); [Horstkotte et al., 2014](#)). Generally, availability of old forests would be desirable during adverse winter conditions because they capture large amounts of snow in the canopy.

In Russia, where precipitation is lower, deep snow causes difficulties only in some forested areas, which are nowadays usually not used for winter grazing. Since control is important for reindeer herding in Russia, replacing the old-style sledges with motor vehicles (which took place during the last 20–30 years) has led to the abandonment of forested grazing grounds in favor for forest-tundra ([Fig. 6](#)). Nowadays reindeer herders routinely use snowmobiles for rounding up reindeer, moving them from one place to another and searching for stray animals. This can only be done effectively in open areas, thus, we can discern here a significant shift in the use of winter pastures in northwest Russia. Strong winds and winter storms are harmful, while modest winds can prevent snow from becoming too wet and refreeze during warm periods. In Russia, supplementary feeding is not used except in some reindeer farms for tourists.

Extremely low temperatures are difficult for humans and animals. However, in recent times, temperatures above 0 °C constitute more frequent problems. Rain-on-snow events or mild temperatures in January–February can melt the snow, resulting in a hard layer on top of snow too early or ice layers within the snowpack. Any thick ice crust on the snow *salaba* [TN] at the beginning and the end of winter means a complete disaster for both reindeer herders and their reindeer. In Nenets *serad' po* refers both to “year with the ice crust on the ground” and “misfortune, trouble, poverty, misery” (field materials RL). With the migration back to calving areas at the end of winter, a new herding year begins.

4. Comparison of the critical conditions in Fennoscandian and northwestern Russian reindeer herding

The narratives reported in the previous section show both similarities and differences in conditions reindeer herders perceive as the most critical in Fennoscandia and northwestern Russia. Here, we paid attention to conditions of temperature, precipitation and the ground during different periods of the reindeer herding year and their role for



Fig. 6. The Nenets winter pastures in the forest tundra. Photo Roza Laptander.

successful work with reindeer. Among the conditions defined as critical by all groups, icing on the ground, caused by rain-on-snow or thaw-freeze events during the winter and the spring, is probably the most detrimental, as it can lead to mass starvation. It is also crucial that the quality of the snow and its accumulation during the winter allows reindeer to access the terricolous lichens. Furthermore, reindeer herders emphasized frequent temperature fluctuations around 0 °C in autumn and in spring and consider these fluctuations as negative events by themselves. The herders also reported the more frequent occurrence of these fluctuations in the last decade.

Besides the conditions which seem to coincide for both groups, there were conditions mentioned by both groups but in different contexts. Both Fennoscandian and Russian reindeer herders seem to agree that hot summers represent a bad thing. However, while Fennoscandian reindeer herders seem to be concerned mostly by the effects of hot weather on reindeer health and nutrition, reindeer herders in Russia are equally if not more concerned by the significant difficulties they experience with herd control. This, as it seems, makes hot summer weather much worse for them in comparison to cold summer weather, which could also be problematic for reindeer but makes herd control much easier. Hence, while Fennoscandian reindeer herders experience that extremely hot and extremely cold summer weather as equally bad, herders from Russia think that cold summers are actually good for reindeer herding and, in any case, much more preferable to the hot ones. For the same reason, herders from Russia seem to attach much more weight to the mosquito season as a negative critical event in comparison to Fennoscandian reindeer herders. Early freezing of the ground represents an opposite example: both groups of herders consider it positive and important for reindeer herding. At the same time, Fennoscandian herders seem to attach more weight to it as it is critical for round-ups, one of their most important herding procedures. Herders from Russia, by contrast, welcome early snow as making herd control easier, but they do not see it critical up to the same degree. However, both reindeer herding groups recognized that the first snow should fall on dry and frozen ground.

There are two critical events that seem to be perceived very differently in Fennoscandian and northwestern Russian reindeer herding. The first is river freezing and breaking up, which have been repeatedly mentioned by Komi and Nenets reindeer herders as being of vital importance but, as it seems, have rarely been mentioned by Fennoscandian herders. This can be related to a geographical difference: the relatively flat areas of northeastern Europe and northwestern Siberia feature more large rivers than in Fennoscandia, and crossing these rivers with reindeer herds is more problematic. Migration routes in Fennoscandia, and in Sweden in particular, often follow the larger rivers rather than cross them. The second critical ambivalent event is the mushroom season: for Fennoscandian reindeer herders the mushroom season creates a positive outcome, while for reindeer herders in Russia it creates a negative outcome. As stated above, herders' perception in Russia of the mushroom season is that the problem of herd dispersion seemingly outweighs the significance of mushrooms in reindeer diet – despite the positive impact on reindeer body condition and digestion – and it markedly diverts from the perception by herders in Fennoscandia (even though the Nenets reindeer herders call mushrooms *tudako* 'making reindeer fat', from the word *tu* 'reindeer fat').

Moreover, the differences in control and herd management between Fennoscandian and Russian reindeer herders can be further generalized and explained but putting them in context of the interactionist model of reindeer herding as developed by (Dwyer and Istomin, 2008; see also Istomin and Dwyer, 2010). From the viewpoint of this model, the core part of reindeer husbandry, on which its reaction to environmental change essentially depends, consists in behavioural interaction between reindeer, whose behavior is determined mainly by biotic as well as abiotic factors and reindeer herders, whose behavior is essentially influenced by social, economic and political considerations (Forbes, 2013; Stammer and Ivanova, 2020; Forbes et al., 2022). Therefore, many of the changes in the natural environment, including at least some

of the critical conditions discussed here, influence reindeer herding by affecting the mentioned behavioural interaction through modifications in reindeer behavior they cause. Reindeer herders perceive and report this as difficulties in maintaining herd control and generally dealing with reindeer. However, the mode in which the behavioural interaction is organized can change from one reindeer herding tradition to another as a result of the process (Istomin and Dwyer, 2010) call "dynamic mutual adaptation". Therefore, reindeer behavior in response to certain environmental conditions (e.g. fungi) that disrupt the behavioural interaction in one reindeer herding tradition can be much less detrimental in another tradition. It seems like Nenets and Komi reindeer herding traditions are more sensitive to the problems related to the behavioural interaction with the reindeer (probably because in their case this interaction happens almost permanently as a part of intensive herding) and, therefore, they attach more weight to the factors affecting it.

5. Conclusion and outlook

This manuscript discusses which events in the reindeer herding year are seen as critical by herders in Fennoscandia and northwestern Russia, where the outcomes of these critical events may require intensive herding work to mitigate their effects on reindeer and herders. Strategies applied for mitigation include temporary reliance on artificial feeding (Fennoscandia), letting animals to spread over the territory (northwestern Russia) or even intentionally spreading them (Fennoscandia) in order to mitigate the effects of continuous basal ice, dividing one's animals between several separate herds pastured in different areas (northwestern Russia and Fennoscandia). Within this framework, the most important, the most effective, and the most consistently used strategy is movement, whether it is implemented as spreading the herd or dividing it between several pastures (Fennoscandia) or as a genuinely nomadic way of dealing with problems by walking away from them (northwestern Russia) (Myres, 1941). On the onset of a critical condition, a very first reaction of reindeer herders is to move their herds to pastures where the conditions are less severe or absent: to a windy seacoast to avoid heat and mosquitoes, to forested areas to avoid hard snow, or away from the area affected by rain-on-snow. Modern Fennoscandian reindeer herders cannot be properly named nomadic, they nonetheless utilize movement to deal with critical conditions and events. Thus, also in Fennoscandia the flexibility to move between different landscape elements as a response to different weather events is very important, such as moving up to mountainous areas or to forest areas to utilize arboreal lichen if the snow cover is deep or icy. These movements might in selected cases also lead across nation borders. Several herding communities have used this strategy in the past and in recent years, endorsed by the authorities, for example in Karasjok in the winter 2017–18 (Johnsen et al., 2017) and in Saarivuoma and Gabna herding communities in Sweden, in the 1970s and up to present time (Riseth et al., 2011, 2016).

Climate change is one of the most challenging problems for contemporary reindeer herding. Changes in temperature and precipitation, snow conditions on the ground and wind lead to unusual, extreme or new weather events. Seasons might change in terms of timing and duration (for example, winters might become shorter, while autumn and spring may last longer), they may shift and/or lose their character compared to earlier experiences – as a "new normal" (Landrum and Holland, 2020). The impacts of these changes on the timing, severity and frequency of occurrence of the critical events will shape the outcomes of those events in reindeer herding, challenging existing adaptation strategies to critical events in their effectiveness, also due to their cumulative impact during the herding year, and their interdependence with socio-economic drivers and feedbacks (Matthes et al., submitted). This is already evident under recent conditions, exemplified by more frequent rain-on-snow events, which have increased reindeer mortality or weakened their health. The development of new adaptation strategies,

and more importantly the possibilities to implement them, will determine the future of reindeer husbandry in Fennoscandia and northwestern Russia.

However, the ability of reindeer herders to make use of their mobility as an important adaptation and mitigation strategy can be compromised by social, economic and political factors (Niamir-Fuller, 1998): in recent years, in both Fennoscandia and northwestern Russia, reindeer herding mobility has become increasingly restricted due to a reduction of the area available for reindeer herding due to the impacts of developing infrastructure and extractive industries (and tourism in Fennoscandia). The attempts to enforce land-use rights of reindeer-herding enterprises in the northern Urals mountains (Vorkuta area) have infringed the mobility of Nenets private reindeer herders (Istomin, 2022). However, probably the most important factor limiting mobility of reindeer herders in Russia, particularly in northwestern Siberia, is their increasing poverty. Indeed, to be mobile, one needs a reindeer herd of a particular size: an owner of a too small reindeer herd is inevitably dependent on economic activities other than reindeer herding (i.e., fishing, paid jobs) and/or state social payments to meet his/her ends. These activities are typically incompatible with the extended mobility required to evade environmental hazards. Instead, these activities force owner of small herds to stay put – even if in the interest of their herd they should move. Recent studies (Forbes et al., 2009; Zuev, 2020) show that most private reindeer herders of the Yamal area have fewer reindeer than necessary to rely exclusively or even mostly on reindeer herding as a source of income.

In Fennoscandia, the situation is somewhat different. While the threat of a poverty trap is not of the same magnitude as in Russia, cumulative land use pressures from extractive industries such as forestry, mining, and wind-power development greatly reduce the scale and options to move herds and find alternative grazing sites in response to environmental stochasticity (Horstkotte et al., 2014; Hovelsrud et al., 2021). Developments of artificial reservoirs for hydropower in the early to mid-20th century have greatly affected flexibility of land use patterns, shifted migration patterns due to unsafe ice conditions caused by fluctuating water levels, and in some cases completely eliminated migration routes (Össbo and Lantto, 2011). While supplementary feeding of reindeer with hay or commercial feeds is a short-term remedy to buffer severe winters, it does not contribute to finding a systemic solution to the underlying challenges of the continued decline of pastures in quality and quantity, their increasing fragmentation, and the impacts of climate change.

Furthermore, our comparison of practices and strategies in reindeer herding in Fennoscandia and northwest Russia shows that for both pastoral societies it is not possible to stay sustainable and be resilient without any support from the state. In both Fennoscandia and northwestern Russia, reindeer husbandry is an important symbolic resource for local and regional administrations, which use reindeer and reindeer-herding cultures as emblems in their self-presentation and advertising campaigns. But rather than treating reindeer husbandry merely as “picturesque”, regional and national authorities should ensure that this type of land use has equal opportunities and grant equal rights in decision-making. The resulting challenges need to be assessed in the context of social and economic dynamics. In both regions, reindeer herders particularly need support from local, regional, national, and transnational authorities to develop management actions in response to the cumulative effects of land use change and climate change. To adapt to climate change and develop new strategies, reindeer herders must have access to pastures, in particular in times of crisis; they must be able to maintain a high degree of mobility and flexibility; their participation in land-use planning with the state decision makers must be endorsed. Moreover, it is consequential to develop region-specific policies aimed at strengthening the rights, opportunities and empowerment of reindeer herders to meaningfully participate in land use planning for resource development. Among these, for both Fennoscandia and Russia, it is essential to mention: changing methods of forest management to reduce

the detrimental impact on winter grazing resources to prevent the need to give supplementary feeding; construction of “green infrastructure” that helps reindeer and herders to cross pipelines, roads or railroads; restoration of old migration routes; increased financial compensation for losses to predators (Horstkotte et al., 2022; Löf et al., 2022); and recognition of Indigenous and Local Knowledge as evidence base (Johnsen et al., 2017; Wheeler et al., 2020) for the continuation of this unique Arctic culture and livelihood for future generations.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

This article’s research materials are based on numerous reindeer herders’ detailed knowledge of reindeer behavior, herding techniques, landscape, weather, and seasonality. We are very grateful to all our research partners in Fennoscandia and northwest Russia for supporting this work about the influence of climate change in their reindeer herding work. Special thanks to Irina Wang for making wonderful graphic work and tables for this article.

This work was supported by funding under the European Commission Research and Innovation Action, grant no. 869471 (CHARTER), by the Academy of Finland, grant no. 338558 (to JTE), the Kone Foundation (to JTE), and the National Science Foundation (NSF), grant NNA no. 198230 (AROSS).

Glossary

Names of reindeer herding year eight seasons in Northern Sámi, Southern Sámi and Tundra Nenets

Late winter – early spring Giddadálvi [NS] and Gijredaelvie [SS]; Narey/Nara [TN]

Late spring – early summer Gidda [NS], Gijre [SS]; Tangy [TN]

Early summer Giddageassi [NS], Gijregiesie [SS]; Ta [TN]

Summer (Geassi [NS], Giesie [SS]; Yepdyta [TN]

Late summer/early autumn Čakčageassi [NS], Tjaktjegiesie [SS]; Ngeryoy [TN]

Autumn Čakča [NS], Tjaktje [SS]; Ngeryo (Sel’byanyangy) [TN]

Late autumn/early winter (Čakčadálvi [NS], Tjaktjedaelvie [SS]); Syrey [TN]

Winter Dálvi [NS], Daelvie [SS]; Syra [TN]

References

Åhman, B., Turunen, M., Kumpula, J., Risvoll, C., Horstkotte, T., Lépy, É., Eilertsen, S.M., 2022. 12 Role of supplementary feeding in reindeer husbandry. Reindeer husbandry and global environmental change: Pastoralism in Fennoscandia 232. <https://doi.org/10.4324/9781003118565-17>.

Andreyev, V.N., 1977. Reindeer pastures in the subarctic territories of the USSR. In: Application of Vegetation Science to Grassland Husbandry. Springer Netherlands, Dordrecht, pp. 275–313.

Backström, E., 2021. Impact of fire and frost drought events on vegetation greenness and albedo in Subarctic Scandinavia. Student thesis series INES. No 552.

Baskin, L.M., 2000. Reindeer husbandry/hunting in Russia in the past, present and future. Polar Res. 19 (1), 23–29.

Beach, H., 1981. Reindeer-herd Management in Transition. The Case of Tuorpon Saameby in Northern Sweden [intensive Herding, Extensive Herding, Rational Herding, Legislation, Saamish-Swedish Relations, Minority Politics]. Uppsala Studies in Cultural Anthropology, Sweden, p. 3.

Beniston, M., Farinotti, D., Stoffel, M., Andreassen, L.M., Coppola, E., Eckert, N., Fantini, A., Giacoma, F., Hauck, Ch., Huss, M., Huwald, H., Lehning, M., López-Moreno, J.-I., Magnusson, J., Marty, Ch., Morán-Tejeda, E., Morin, S., Naaim, M., Provenzale, A., Pabatet, A., Six, D., Stötter, J., Strasser, U., Terzago, S., Vincent, Ch., 2018. The Cryosphere 12, 759–794. <https://doi.org/10.5194/tc-12-759-2018>.

Bergland, K., Magga, L.M., 1993. Årjelsaemien-daaroen Baakoegærga. Sydsamis –nors orðbo . Idut, Oslo.

Boas, F., 2006. The limitations of the comparative method of anthropology. In: Moore, H., Sanders, T. (Eds.), *Anthropology in Theory: Issues in Epistemology*. Blackwell Pub, Oxford, pp. 58–67.

Boas, F., 1896. The limitations of the comparative method of anthropology. *Science* 4 (103), 901–908.

Drake, S., 1918. *Västerbottenslapparna*. Två Förläggare Bokförlag, Stockholm, Sweden.

Dwyer, M.J., Istomin, K., 2008. Theories of nomadic movement: a new theoretical approach for understanding the movement decisions of Nenets and Komi reindeer herders. *Hum. Ecol.* 36 (4), 521–533.

Dyson-Hudson, R., Dyson-Hudson, N., 1980. Nomadic pastoralism. *Annu. Rev. Anthropol.* 9 (1), 15–61.

Fauchald, P., Park, T., Tømmervik, H., Myneni, R., Hausner, V.H., 2017. Arctic greening from warming promotes declines in caribou populations. *Sci. Adv.* 3 (4), e1601365.

Forbes, B.C., Stammer, F., Kumpula, T., Meschtyb, N., Pajunen, A., Kaarlejärvi, E., 2009. High resilience in the Yamal-Nenets social-ecological system, west Siberian Arctic, Russia. *Proc. Natl. Acad. Sci. USA* 106 (52), 22041–22048.

Forbes, B.C., 2013. Cultural resilience of social-ecological systems in the Nenets and Yamal-Nenets Autonomous Okrugs, Russia: a focus on reindeer nomads of the tundra. *Ecol. Soc.* 18 (4) <https://doi.org/10.5751/ES-05791-180436>.

Forbes, B.C., Kofinas, G., Beach, H., Brattland, C., Kankaanpää, P., Keskitalo, C., Lennert, M., Meek, C.L., Metcalf, V.K., Robards, M.D., Young, O.R., 2014. Resource governance. In: Larsen, J.N., Fondahl, G. (Eds.), 2015. *Arctic Human Development Report: Regional Processes and Global Linkages*. Nordic Council of Ministers, TemaNord, pp. 253–296.

Forbes, B.C., Kumpula, T., Meschtyb, N., Laptander, R., Macias-Fauria, M., Zetterberg, P., Verdonen, M., Skarin, A., Kim, K.Y., Boisvert, L.N., Stroeve, J.C., 2016. Sea ice, rain-on-snow and tundra reindeer nomadism in Arctic Russia. *Biol. Lett.* 12 (11), 20160466.

Forbes, B.C., Turunen, M.T., Soppela, P., Rasmus, S., Vuojala-Magga, T., Kitti, H., 2019. Changes in mountain birch forests and reindeer management: comparing different knowledge systems in Sápmi, northern Fennoscandia. *Polar Rec.* 55 (6), 507–521. <https://doi.org/10.1017/S0032247419000834>.

Forbes, B., Kumpula, T., Meschtyb, N., Laptander, R., Macias-Fauria, M., Zetterberg, P., Verdonen, M., Skarin, A., Kwang-Yul, K., Boisvert, L.N., Stroeve, J.C., 2022. Coping with a warming winter climate in arctic Russia: patterns of extreme weather affecting Nenets reindeer nomadism. In: *Resilience through Knowledge Co-production: Indigenous Knowledge, Science, and Global Environmental Change*. Cambridge University Press, pp. 217–232.

Habeck, J.O., 2005. What it means to be a herdsman: The practice and image of reindeer husbandry among the Komi of northern Russia. LIT Verlag.

Habeck, J.O., 2006. Experience, movement and mobility: Komi reindeer herders' perception of the environment. *Nomadic Peoples* 10 (2), 123–141.

Hanssen-Bauer, I., Benestad, R.E., Lutz, J., Vikhamar-Schuler, D., Svyashchennikov, P., Førland, E.J., 2022. Comparative analyses of local historical and future climate conditions important for reindeer herding in Finnmark, Norway and the Yamal Nenets autonomous Okrug, Russia. In: *Reindeer Husbandry: Adaptation to the Changing Arctic*, vol. 1. Springer International Publishing, Cham, pp. 187–222.

Holand, Ø., Horstkotte, T., Kumpula, J., Moen, J., 2022. Reindeer Pastoralism in Fennoscandia. Reindeer Husbandry and Global Environmental Change, pp. 7–47.

Horstkotte, T., Roturier, S., 2013. Does forest stand structure impact the dynamics of snow on winter grazing grounds of reindeer (*Rangifer t. tarandus*)? *For. Ecol. Manag.* 291, 162–171.

Horstkotte, T., Sandström, C., Moen, J., 2014. Exploring the multiple use of boreal landscapes in northern Sweden: the importance of social-ecological diversity for mobility and flexibility. *Hum. Ecol.* 42, 671–682.

Horstkotte, T., Utsi, T.A., Larsson-Blind, Å., Burgess, P., Johansen, B., Käyhkö, J., Oksanen, L., Forbes, B.C., 2017. Human–animal agency in reindeer management: Sámi herders' perspectives on vegetation dynamics under climate change. *Ecosphere* 8 (9), e01931.

Hovelsrud, G.K., Risvoll, C., Riseth, J.Å., Tømmervik, H., Omazic, A., Albihn, A., 2021. Reindeer herding and coastal pastures: adaptation to multiple stressors and cumulative effects. Nordic perspectives on the responsible development of the Arctic: Pathways to action 113–134. https://doi.org/10.1007/978-3-030-52324-4_6.

Horstkotte, T., Heikkilä, H.I., Næss, M.W., Landauer, M., Forbes, B.C., Risvoll, C., Sarkki, S., 2022. Implications of norms and knowledge in customary reindeer herding units for resource governance. *Reindeer Husbandry and Global Environmental Change*, 133–149.

Inga, B., 2007. Reindeer (*Rangifer tarandus tarandus*) feeding on lichens and mushrooms: traditional ecological knowledge among reindeer-herding Sami in northern Sweden. *Rangifer* 27 (2), 93–106. <https://doi.org/10.7557/2.27.2.163>.

Ingold, T., 1980. *Hunters, Pastoralists, and Ranchers: Reindeer Economies and Their Transformations*. Cambridge University Press, Cambridge.

Istomin, K.V., 2020. Post-soviet reindeer herders: between family and collective herding. *Region* 9 (1), 25–52.

Istomin, K.V., 2022. *Nevidimye ludi: istorija i sovremennoe polozeniie vorkutinskikh nentsev-chstnikov*. In: Shabaev, Yuri P. (Ed.), *Kulturnoe Nasledie I Kulturnye Realii Evropeiskogo Severa: Izuchenie, Problemy, Poiski*. Komi NTs UrO RAN, Syktyvkar, pp. 74–103.

Istomin, K.V., Dwyer, M.J., 2010. Dynamic mutual adaptation: human-animal interaction in reindeer herding pastoralism. *Hum. Ecol.* 38, 613–623. <https://doi.org/10.1007/s10745-010-9341-3>.

Istomin, K.V., Habeck, J.O., 2016. Permafrost and indigenous land use in the northern Urals: Komi and Nenets reindeer husbandry. *Polar Science* 10 (3), 278–287.

Jernsletten, J.L.L., Klokov, K.B., 2002. Sustainable Reindeer Husbandry. Published by Centre for Saami Studies University of Tromsø.

Johnsen, K.I., Mathiesen, S.D., Eira, I.M.G., 2017. Sámi reindeer governance in Norway as competing knowledge systems. *Ecol. Soc.* 22 (4).

Kitti, H., Gunsly, N., Forbes, B.C., 2006. Defining the quality of reindeer pastures: the perspectives of Sámi reindeer herders. In: *Reindeer Management in Northernmost Europe: Linking Practical and Scientific Knowledge in Social-Ecological Systems*. Springer Berlin Heidelberg, Berlin, Heidelberg, pp. 141–165.

Klokov, K.B., Antonov, E.V., 2022. *Etnokul'turno-landschaftne raionirovanie traditsionnogo severnogo olenevodstva v razreze munitsipal'nykh obrazovani Rossiiskoi Federatsii* [transl. *Vestnik Sankt-Peterburgskogo Universiteta: nauki o zemle* 67 (4), 696–713].

Krupnik, I., 2002. *Arctic Adaptations: Native Whalers and Reindeer Herders of Northern Eurasia*. Dartmouth College Press.

Krupnik, I., 2000. Reindeer pastoralism in modern Siberia: research and survival during the time of crash. *Polar Res.* 19 (1), 49–56.

Ksenofontov, S., Backhaus, N., Schaeppman-Strub, G., 2019. 'There are new species': indigenous knowledge of biodiversity change in Arctic Yakutia. *Polar Geogr.* 42 (1), 34–57.

Kumpula, T., Pajunen, A., Kaarlejärvi, E., Forbes, B.C., Stammer, F., 2011. Land use and land cover change in Arctic Russia: ecological and social implications of industrial development. *Global Environ. Change* 21 (2), 550–562. <https://doi.org/10.1016/j.gloenvcha.2010.12.010>.

Landbruksdirektoratet, 2019. *Ressursregnskap for Reindriftsnæringen*. For Reindriftsåret 1. April 2018–31. Mars 2019. Landbruksdirektoratet, Alta.

Landrum, L., Holland, M.M., 2020. Extremes become routine in an emerging new Arctic. *Nat. Clim. Change* 10, 1108–1115. <https://doi.org/10.1038/s41558-020-0892-z>.

Laptander, R., Stammer, F., 2017. Reflections of the future of Yamal reindeer herding after the anthrax outbreak on Yamal in summer 2016. Salekhard. *Nauchnyi vestnik YNAO* 1 (94), 49–54.

Laptander, R., 2018. They did not think about people, they just needed polar fox Fur more than gold. *Severjane* 4, 64–66.

Laptander, R., 2020. When we got reindeer, we moved to live to the tundra: the Spoken and Silenced History of the Yamal Nenets. In: *Acta Electronica Universitatis Lapponiensis*, vol. 278. University of Lapland. <https://urn.fi/URN:ISBN:978-952-337-200-9>.

Löf, A., Raitio, K., Forbes, B.C., Labba, K., Landauer, M., Risvoll, C., and & Sarkki, S., 2022. Unpacking reindeer husbandry governance in Sweden, Norway and Finland. In: Horstkotte, T., Holand, Ø., Kumpula, J., Moen, J. (Eds.), *Reindeer Husbandry and Global Environmental Change: Pastoralism in Fennoscandia*. Routledge.

Lyftingsmo, E., 1965. *Norske Fjellbeite - Oversyn over Fjellbeite I Finnmark*, vol. XV. Mosjøen: Selskapet for Norges Vel.

Manker, E.M., 1972. *People of Eight Seasons*. Wahlström and Widstrand, Stockholm.

Myers-Smith, I.H., Elmendorf, S.C., Beck, P.S., Wilmking, M., Hallinger, M., Blok, D., et al., 2015. Climate sensitivity of shrub growth across the tundra biome. *Nat. Clim. Change* 5 (9), 887–891.

Myres, J.L., 1941. Nomadism. *J. Roy. Anthropol. Inst. G. B. Ireland* 71 (1/2), 19–42. <https://doi.org/10.2307/2844399>.

Nakashima, D., Krupnik, I., Rubis, J.T., 2018. Indigenous Knowledge for Climate Change Assessment and Adaptation. In: *Local and Indigenous Knowledge*, vol. 2. Cambridge University Press and UNESCO, Cambridge and Paris.

NBR/RSR, 1986. *Seminara Boazobargi Giella - Cöhkkiras/Jukkasjärvi* 13–16. Norgga Boazosámiid Riikkasearvi, NBR/Ruota Sámiid Riikkasearvi. Report, p. 70. March 1986.

Niamir-Fuller, M., 1998. The resilience of pastoral herding in Sahelian Africa. In: Berkes, F., Folke, C., Colding, J. (Eds.), *Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience*. Cambridge University Press, Cambridge, pp. 250–284.

Nieminen, M., Heiskari, U., 1989. Diets of freely grazing and captive reindeer during summer and winter. *Rangifer* 9 (1), 17–34.

Össbo, Å., Lantto, P., 2011. Colonial Tutelage and Industrial Colonialism: reindeer husbandry and early 20th-century hydroelectric development in Sweden. *Scand. J. Hist.* 36 (3), 324–348. <https://doi.org/10.1080/03468755.2011.580077>.

Paine, R., 1964. Herding and husbandry: two basic distinctions in the analysis of reindeer management. *Folk* 6 (1), 83–88.

Paine, R., 1994. *Herds of the Tundra. A Portrait of Saami Reindeer Pastoralism*. Smithsonian Institution Press, Washington and London.

Ran Herding Community, 2018. *Klimatpåverkan På Renskötseln Nu Och I Framtiden*.

Rantanen, M., Karpechko, A.Y., Lippinen, A., Nordling, K., Hyvärinen, O., Ruosteenoja, K., Vihma, T., Laaksonen, A., 2022. The Arctic has warmed nearly four times faster than the globe since 1979. *Communications Earth & Environment* 3 (1), 168. <https://doi.org/10.1038/s43247-022-00498-3>.

Rasmus, S., Horstkotte, T., Turunen, M., Landauer, M., Annette, L., Lehtonen, I., Rosqvist, G., Holand, Ø., 2022. *Reindeer Husbandry and Climate Change. Challenges for Adaptation*. Routledge Swedish University of Agricultural Sciences (SLU).

Matthes, H., Habeck, J.O., Horstkotte, T., Laptander, R., Istomin, K., Komu, T., Rasmus, S., Bjørke, J.W., Tømmervik, H., Translating Critical Seasonal Conditions of Reindeer Herding into Climate Modelling (submitted).

Rasmus, S., Laptander, R., Horstkotte, T., Habeck, J.O., Istomin, K., Komu, T., Matthes, H., Sarkki, S., Tømmervik, H., Forbes B.C., Eronen, J. T., Rethinking the adaptation in rapidly changing Arctic. *Nat. Sustain. -* (unpublished manuscript).

Rasmus, S., Turunen, M., Luomaranta, A., Kivinen, S., Jylhä, K., Räihä, J., 2020. Climate change and reindeer management in Finland: co-analysis of practitioner knowledge and meteorological data for better adaptation. *Sci. Total Environ.* 710 (2020) <https://doi.org/10.1016/j.scitotenv.2019.136229>.

Riseth, J.Å., 2009. *Modernization and Pasture Degradation. A Comparative Study of Two Sámi Reindeer Pasture Regions in Norway 1960–1990*. Saarbrücken. VDM Verlag.

Riseth, J.Å., Vatn, A., 2009. Modernization and pasture degradation. A comparative study of two Sámi reindeer pasture regions in Norway. *Land Econ.* 85 (1), 87–106.

Riseth, J.Å., Tømmervik, H., Helander-Renvall, E., Labba, N., Johanson, C., Malnes, E., Bjerke, J.W., Jonasson, C., Pohjola, V., Sarri, L.E., Schanche, A., Callaghan, T.V., 2011. Sámi TEK as a guide to science: snow, ice and reindeer pasture facing climate change. *Polar Rec.* (47), 202–217.

Riseth, J.Å., Tømmervik, H., Bjerke, J.W., 2016. 175 years of adaptation: north Scandinavian Sámi reindeer herding between government policies and winter climate variability (1835–2010). *J. For. Econ.* (24), 186–204.

Riseth, J.Å., Tømmervik, H., Tryland, M., 2020. Spreading or gathering? Can traditional knowledge be a resource to tackle reindeer diseases associated with climate change? *Int. J. Environ. Res. Publ. Health* (17), 6002. <https://doi.org/10.3390/ijerph17166002>.

Rosqvist, G.C., Inga, N., Eriksson, P., 2022. Impacts of climate warming on reindeer herding require new land-use strategies. *Ambio* 51, 1247–1262.

Serreze, M.C., Gustafson, J., Barrett, A.P., Duckenmiller, M.L., Fox, S., Voveris, J., Stroeve, J., Sheffield, B., Forbes, B.C., Rasmus, S., Laptander, R., Brook, M., Brubaker, M., Temte, J., McCrystall, M.R., Bartsch, A., 2021. Arctic rain on snow events: bridging observations to understand environmental and livelihood impacts. *Environmental research letters* 16 (105009). <https://doi.org/10.1088/1748-9326/ac269b>.

Skjenneberg, S., Slagsvold, L., 1979. Reindeer husbandry and its ecological principles by - reindriften og dens naturgrunnlag. Translated from Norwegian. In: Anderson, Candy M., Luick, Jack R. (Eds.), TRANSLATOR Tone Treider Deehr. Published by the U.S. Department of the Interior Bureau of Indian Affairs Juneau, Alaska, 1979.

Skum, N.N., Pellijeff, G., 1955. In: Renar, Valla (Ed.), Ernst Manker. *Nordiska Museet: Acta Lapponica; X. Almqvist and Wiksell/Gebers, Stockholm, Sweden.*

Stammer, F.M., Ivanova, A., 2020. From spirits to conspiracy? Nomadic perceptions of climate change, pandemics and disease. *Anthropol. Today* 36 (4), 8–12. <https://doi.org/10.1111/1467-8322.12589>.

Stammer, F., 2008. Opportunities and threats for mobility: reindeer nomads of the west siberian coastal zone (yamal) respond to changes (MOVE, IPY #436). *Ecologicheskoe planirovaniye i upravlenie* 3–4.

Stépanoff, C., 2017. The rise of reindeer pastoralism in Northern Eurasia: human and animal motivations entangled. *J. Roy. Anthropol. Inst.* 23 (2), 376–396.

Tømmervik, H., Bjerke, J.W., Gaare, E., Johansen, B., Thannheiser, D., 2012. Rapid recovery of recently overexploited winter grazing pastures for reindeer in northern Norway. *Fungal Ecology* (5), 3–15.

Tømmervik, H., Forbes, B.C., 2020. Focus on recent, present and future Arctic and boreal productivity and biomass changes. *Environ. Res. Lett.* 15 (8), 080201 <https://doi.org/10.1088/1748-9326/ab79e3>.

Tryland, M., Åhman, B., Romano, J.S., 2022. Health and diseases of semi-domesticated reindeer in a climate change perspective. In: *Reindeer Husbandry and Global Environmental Change*. Routledge, pp. 249–262.

Turi, J.M., 2002. The world reindeer livelihood – current situation, threats and possibilities. In: Kankaanpää, S., Müller-Wille, L., Susiluoto, P., Sutinen, M.-L. (Eds.), *Northern Timberline Forests: Environmental and Socio-Economic Issues and Concerns*, 70–5. The Finnish Forest Research Institute, Kolari.

Turunen, M., Rasmus, S., Bavay, M., Ruosteenoja, K., Heiskanen, J., 2016. Coping with increasingly difficult weather and snow conditions: reindeer herders' views on climate change impacts and coping strategies. *Climate Risk Management* 11 (2016), 15–36. <https://doi.org/10.1016/j.crm.2016.01.002>.

Turunen, M., Vuojala-Magga, T., 2014. Past and present winter feeding of reindeer in Finland: herders' adaptive learning of feeding practices. *Arctic* 67, 173–188.

Vitebsky, P., Alekseyev, A., 2015. What is a reindeer? Indigenous perspectives from northeast Siberia. *Polar Rec.* 51 (4), 413–421.

Volkovitskyi, A., Terekhina, A., 2022. 'We used to cross over the ice': climate change in the perception of the tundra dwellers of Yamal (in Russian). In: *Human and Nature in Siberia. Ecological Knowledge and Sustainable Natural Relations in the Time of Climate Change*. Verlag der Kulturstiftung Sibirien/SEC Publications, pp. 39–66.

Vorren, Ø., 1986. Reindrift og nomadisme på Helgeland. *Troms Mus. Skr.* 21 (3), 1986–2002.

Wheeler, H., Danielsen, F., Fidel, M., Hausner, V.H., Horstkotte, T., Johnson, N., Lee, O., Mukherjee, N., Amos, A., Ashtorn, H., Ballari, Ø., 2020. The need for transformative changes in the use of Indigenous knowledge along with science for environmental decision-making in the Arctic. <https://doi.org/10.1002/pan3.10131>.

Yuzhakov, A.A., Mukhachev, A.D., Laishev, K.A., 2023. *Breeds and Problems of Reindeer Breeding in Russia*. Nauka, Moscow.

Zuev, S., 2020. The "success story" of private reindeer husbandry in Yamal? Look at the herders' budgets 30 years after. *Region: Regional Studies of Russia, Eastern Europe, and Central Asia* 9 (1): 83–115.