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Changing Winter Landscapes: Extreme Weather Events and Meanings of Snow for Sámi Reindeer Herders

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ABSTRACT. Snow is a crucial part in the lives of Sámi reindeer herders, and changes in snow conditions can affect their well-being in multiple ways. However, meanings and emotions associated with snow are rarely considered in research on reindeer herding and climate change. Based on thematic interviews with reindeer herders in two reindeer herding co-operatives in the Sámi Homeland in Finland, we examined the roles and meanings of snow for Sámi reindeer herders and impacts of the extreme winter events of recent years on their well-being. In addition, based on a literature survey, we considered the role of reindeer herders' snow knowledge in climate change research related to the Sámi area in Finland, Sweden, and Norway. Our results show that snow plays multiple roles in the lives of reindeer herders. The extreme snow conditions of recent years have had a significant negative impact on reindeer herder well-being, and at the same time, snow is connected to happiness, sense of place, and cultural continuity. The embeddedness of snow with different kinds of cultural and intrinsic meanings should receive more attention in research on the impacts of climate change on the lives of Sámi and other Arctic peoples. In the literature we analyzed, the snow knowledge of Sámi reindeer herders was constructed in multiple ways. This practical knowledge system informing, as it does, daily activities and assessments of the future, is not only crucial for reindeer herders themselves, but also for society at large, as it can enhance education and bring important insights into climate change research and adaptation.

Keywords: climate warming; snow change; reindeer herding; Sámi Homeland; Indigenous people

RÉSUMÉ. La neige joue un rôle important dans la vie des Sámis éleveurs de rennes. Les changements caractérisant l'état de la neige peuvent donc avoir des incidences sur leur bien-être de plus d'une manière. Cependant, il arrive rarement que les recherches sur l'élevage des rennes et le changement climatique tiennent compte des significations de la neige et des émotions qui s'y rattachent. À partir d'entretiens thématiques avec des éleveurs de rennes faisant partie de deux coopératives d'élevage de rennes dans la patrie des Sámis en Finlande, nous avons analysé les rôles et les significations de la neige pour les Sámis éleveurs de rennes de même que les conséquences des événements météorologiques hivernaux extrêmes des dernières années sur leur bien-être. De plus, le dépouillement de la documentation nous a permis de considérer le rôle que jouent les connaissances de la neige détenues par les éleveurs de rennes dans la recherche sur le changement climatique touchant la région occupée par les Sámis en Finlande, en Suède et en Norvège. D'après nos résultats, la neige joue de nombreux rôles dans la vie des éleveurs de rennes. Les conditions extrêmes des dernières années en matière d'enneigement ont eu d'importantes incidences négatives sur le bien-être des éleveurs de rennes. En même temps, il y a lieu de savoir que la neige est liée au bonheur, au sentiment d'appartenance et à la continuité culturelle. La recherche sur les incidences du changement climatique sur la vie des Sámis et d'autres peuples de l'Arctique devrait porter davantage sur le rôle de la neige dans différentes significations culturelles et intrinsèques. Dans la documentation que nous avons analysée, les connaissances de la neige par les Sámis éleveurs de rennes avaient de multiples facettes. Ces connaissances pratiques éclairent, en réalité, les activités quotidiennes et les évaluations de l'avenir, ce qui revêt une importance primordiale non seulement pour les éleveurs de rennes, mais aussi pour la société en général, car elles peuvent permettre de rehausser la sensibilisation et de jeter de la lumière sur la recherche sur le changement climatique et sur l'adaptation qui en découle.

Mots-clés : réchauffement climatique; changement de l'enneigement; élevage des rennes; patrie des Sámis; peuples autochtones

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INTRODUCTION

The seasonality and physical properties of snow are central to the lives of Indigenous Sámi people and others throughout the north and regulate critical ecosystem properties and services (direct and indirect contributions ecosystems provide to humans) (Rixen et al., 2021). Because snow cover dominates the annual Arctic cycle of life, with distinct seasonality (i.e., snow on; snow off; snow depth variation), the Sámi have a calendar that is traditionally divided into eight seasons: summer, autumn-summer, autumn, autumn-winter, winter, spring-winter, spring, and spring-summer. This calendar is the basis for the rhythm of their life (Fig. 1). These seasons of Sápmi, the traditional Sámi land, are each characterized by a unique combination of weather, cultural practices, and livelihoods that reflect local adaptations to the climates of the north.

However, over the last decades, characteristics of the seasons, duration of snow cover, and the amount and structure of snow in Sápmi have changed. The average temperature has risen by 2.3°C since the post-industrial period, in particular during autumn and early winter, and the snow-free season is becoming longer (Turunen et al., 2016; Kivinen et al., 2017; Luomaranta et al., 2019; Rasmus et al., 2020). According to a recent study, the Arctic has warmed nearly four times faster than other regions of the globe since 1979 (Rantanen et al., 2022), with an entire range of consequences, including changes to the quality of caribou and reindeer forage (Richert et al., 2021).

Snow constitutes the basis for one of the most important traditional Sámi livelihoods, reindeer herding. Snow conditions determine the success of the reindeer year, and snow forms a significant ecological factor for behaviour, life history, and population dynamics of reindeer (Helle, 1981, 1984; Helle et al., 2001; Kumpula and Colpaert, 2007; Eira, 2012; Turunen et al., 2016; Näkkäläjärvi, 2019). The impacts of changing winter conditions on reindeer herding and the adaptation of reindeer herders to effects of climate change, such as increasing or decreasing snow, have been the focus of numerous studies (e.g., Tyler et al., 2007; Maynard et al., 2010; Pape and Löffler, 2012; Furberg et al., 2013; Löf, 2013; Rasmus et al., 2016; 2020; 2021; Turunen et al., 2016). These studies indicate that dramatic increases in snow can have serious consequences for reindeer by reducing their movement and causing excessive vulnerability to predators such as wolverines, and by leading to dramatic increases in the need for human management of herds, especially winter hay feeding.

As a result of climate warming and sea ice loss over the last decade, there has been an increase in rain days and thaw–freeze events during the winter whereby extensive ground ice occurs more frequently on reindeer pastures (Rasmus et al., 2018; Hansen et al., 2019). In recent years, reindeer herders in Northern Fennoscandia have needed to cope with extremely difficult snow conditions, driven in large part by the absence of sea ice in the Barents Sea (Bailey et al., 2021). During winter 2019–20, exceptionally great snow depths led to big losses of reindeer (Kumpula et al., 2020), and during winter 2021–22, pasture conditions were unusually difficult in some parts of the herding area due to ground-ice and mold formation (Sámediggi, 2021; Kumpula et al., 2022).

While the economic costs of climate change on reindeer husbandry have not yet been calculated (Ocobock et al., 2022), in general, the economy of reindeer herding can be negatively affected by variability of winter weather (Pekkarinen et al., 2022). We know, for example, that excessive use of feed (hay, silage, pellets) is required, which can be expensive, that snowmobile travel requiring gas increases to rescue snow-trapped reindeer, and that additional herder time is required, taking time away from, for instance, secondary sources of income at salaried positions. These new Arctic conditions can also affect other traditional livelihoods, such as fishing and hunting (Näkkäläjärvi et al., 2020; Metsähallitus, 2022), and snow conditions are important for winter tourism. Moreover, land use (e.g., forestry) and natural resource governance exert additional pressure on reindeer herding and the Sámi way of life (Landauer et al., 2021), making adaptation to changing climates more difficult, yet increasingly necessary.

Throughout their history, when practising their traditional livelihoods, such as reindeer herding, fishing, hunting, and gathering, Sámi have needed to adapt to a cold climate and changing snow conditions. This is reflected in the Sámi languages, which have a rich vocabulary related to snow and ice. In her doctoral dissertation, The Silent Language of Snow, Eira (2012) points out that the Sámi languages have the richest snow terminology, maybe even richer than that of Inuit languages that, since the end of the 1800s, have been believed by linguists to have the most snow words (Krupnik et al., 2010). Detailed knowledge of snow and ice conditions has been a necessity for subsistence and survival of the Sámi people (Eira, 2012, 2022; Ryd, 2020). Moreover, traditional Sámi snow knowledge can be used in climate change studies, in part because oral history, much like meteorological data, records historical events and trends over time, such as the timing of snow on and snow off, and the frequency and regularity of extreme events (Riseth et al., 2011; Eira et al., 2012). However, even though the importance of Indigenous peoples' traditional knowledge (TK) was recognized in the 1992 Convention on Biodiversity, the Sámis' generational knowledge as a valuable source of information in research and natural resource management has been underappreciated (Peters, 2003; Turi and Keskitalo, 2014; Johnsen et al., 2015; Eira et al., 2018). Previous research suggests, however, that Sámi snow knowledge may have helped to establish and foster the idea of Sámi TK as a valid and equal counterpart to formal (western) science (DuBois, 2018), but no further studies on the subject have been conducted so far.

Snow not only shapes the conditions for traditional livelihoods in Arctic environments, but also encompasses emotional and social aspects. Indigenous peoples who

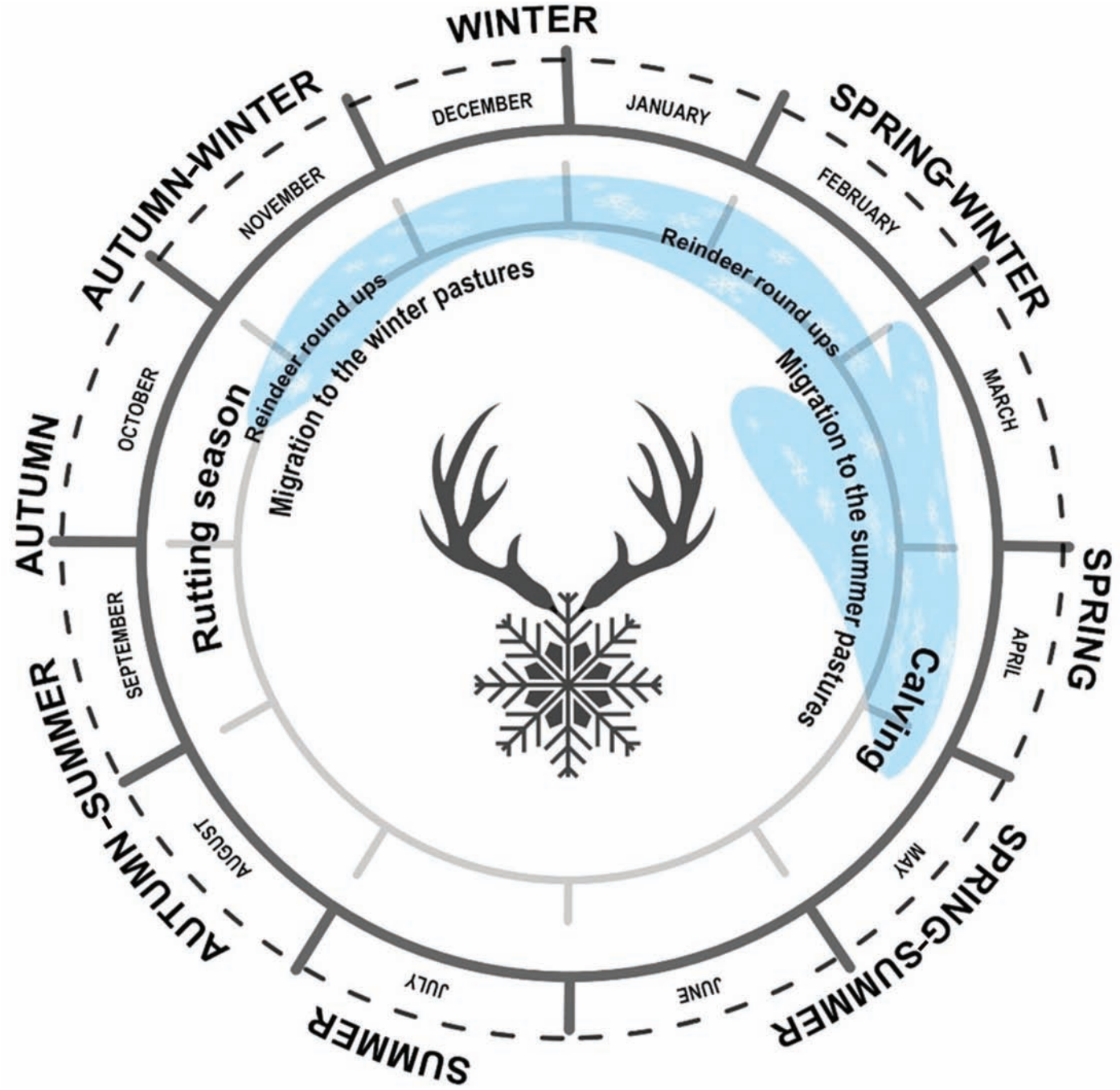

FIG 1. Seasons in reindeer life and herding in our study region. Typical snow season is marked in blue. See also Figure 3a–d. Credit: Philip Burgess.

practise traditional livelihoods have deep emotional and spiritual connections with the surrounding environment, and the rapidly changing climates and weather patterns can have a strong impact on their sense of place and connections to landscapes, including to the ecosystem services these provide (Cunsolo Willox et al., 2012; Sakakibara, 2020; Mentzen Ness and Munkejord, 2021). Winter landscapes are places of activities and practices inextricably intertwined with livelihoods and cultures. As such, they embody TK, stories, and history. Previous studies have reported that snow, ice, and winter landscapes are embued with different kinds of aesthetic, spiritual, and intrinsic environmental values (Cunsolo Willox et al., 2013; Durkalec et al., 2015; Schirpke et al., 2021; Mameno et al., 2022). However, meanings and emotions related to snow are rarely considered in research on climate change and reindeer herding.

This article deals with multiple aspects and meanings of snow, snow change, and winter landscapes. Based on a literature survey and interviews with reindeer herders in two herding co-operatives in Sámi Homeland in Finland, we examine: 1) meanings of snow for Sámi reindeer herders; 2) impacts of the extreme winter events of recent years on reindeer herder well-being and emotions within the

context of climate change; and 3) the role of Sámi reindeer herders' snow knowledge in climate change research.

Theoretical Background

Dwelling and Taskscape. Drawing, theoretically, from Tim Ingold's work on dwelling and taskscape (Ingold, 2000), this study addresses the multiple meanings of snow in connection to winter landscapes.

The idea behind the concept of "dwelling" is that landscape is a continually unfolding story that bears witness to the passing of time: "Landscape is constituted as an enduring record of—and testimony to—the lives and works of past generations who have dwelt within it, and in so doing, have left there something of themselves" (Ingold, 1993:152). According to Ingold, landscapes develop through processes of temporality; that is, time as it emerges in the unfolding of life through action. Landscapes are thus socially constructed spaces of human activity, "taskscapes." According to Ingold (2000:195), landscape is "an array of related features," and taskscape is "an array of related activities." These concepts are comparable to the Sámi concept "meahcci," and thus, are adequate for studying the meanings of snow for Sámi reindeer herders. Meahcci is often translated as nature, wilderness or landscape, but its meaning extends beyond that. For example, Joks et al. (2020:307) refer to it as "a creative collection of practical places and relations—a set of activity spaces" (see also Valkonen and Valkonen, 2018). Joks et al. (2020:310) point out that "Sámi land practices *work* [emphasis in original] the land and have no notion of wilderness or a nature–culture distinction." Thus, Sámi meahcci is less a cartographically delineated territory on a map, and more a series of circumstantial and practical task-related activities.

In this study, we understand winter and snowy landscapes as taskscapes: spaces of activities, relations, and emotions.

Árbediehtu. Sámi snow knowledge is part of their *árbediehtu*, TK, which is practical knowledge passed from one generation to the next that includes values, practices, and holistic understanding of the interlinkages between people and nature/environment. Árbediehtu is inherited throughout life in all its aspects and is the core element in Sámi culture, languages, and traditional livelihoods (Porsanger and Guttorm, 2011). We also understand Sámi *árbediehtu* and TK through the Ottawa Traditional Knowledge Principles (2014:1), in which TK is defined as:

> Systematic way of thinking and knowing that is elaborated and applied to phenomena across biological, physical, cultural and linguistic systems. Traditional Knowledge is owned by the holders of that knowledge, often collectively, and is uniquely expressed and transmitted through Indigenous languages. It is a body of knowledge generated through cultural practices, lived experiences including extensive and multigenerational observations, lessons and skills. It has been developed and verified over millennia and is still developing in a living process, including knowledge acquired today and in the future, and it is passed on from generation to generation.

By "traditional livelihoods," we mean those traditional economic or subsistence activities Sámi people have historically practised and continue to practise. By "practices," we mean actions and decisions reindeer herders make, and the organization (e.g., transport, labour) of the herding work. By "values," we refer to the non-economic social values that are associated with the environment and its goods and services (i.e., its benefits, direct and indirect, to humans).

METHODS

Study Area

Our study area includes Muotkeduoddar (Muotkatunturi) and Gálddoaivi (Kaldoaivi) herding co-operatives, which are situated in Northern Finland in the Sámi Homeland region, and in the specific reindeer herding area (Fig. 2). This area currently consists of 54 reindeer herding co-operatives, of which 13 are in the Sámi Homeland. The study area is located in the subarctic region, and the most common habitat types in the area are mountain birch forests, mountain heaths, and aapa and palsa mires. There are also pine forests in the area (Metsähallitus, 2010; 2011).

Gálddoaivi herding co-operative is situated in Ohcejohka (Utsjoki) municipality in the northernmost part of Finland. The mean annual temperature in the area is –0.7°C and mean annual precipitation is 440 mm (Jokinen et al., 2021). The area of the Gálddoaivi co-operative (2411 km^2) includes the largest wilderness area in Finland, Gálddoaivi Wilderness, where the reindeer pastures are situated. The Finnish government established such wilderness areas in 1991 to protect nature and Sámi traditional livelihoods; they were managed by Metsähallitus, Parks & Wilderness Finland. There are 78 reindeer owners in the Gálddoaivi herding co-operative, and the highest allowed number of reindeer in its area is 5300 (RHA, 2023). The northernmost part of the Gálddoaivi herding co-operative is situated in Njuorggán (Nuorgam), only about 30 km from the Barents Sea. Given the topography and proximity of the sea, weather and snow conditions vary locally between the northern and southern parts of the co-operative.

The Muotkeduoddar herding co-operative is situated in Aanaar (Inari) Municipality. The area of the Muotkeduoddar co-operative is 2580 km^2. There are 100 reindeer owners in the co-operative, and the highest allowable number of reindeer is 6800 (RHA, 2023). Important reindeer pastures in the area are situated in the Muotkeduoddar Wilderness Area and Lemmenjoki National Park, the oldest national park in Finland. The mean annual temperature in the area is

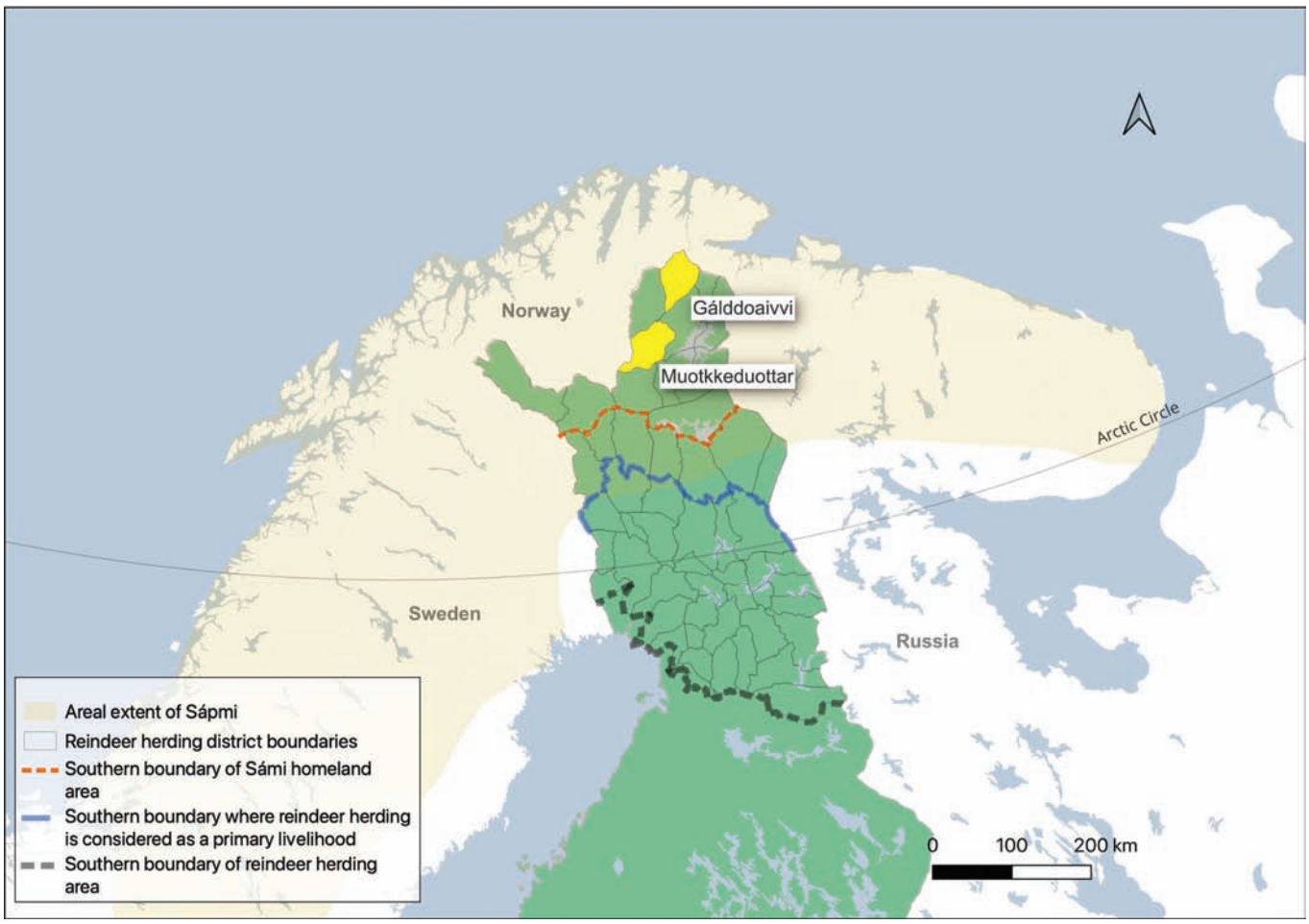

FIG 2. Map of Northern Fennoscandia (a), showing areal extent of Sápmi, southern boundaries of reindeer herding area, specific reindeer herding area, and Sámi Homeland area in Finland, as well as the boundaries of herding districts. Gálddoaivi and Muotkeduoddar are also marked. In Finland, reindeer herding is a livelihood for both Finns and Sámi, but in Norway and Sweden only Sámi people can own reindeer.

approximately –0.7˚C and mean annual precipitation is 500 mm (Jokinen et al., 2021).

Recent Snow Conditions

Northern Finland experienced an exceptionally snowy winter in 2019–20. Even during autumn, weather conditions were difficult for herding. The summer had been very dry, and by fall, mushrooms, which are an important source of forage for reindeer, were scarce. Heavy snowfall started early in the autumn and increased throughout the winter. In the areas of Muotkeduoddar and Gálddoaivi, mean precipitation during winter 2019–20 was 25–35 mm higher, and snow depth 30 cm higher, compared to the average of years 2009–18 (Kumpula et al., 2020). In addition, there was extensive ice crust formation within snowpack and mold growth on the ground under the deep snow (Kumpula et al., 2020). Snow melted in the spring one month later than usual. In late winter and spring 2020, snow depth, density, weight, hardness, and number of ice crust layers within snowpack were all higher compared to a normal year (Kumpula et al., 2020; winter 2008–09 was used for comparison). Snow conditions were very difficult for reindeer and prevented digging for forage from under the snow. This heavy-snow winter resulted in reindeer exhibiting poor physical condition, increased reindeer deaths, and significantly reduced meat production (Kumpula et al., 2020). Of our study areas, deep snow covers and ice crust formations within snowpack were recorded in Muotkeduoddar co-operative and in southern parts of Gálddoaivi, while in northern parts of Gálddoaivi, snow conditions were not as exceptional as in other regions.

Exceptionally difficult pasture conditions were also recorded in western parts of Lapland and in some parts of northern Lapland in winter 2021–22, including the Muotkeduoddar co-operative.

In mid-October 2021, a thick wet blanket of snow fell onto the unfrozen ground, then froze, forming a thick layer of ground ice. Even though snow depth and density were not different compared to a normal winter (2008–09), the hardness of the snow was particularly high in the areas of 11 co-operatives, including the Muotkeduoddar co-operative (Kumpula et al., 2022). In field studies conducted by the Natural Resources Institute Finland, ground ice was found in all 15 study locations in Muotkeduoddar (Kumpula et al., 2022). Wet autumn conditions were also favourable for

growth of mold. Mold dramatically decreases the quality of pastures and forage, which can cause reindeer herds to disperse in different directions in search of better forage. Plants and lichen affected by mold can be toxic for reindeer and cause illness. In field studies, three kinds of mycotoxins were found in reindeer pastures in the Muotkeduoddar co-operative (Kumpula et al., 2022). Because of ground ice, reindeer were unable to dig for food, and mold formation on pastures made the natural forage inedible and resulted in reindeer migration (Kumpula et al., 2022). Many of the herding co-operatives that were impacted by extreme winter-time weather events in 2021–22 had also experienced a difficult winter in 2019–20 (Kumpula et al., 2022).

Interviews

We conducted thematic interviews with 15 Sámi reindeer herders in the Gálddoaivi and Muotkeduoddar herding co-operatives between January and December 2022. Our study consists of 11 interviews carried out as part of the Interacting Processes in Arctic Reindeer Systems Experiencing Rapid Climate Change Project, and five interviews as part of the Global Drivers, Local Consequences: Tools for Global Change Adaptation and Sustainable Development of Industrial and Cultural Arctic 'Hubs' Project. One person took part in interviews for both projects, and thus the total number of participants was 15. The themes of the first 11 interviews included meanings of snow, experiences of extreme weather events, coping during difficult winters, and the future of reindeer herding. The themes of the five additional interviews consisted of observations of environmental change, including changes in snow and pasture conditions; land use; land use-related conflicts; and impacts of land use and environmental change on herding practices. In the first 11 interviews, participants were asked directly about their relationships with snow, while in the additional five interviews, the snow theme emerged during the interviews.

Participants included 12 males and 3 females aged between 19 and 65, and all were actively involved in reindeer herding. The number of years the participants had been professionally practising reindeer herding ranged from three to over 40, but all of them had been involved in some capacity in herding since childhood. Reindeer herding was the main occupation for 11 participants, while four had permanent jobs (e.g., in education or social services). However, the majority of participants with herding as their main occupation also had part-time jobs, for example, seasonal jobs in tourism. It is common among Sámi reindeer herders to practise a combination of livelihoods, and herders who have full-time jobs elsewhere try to organize their work in a way that enables their participation in important herding activities, for example, roundups and calf marking.

Interviews were conversational and semi-structured, and lasted one hour on average, ranging from 30 minutes up to two hours. The authors (IM, TR, VK) conducted and recorded the interviews. One participant did not want the interview to be recorded, and thus the interviewer took written notes. The first 11 interviews were transcribed by one of the authors, and the additional five by Tutkimustie Oy Research Services. Quotes from the interview transcripts presented in the text and table were translated by the authors from Finnish, the language of the interviews. Participants were informed about the aim of the study and how the material was going to be used and were asked for consent before the interviews. The interview themes were discussed prior to the interviews with representatives of the herding communities who could express their views on the study setting and suggest themes they considered important. The interviews were conducted in herding co-operatives where collaboration between researchers and herders has lasted for several years. Previously, herders and researchers collaborated in collecting material on reindeer movement and diet, and the researchers took part in reindeer winter feeding and roundups.

Following the Ottawa Traditional Knowledge Principles, we did not collect TK. Also, as non-Sámi researchers and non-Sámi speakers, we could not discuss the meanings of snow with the participants using Sámi terms. For these reasons, our discussion of Sámi snow knowledge and snow lexicon is based on literature. However, our interviews revealed interesting aspects of snow that we believe are worth discussing. Also, all participants were fluent in Finnish, and most of them had previous experience talking about climate change-related themes in Finnish. One third of the participants identified as bilingual, having both one of the Sámi languages and Finnish as their first language.

Literature Survey

We conducted a literature survey to analyze the extent to which Sámi snow knowledge has been considered in studies about climate change and its impacts on Sámi culture and reindeer herding in Finland, Norway, and Sweden. First, we performed a search in Google Scholar with the keywords "Saami/Sámi AND climate change/climate warming/global warming"; and "reindeer herding/husbandry AND climate change/climate warming/global warming." To ensure that all studies on Sámi snow knowledge were included, we did a second search with the keyword combinations of "Saami /Sámi traditional knowledge"; "Saami/Sámi traditional ecological knowledge": Saami/Sámi Indigenous knowledge"; and Saami/ Sámi reindeer herders' knowledge AND climate change/climate warming/global warming."

For the purpose of this study, we included scientific articles, book chapters, and reports published in English before or during 2022. Academic theses and popular science papers were excluded. We included only studies that concentrated on climate change and Sámi people and excluded studies dealing with other Indigenous peoples in the Arctic or Arctic Indigenous peoples in general.

We included studies focusing on climate change and reindeer herding in Norway and Sweden. Studies from

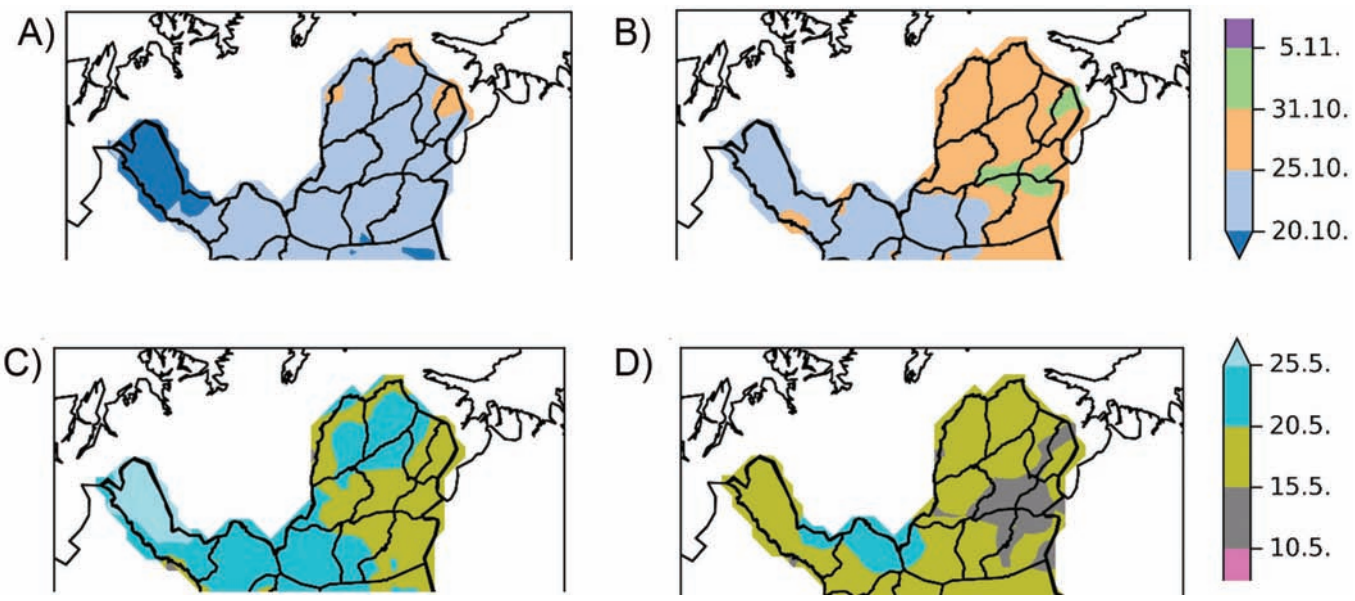

FIG 3a-d.Average snow cover formation date (day/month) in 1961–90 (a) and 1991–20 (b); average snow cover melt date (day/month) in 1961–90 (c) and 1991–2020 (d). Graphs: Philip Burgess (a) and Ilari Lehtonen (b–d). Data for b–d: Finnish Meteorological Institute.

Finland were included if they were conducted in or included Sámi Homeland region. Studies dealing with climate change mitigation actions were also included. After the literature search, we took a closer look at climate change studies that dealt with Sámi snow knowledge and analyzed them using thematic content analysis (Tuomi and Sarajärvi, 2009). We sought to identify patterns in how Sámi snow knowledge was understood and presented in the research papers. From the materials we analyzed, we identified six categories of roles played by Sámi snow knowledge.

RESULTS

Meanings of Snow

In the interviews, we observed that snow carries both personal and shared meanings in the lives of Sámi reindeer herders. Snow plays different roles in the participants' lives: it is an important part of seasonality and the circle of life, a carrier of culture, a bringer of light and happiness, and a means of documenting movement. The herders brought up concerns over the change in the Sámi life cycle, which is based on eight seasons (Fig. 1). According to participants, winter is generally shorter than it used to be: first snow comes later, then snow melts earlier (Fig. 3a-d). Of the eight seasons, summer–autumn, autumn–winter, winter–spring, and spring–summer are most affected. However, there is local variation. Participants described the changes:

> Winter is nowadays one month shorter than before.

> First snow comes later. Snow is unpredictable, you don't know what will happen.

> Autumn lasts longer. There used to be permanent snow on the ground before mid-October. [Now] it's fifteen, even twenty degrees in the autumn. In the old times snow came in mid-October and it stayed on the ground.

> Last winter there was very little snow until January. Spring came early, and snow came late. There was so little snow that we could not drive snow mobiles before January.

> There was no snow in the forest on the twenty-fifth of January. It felt like May.

Timely snowfall in the autumn is important, as snow is a precondition for the start of reindeer roundups. A herder from Muotkeduoddar described the feelings of happiness that snowfall in autumn brings:

> It feels like love … in the autumn when snow starts to fall, and you know it is your season now. When snow falls you know that reindeer roundups start. It also means you get money. It is something you really wait for, the snow to fall and the roundups to start.

Timely roundups are important for the success of reindeer herding work. Absence of snow or icing of pastures can cause delays in roundups because reindeer herds disperse (see also Turunen et al., 2016). If herders use snowmobiles for gathering and moving reindeer to roundup sites, the roundups cannot begin until there is enough snow. Late formation of ice cover in rivers and lakes can also result in delays in roundups. Good conditions for roundups include sufficient snow, dry weather, and temperatures well below freezing. The later the roundups take place, the less money herders will get for their year's work (Laptander et al., 2024).

Early snowmelt in spring is beneficial for reindeer: more forage is available, and warmer temperatures are good for newborn calves. However, early snowmelt and thin ice cover on lakes and rivers can slow down reindeer migration and make it difficult to guard reindeer against predators (Laptander et al., 2024). Both young and middle-aged herders noted that rapid changes and unpredictability in winter weather challenge their ways of knowing: their TK of weather, seasons, and travel routes is no longer useful, and there is a need to constantly develop new knowledge. Unsafe ice conditions and early snowmelt also affect spring activities, such as skiing and ice fishing.

> This year was close to normal, you could still go ice fishing on first of May and on Mother's Day. It was like in the old times, when ice conditions were good, when it was normal.

Changes in seasons also impact the Sámi way of life through changes in the abundance of culturally important species:

> Sámi life circle and reindeer herding are based on and follow the rhythm of seasons and weather. Each season has its own meanings and actions. When winter comes later and spring comes earlier, it means that certain actions and traditions diminish. Also, due to warming, species which are adapted to cold, those which spawn in cold water, trout for example, are decreasing. And species which spawn in spring will thrive. There is a change in game species and consequently change in culture, because of trout decrease we will catch more pike and perch.

One participant noted that despite the changes, in northern Finland, as opposed to the southern parts of the country, you can count on snow coming every winter.

> Winters in southern Finland are so dark nowadays [because of lack of snow]. Here you can still experience the seasons.

Snow is a carrier of culture and brings joy when one can follow the rhythm of the seasons:

> Our rhythm of life is connected to snow in certain ways, snow is part of our life, and I can't imagine living without it. If you think of all the snow activities, ice fishing, winter fishing with nets, skiing and driving with snow scooters, and that you can put lots of clothes on and then again wear less clothes when the spring comes. And during winter when it is cold and snow is dry you can wear shoes made of reindeer fur, that is so nice.

When asked what snow means to them, many herders mentioned light that snow brings during dark winters.

> Snow brings the light. Kaamos [polar night] does not feel so dark, because there is snow.
>
> At first, snow brings the light in the autumn. When the land is black and snow falls, it lightens up the whole landscape.

Moreover, snow is essential for winter travel and tracking. A herder from Gálddoaivi described how snow documents life and movement:

> Snow tells you so much. All the tracks caught on snow tell you who has been at that place and what has happened, you can just read everything from the snow […] And then snow changes the ways of movement completely when winter proceeds, it covers all the rocks and hummocks in peatlands.

When asked if they could imagine life without snow, the participants said they could not. One participant said snow was the reason to live so far in the North.

> I could not live without snow. Why would we live here if there was no snow?

Total loss of snow is an unlikely scenario in the Sámi Homeland region. However, later snowfall in the autumn and great variation in winter-time temperature can lead to longer snow-free periods during winter. Lightness and whiteness brought by snow can be very important for the well-being of people living far north under extreme light conditions, which is well illustrated in the words of a herder from Gálddoaivi:

> It would be too much if there were no snow here during polar night, it is already dark enough here during winter, and that would be too much. I hope I'll never have to see that day.

The Most Difficult Winters of Our Lives

Snow conditions in the Sámi Homeland are changing. According to reindeer herders who participated in our study, rainy winter days and freeze/thaw events leading to ground-ice conditions and ice-layer formation within snowpack have become more common during the last 10 years. Exceptional weather events have also become more severe, which was illustrated in the interviews. Herders from Muotkeduoddar referred to the winter of 2021–22 as the most difficult during their whole lifetime, and herders from the southern parts of Gálddoaivi described the winter of 2019–20 as the snowiest they had ever seen. Snow conditions in the northern parts of the Gálddoaivi co-operative were close to normal in 2019–20, while herders in the area had experienced difficult winters with extensive ground-ice conditions in 2013 and 2017. Table 1 presents quotes from the interviews regarding snow conditions.

Herders' main coping strategy during difficult winters is supplementary feeding of reindeer (Turunen and Vuojala-Magga, 2014; Turunen et al., 2016). Reindeer are taken into enclosures and given supplementary feed daily or are fed with supplementary feed in their natural pastures (Turunen and Vuojala-Magga, 2014). Other strategies include increased control over herds, intensified utilization of pasture diversity, pasture rotation, and use of reserve pasture areas (Turunen et al., 2016). Supplementary feeding is not considered a culturally sustainable way of herding in parts of Sámi Homeland. However, in Gálddoaivi, the herders emphasized that a long history of regular supplementary feeding (almost 30 years) helped them to cope with difficult snow conditions in winter 2019–20 because their reindeer were used to foraging on hay, and the herders had proper equipment and capacity for hay production. Over the past decades, when extensive supplementary winter feeding was not practised, difficult winters led to big losses of reindeer. However, there are still reindeer losses in difficult winters despite supplementary feeding.

In Gálddoaivi, reindeer are fed with hay mainly in their natural pastures, while in Muotkeduoddar, reindeer are given hay or pellets either in enclosures or in their natural pastures. Supplementary feed is also provided in normal winters, but the amounts are much smaller and the period of feeding much shorter than in difficult winters. Extensive supplementary feeding increases the costs of herding dramatically because of the high costs of feed and transportation, making it harder to earn a living as a herder. The winters of 2019–20 and 2021–22 were concrete examples of that in the herding co-operatives we studied. According to the herders, they had to feed the reindeer for two months longer than usual (Table 1). Feeding costs during winter 2019–20 were, on average, 80%–90% higher compared to years with normal snow conditions (Kumpula et al., 2020).

All participants mentioned the increased costs as the main consequence of extreme winter weather events. Extensive supplementary feeding, together with more intensive herding of reindeer, increased the workload of the herders. Some of the herders had part-time jobs besides herding that allowed them to cover the costs of supplementary feed, further increasing their workload (Table 1).

Difficult winters caused two kinds of uncertainty among herders: short-term uncertainty about weather conditions over the next week or month, and long-term uncertainty about the future of reindeer herding as a livelihood. Both the extreme weather events themselves and their consequences, and in particular, the high costs of supplementary feed, had an impact on herders' future prospects. This emerged in the interviews with the herders who had experienced recent extreme weather events. However, herders in the northern part of Gálddoaivi, who were not so heavily impacted by unusual weather event in winters 2019–20 and 2021–22, were also worried about the acceleration of global warming and the future of their traditional livelihood (Table 1).

It should be noted, however, that many of the herders emphasized that reindeer herding is a very adaptive livelihood. Reindeer herding is considered an important feature of Sámi culture, values, and traditions, and forms a central part of the identity of herders. This is well illustrated in the words of a herder from the Muotkeduoddar co-operative:

> Well, the future does not seem very bright, but this is our way of life, our tradition. I would never give up on herding. […] When you are born to be a herder, it is in your blood, in your heart […] Even when the snow conditions get very bad and we lose reindeer, we don't give up. This is how it goes. But if you get nothing you have to stop at some point…but we will try to live this way until the last one.

Participants also noted that other land uses are as important as, or even more significant than, climate change in shaping their future.

> We will survive, we always have survived […] and it is not the changing climate but the land use that will put an end to reindeer herding if anything.

Thus, while climate change stresses herders, questions about how lands will be used in the future (for example, through increased forestry) are also sources of stress.

> This threat [from land use] impacts your mental well-being and your ability to cope. It is hard when you constantly need to defend your livelihood.

Reindeer herders from both Gálddoaivi and Muotkeduoddar estimated that in the future there will be fewer herders due to increased competition caused by compounding negative effects of land use and climate change. This may lead to a situation in which defending reindeer herding as a livelihood becomes even more difficult.

> Reindeer herding is a very adaptive livelihood, and we have adapted so far. But I think that the herding units need to be bigger, they need to grow. Which means that in the future there will be less of us. And when there are less herders and less people living from reindeer herding, it gets harder to compete with other land users and other means of land use.

Sámi Reindeer Herders' Snow Knowledge in Research

Our search for research literature on climate change and Sámi people resulted in 71 research articles, book chapters, and reports. In 33 of these, Sámi TK was the main topic or one of the main topics. Papers dealing with Sámi TK discussed general impacts of climate change on Sámi traditional livelihoods and knowledge; Sámi people's

Table 1. Quotes from reindeer herders describing difficult winters and their impacts on their lives (See also Markkula et al., 2024).

Exceptional winters	Impacts on livelihood	Well-being and future views
It has happened during the last 10 years, the winter conditions are getting more and more difficult, at least here, there are often these winter conditions with ground ice and ice layers within and on snow. This winter [2021–22] was like that and winter 2019–20 too. Last winter [2020–21] was good though.	If this goes on like this, we need to feed reindeer every year and it costs a lot. All the money we have will be spent on feeding costs.	I am very concerned, afraid of what's going to happen. Is it possible to continue [herding] this way. Maybe I still can but what about the next generations? Are there no longer prerequisites for herding? Can reindeer live here, or anything or anyone?
Winter 2019–20 was astounding. I have never seen that much snow before. Of course, there has been lots of snow before too, but nothing like this during the time that I have been active in herding [40 years].	It gets very expensive, when you need to feed the reindeer for almost 100 days. And there will be losses anyway.	It's three months with constant stress about the weather and snow conditions.
In winter 2019–20 there was so much snow here. My grandfather said he had never seen that much snow here. I remember when we were gathering reindeer up in the fells and there was so much snow in places where snow cover is usually quite thin at that time of the year. We were just digging and digging, and it seemed like we are never going to reach the ground.	In southern herding districts they start supplementary feeding already in November. We may have to do the same in the future here too. And that increases the costs and workload quite a lot.	In the evening, when I go to sleep, I often think about the future, whether reindeer herding still exists 20 years from now. […] I don't know, at the moment reindeer herding is profitable here. But in 20 years, who knows if it is even allowed to have reindeer anymore.
We had awful a lot of snow here [in winter 2019–20]. It was terrible.	I have a daytime job and then on my free time I feed the reindeer. And if there is any time left, I work more, do translations for example, so I can cover the costs of supplementary feeding.	Future looks bright, at least for now. But climate change is a big threat, if it is really getting so much stronger, it looks like that now. I don't know, we just need to see what future brings. It may be that climate change gets stronger after ten years or it gets stronger next year, I don't know really.
Winter 2013 was the worst in near history. There was a 5 cm layer of ice on reindeer pastures everywhere. Also, in February 2017 it was raining for two days in a row, and then it got cold again. It was unbelievable. Snow turned into ice, and it was just ice until the bottom everywhere.	If this kind of winter conditions, when there are ground ice and ice layers within snowpack, become more frequent, reindeer herding gets very difficult.	The only option is supplementary feeding. And considering the high costs, you may no longer earn living from herding.

observations of changes, adaptation, and vulnerability of reindeer herding under changing climate; the role of TK in climate-driven disease prevention; the role of TK in decision-making in the context of climate change; impacts of techno-scientific knowledge on TK in the context of climate change; health impacts of climate change and traditional medicine; TK regarding vegetation dynamics under changing climate; and TK regarding moth outbreaks and their ecosystem impacts. Sámi TK related to snow, ice, and winter weather conditions was discussed in detail in 19 papers. Table 2 details the six themes we drew from these overall topics.

Snow knowledge was presented as a counterpart to science, in particular in research papers written by Sámi scholars (Oskal, 2008; Magga et al., 2009; Maynard et al., 2010; Riseth et al., 2011; Eira et al., 2012, 2018; Eira, 2022; Rosqvist et al., 2022). In these works, snow knowledge was described as a knowledge system that has the same characteristics as science, while being holistic in nature. According to Eira (2012:128), the holistic nature of Sámi snow knowledge becomes evident when two knowledge systems, formal scientific knowledge and traditional snow knowledge, are compared:

> The reindeer herders tend to consider the whole winter season and how the snow and weather conditions might influence their future economy and the condition of the herd. The richness of Sámi traditional snow terms shows a distinctly different view of snow compared to the purely physically-based international classifications. Herders characterize snow cover, temperature, moisture, wind, behavior of the herd, and condition of the animals [in relation to snow conditions].

In many papers, Sámi herders' knowledge of snow and ice was presented as a system that combines two ways of knowing: traditional and scientific (Oskal, 2008; Maynard et al., 2010; Riseth et al., 2011; Eira et al., 2012; 2022). Snow knowledge was presented in papers by Sámi scholars as a counterpart to science, where the knowledge system shared characteristics of science while being more holistic in nature (Oskal, 2008; Magga et al., 2009; Riseth et al., 2011; Maynard et al., 2011; Eira et al., 2012, 2018; Eira, 2022; Rosqvist et al., 2022) (Theme 1).

Because of its exactness and holism, snow knowledge can guide science and natural resource management (e.g., Roturier and Roue, 2009; Riseth et al., 2011; Roturier,

Table 2. Six themes of Sámi snow knowledge identified from research articles.

Theme	References	Meaning/context of use	Example quote
1. Snow knowledge as a counterpart to science	Oskal, 2008; Magga et al., 2009; Riseth et al., 2011; Maynard et al., 2010; Eira et al., 2013, 2018; Eira, 2022; Rosqvist et al., 2022	Contributes to climate change research, Sámi perspective	"[Snow knowledge] encompasses theoretical models and practical reindeer herding that are linked to different types of science and knowledge, such as hydrology, meteorology, biology, topography, reindeer herding, animal welfare, land management, adaptation strategies to climatic conditions etc." (Eira, 2022:184)
2. Snow knowledge as a guide to science and natural resource management	Riseth et al., 2011; Roturier, 2010; Roturier and Roue, 2009	Contributes to climate change research and land use planning, Sámi perspective	"TEK-holders tend to observe a greater range of changes than do scientists and also that scientists do not realize the importance of some changes. However, the measurements made by scientists have high quality with measured uncertainties, and can be generalized over large areas while being projected into the future." (Riseth et al., 2011:214)
3. Snow knowledge as a part of local observations that can contribute to climate science, and as part of local community perceptions of climate change	Furberg et al., 2018; Markkula et al., 2019; Rasmus et al., 2020; Rosqvist et al., 2022	Contributes to climate change research, researcher perspective outside Sámi community	"In places where meteorological sensors and people are collocated, mixed methods research can reveal a richer understanding of the specific mechanisms by which climate change affects society. […] In places where no meteorological sensors exist, the traditional knowledge of local people may provide equally useful information." (Furberg et al., 2018:85)
4. Snow knowledge as a precondition for sustainable reindeer management and key for survival and adaptation in the past, now and in the future	Magga, 2006; Magga et al., 2009; Oskal, 2008; Roturier and Roue, 2009; Riseth et al., 2011; Maynard et al., 2010; Eira et al., 2013, 2018; Eira, 2022; Axelsson-Linkowski et al., 2020; Vuojala-Magga et al., 2011; Turunen et al., 2016	Crucial for climate change adaptation and for coping in difficult winters, as well as for reindeer herders' livelihoods as a whole.	"Weather and snow conditions are almost wholly decisive for the reindeers' survival and important for the existence and livelihoods of reindeer-herding communities. […] Successful herding depends on good skills in analyzing everyday conditions, but even more on maintaining an overview of anticipated development throughout the snow season." (Eira, 2022:181)
5. Snow knowledge as evidence of the deep relationship between Sámi and their environment	Magga, 2006; Eira et al., 2018	Reveals the connections between snow and Sámi culture, and meanings of snow	"Knowledge about snow and snow conditions has been developed because of their necessity to survive under extremely challenging and constantly changing climatic conditions." (Eira et al., 2013:118) "The physical environment leaves its mark on every culture. The Saami culture bears evidence of a long, intimate relationship with the Arctic environment and Saami languages have a rich terminology for reindeer, snow, and ice." (Eira et al., 2013:118)
6. Snow knowledge as a knowledge base that can provide education and new insights into the natural environment	Magga, 2006; Magga et al., 2009; Eira, 2022	Contributes to education and planning	"All this is a manifestation of the knowledge among the Saamis acquired through generations of observation and experience. By analysing this kind of [snow] terminology, we would probably learn a lot about snow and ice conditions in the Arctic and living conditions for animals and human beings.[…] This could be one of the sources to more insight into this environment, which perhaps could be a valuable supplement to other kinds of knowledge sources in these times when we have had many reports on dramatic climate changes in the Arctic." (Magga, 2006:25)

2010). In research articles written by mainly non-Sámi scholars, snow knowledge was seen as an important body of knowledge and observations that can support scientific research, increase the depth of knowledge regarding climate change impacts, and create holistic and in-depth understandings of the interaction between nature and humans (Furberg et al., 2018; Markkula et al., 2019; Rasmus et al., 2020; Rosqvist et al., 2022) (Themes 2 and 3).

Snow knowledge was described as practical knowledge that could be learned in nature and in daily work with

reindeer and informs both daily activities and future assessments. Reindeer herders use their snow knowledge when making predictions regarding the whole winter season and about how snow and weather conditions might influence their future economy and the condition of their herd. Snow knowledge was described as a system of knowing that is important for analyzing everyday conditions and for maintaining an overview of anticipated developments throughout the snow season (e.g., Maynard et al., 2010; Eira, 2022). The diverse snow vocabulary plays an important role in sustainable reindeer management. Eira (2012) talks about Sámi snow language, which is foundational to the herders' TK regarding reindeer and the management of the herd on snow-covered landscapes. There are 470 words for snow, ice, and weather in North Sámi language (Näkkäläjärvi et al. 2020), and according to Eira et al. (2018), reindeer herders in the Guovdageaidnu area use 318 words to designate various types of snow and snow conditions (Theme 4).

Snow knowledge is and has always been crucial for survival under exceptional weather and snow conditions and, as part of reindeer herders' TK, facilitates adaptation and coping during difficult times (Vuojala-Magga et al., 2011; Turunen et al., 2016) (Themes 4 and 5). The character of snow knowledge has emerged and continues to evolve through the intimate relationship between Sámi and their Arctic surroundings (Magga, 2006) (Theme 5).

According to the literature we analyzed, Sámi snow knowledge has great importance for Sámi themselves and for society at large, as it can provide insights into climate change research and adaptation and holds great promise to inform science and education. Understanding the different dimensions and contexts of Sámi snow knowledge could probably enhance its recognition and integration into climate change politics (Theme 6).

DISCUSSION

Winter Landscapes and Meanings of Snow

Snow and winter landscapes are central elements of life in the North, which is reflected in the multiple meanings of snow in the lives of reindeer herders and the rich snow vocabulary of the Sámi languages. Winter landscapes are places of interactivity and adaptation, embodying the knowledge of current and past generations. Futures, too, are embedded in winter landscapes, as reindeer herding, as a livelihood, depends on good snow conditions, and reindeer herders build their future through different adaptation activities.

Joks et al. (2020:315) point out that, in the Sámi context, landscapes are processes rather than spaces. Landscapes are better understood as unfoldings instead of regions, and they "are being composed in liveliness, filled with it." According to Ingold (2000:192):

> A place owes its character to the experiences it affords to those who spend time there—to the sights, sounds and smells that constitute its specific ambience. And these, in turn, depend on the kinds of activities in which its inhabitants engage. It is from this relational context of people's engagement with the world, in the business of dwelling, that each place draws its unique significance.

This engagement with the world is reflected in the meanings of snow, in the happiness felt when snow lights up the landscape, and the readiness experienced when first snow falls, and reindeer roundups can start. Winter landscapes are places of activities that are tied to a certain time of the year and certain circumstances, such as reindeer roundups, ice fishing, skiing, or driving snowmobiles. Winter landscapes are filled with liveliness. Winter landscapes draw their significance from dwelling activities, as they are composed of, for example, migration routes, travel routes, reindeer pastures, places of supplementary feeding, and roundups. Winter dwelling activities are informed by Sámi snow knowledge, which captures yearly and local variations in snow and weather conditions.

Meanings and emotions connected to snow are rarely included in studies addressing the impacts of climate change on livelihoods and well-being. As a response to this, we documented aesthetic, cultural, recreational, and intrinsic values that snow and ice entail. Similar values have only been documented in a few previous studies. For example, a study by Middleton et al. (2020) illustrated the connections between weather, snow, ice, and Indigenous peoples' well-being. In a study conducted in an alpine national park, snow patches were shown to have an important aesthetic value, and the disappearance of snow patches decreased park visitors' appreciation for the alpine landscape (Mameno et al., 2022). Another study demonstrated that forest recreation in the snow during winter enhances mental health among young adults living in urban areas (Bielinis et al., 2019). MacDonald et al. (2013) described the feelings of loss connected to winter, snow, and ice among young Inuit living in Nunatsiavut, Canada, who emphasized that valuable aspects of their lifestyle and cultural identity were very much dependent on snow and ice.

Snow, as part of seasonality and the circle of life, as a carrier of culture, and as a bringer of light and happiness, plays an important role in the lives of the reindeer herders who participated in our study. Similar emotions and meanings associated with snow and seasonality have been reported by Middleton et al. (2020) among Inuit in Nunatsiavut, Canada. Weather profoundly influenced the daily emotions and mental well-being of participants of the study, who also expressed the importance of seasons and predictable, cyclic trends in weather. The participants said that they "really need the seasons" (Middleton et al., 2020:6) and described how land-based activities connected to different seasons bring joy and happiness. They also described how snowfall elicited joy and positively impacted

their mental well-being, and how the first snowfall made them feel closer to land (Middleton et al., 2020). In line with our findings, they expressed concern over shorter winters. Finally, participants in that study reported experiences of shorter winters, faster thawing in spring, and warmer autumns, and connected changes in seasonality to concerns about their mental well-being.

Snow Conditions and Livelihoods

Snow conditions and the eight seasons of the Sámi Homeland are changing. Reindeer herders we interviewed reported that the snow season is getting shorter, autumn-winter is almost absent, and summer comes earlier and lasts longer; this finding is in line with previous studies (Furberg et al., 2018; Näkkäläjärvi et al., 2020). Future climate scenarios indicate that mean winter temperatures may increase by approximately five, or even up to eight, degrees over the next 100 years in Sámi Homeland (Benestad, 2011). While this may continue the trend of snow cover forming later and melting earlier, what remains unknown is the impact on the amount of snow during the snow season (Räisänen, 2008; Hanssen-Bauer et al., 2017; Rixen et al., 2021). Climate projections suggest that, in the north, snow depth may be even thicker than today, at least in the medium term (i.e., over the next few decades), which would affect reindeer and caribou across the north, including in terms of migration timing, winter range selection, and herd productivity (Pedersen et al., 2021). Moreover, the loss of sea ice is providing new, open Arctic Ocean water as a source of evaporation that is fueling extreme events (Klein et al., 2015) including massive snow events, such as those experienced in northern Finland and western Europe (Bailey et al., 2021). For reindeer herders in our study, more frequent extreme weather events were the most worrying climate-related phenomenon by the reindeer herders, and the extreme snow conditions experienced in winters 2019–20 and 2021–22 had significant direct and indirect negative impacts on their well-being. These included increased workload, costs, and stress, and concerns over the future of reindeer herding as a livelihood and cultural continuity, which are shared issues across Sápmi (see also IPCC, 2022). According to previous studies, there are three kinds of snow conditions that herders most often report as difficult: formation of ground ice and ice layers within the snowpack, exceptionally deep snow, and late snow melt (Rasmus et al., 2014; Turunen et al., 2016). All these conditions were experienced by the participants during recent years: herders reported conditions with ground ice and ice layers within snowpack in Muotkeduoddar in winters 2019–20 and 2021–22 and also in the northern parts of Gálddoaivi in 2013 and 2017. In winter 2019–20, snow depths were exceptional, and snow melted late in the spring in Muotkeduoddar and the southern parts of Gálddoaivi. Heavy snow winters and ground-ice conditions that co-occurred with bad summer and autumn conditions resulted in what reindeer herders called the most impactful of their lives. While there has long been concern over the impacts of climate change on reindeer herding, the extreme snow and ice conditions of the last years suggest that reindeer communities in the Sámi Homeland are entering a new era of uncertainty.

According to the participants and previous studies (IPCC, 2022), changing snow conditions are just one part of cumulative effects that put pressure on reindeer pastures and Sámi traditional livelihoods. For example, the need for winter feeding of reindeer is increasing because of more frequent extreme weather events, but also because of land use pressures (Rautiainen, 2024). Herders from Muotkeduoddar emphasized the importance of compound effects of difficult snow conditions and forestry. Old-growth forests where tree lichen is abundant are important winter pastures for reindeer, particularly in winters when deep and hard snow or ground-ice conditions prevent reindeer from digging for food. Forestry has led to a decrease in winter forage and caused migration of reindeer. Due to fragmentation of winter pastures, more intensive herding of reindeer is needed, which increases herders' workload. Indeed, two herders noted that long-term impacts of forestry brought about the need for winter supplementary feeding, not difficult snow conditions. In the neighbouring Muttošjávri (Muddusjärvi) co-operative, reindeer herders have participated in inventories of important lichen and tree lichen pastures. These inventories, which were based on both scientific knowledge and TK regarding winter pasture quality, indicated that after logging of old-growth forests, pasture productivity is one third of what it was before (Heinämäki et al., 2023). In a recent study, Stoessel et al. (2022) showed that traditional grazing areas in Northern Fennoscandia have significantly decreased over the last century because of cumulative land-use pressures. Their results indicated that that 85% of the reindeer herding area in Fennoscandia is affected by at least one land-use pressure, and 60% is affected by multiple land-use pressures, co-occurring with rising temperatures.

Climate change can affect the well-being of Sámi in multiple ways (see for example Jaakkola et al., 2018, for a discussion of negative changes to culture, environment, and livelihoods). Because of the crucial role of snow, many of these impacts are related to winter weather, snow conditions, and winter landscapes. Figure 4 summarizes the snow-related impacts of climate change on well-being that emerged in this study. Consequences of climate change on the well-being of Sámi have also been addressed in previous studies, and they can be very severe, including deep depression and increased suicide and suicidal thoughts (Stoor et al., 2015; Jaakkola et al., 2018). Reindeer herders who participated in our study expressed both hope and anxiety. Some were experiencing an existential crisis related to their livelihood and felt a constant need to defend it. At the same time, they were resilient and had strong coping skills. It should be noted, however, that deeply depressed people are unlikely to participate in research projects like ours, leaving the saddest stories untold.

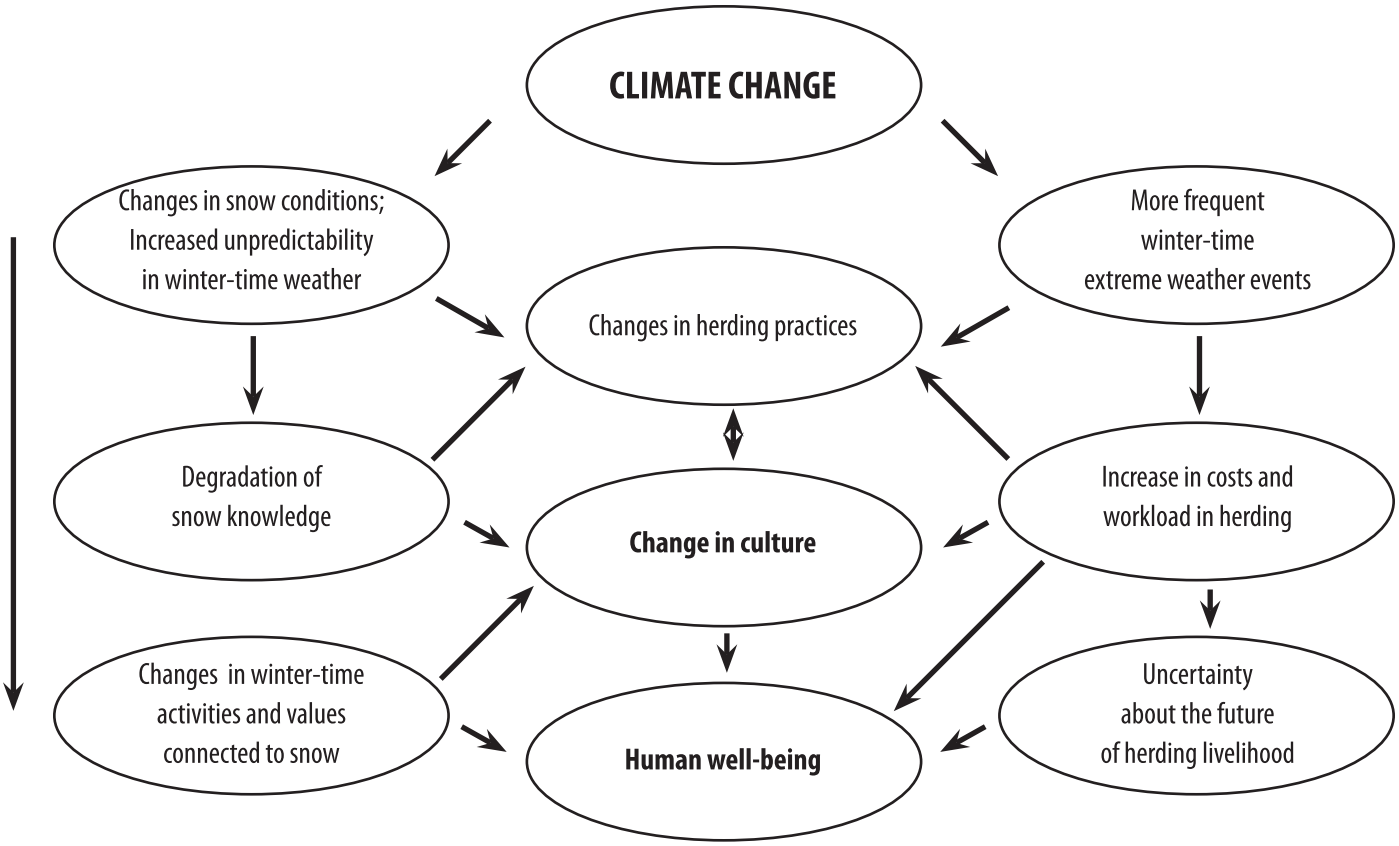

FIG 4. Connections between snow change and reindeer herders' well-being. Snow conditions are grouped as first, extreme winter weather events (e.g., ground ice, deep snow) and second, general changes in snow conditions (e.g., timing of first snow, snow melt, duration of snow cover) plus unpredictability in weather (e.g., timing of snowfall and melt). The figure shows snow-related aspects of climate change; many more impacts of climate change are not considered in this study.

Snow Knowledge of Changing Winters

There is increasing recognition that, in the era of climate crisis, Sámi TK is highly valuable. For example, Metsähallitus is increasingly integrating TK into land use plans regarding the Sámi Homeland (e.g., Metsähallitus, 2022). Recently, the Government of Finland appointed the Sámi Climate Council, the purpose of which is to bring Sámi TK and Sámi perspectives into the climate policy processes. This is very much a welcome development. However, despite its great value, Sámi TK about snow is also threatened. This issue was reflected in some of the research articles (e.g., Eira et al., 2018; Markkula et al., 2019; Harnesk, 2022). The reindeer herders in our study also expressed that their TK regarding weather, seasons, and snow is becoming outdated, and there is a constant need to develop new knowledge. However, developing new knowledge is difficult when winters are unpredictable and ever-changing. The coping capacity and resilience of reindeer herders remains tied to their in-depth understanding of snow, precipitation, and ice conditions. As extreme snow conditions and weather events cause economic losses, herders often need to look for jobs outside herding. According to the participants, this can lead to a situation where less time is spent in herding, and less TK is transferred from one generation to the next. TK is often connected to a personal identity associated with "knowing the land," as well as to the whole cultural system of land-based knowledge that has been passed on through generations, and loss of TK can evoke feelings of sadness and melancholy (see Cunsolo and Ellis, 2018:277).

According to the literature we analyzed, Sámi snow knowledge is multifaceted and, like snow, has many meanings. Snow knowledge was described as both practical and scientific, with long historical roots, used as much in daily activities as it is to predict future snow conditions and plan for future activities. This knowledge derives from dwelling and engagement with the world (Ingold, 2000) and encompasses relations and interactions between animals, plants, weather, people, and landscape (Eira et al., 2022). Given its practical and place-specific nature, Sámi TK about snow is an integral part of winter landscapes, taskscapes, places of liveliness, relations, and actions. As one participant noted, snow tells stories, and these are the unfolding stories of landscape as it bears witness to the passing of time and rapid fluctuations of the climate change era.

CONCLUSIONS

Future snow conditions will play a crucial role in the continuity of Arctic cultures, as snow and traditional Arctic livelihoods are intertwined. Extreme snow conditions can

have a significant negative impact on reindeer herders' well-being, including stress caused by increased workload, costs and concerns over the future of reindeer herding as a livelihood, and cultural continuity. Unpredictability in winter weather can also cause Sámi TK about snow to become outdated. At the same time, Sámi TK regarding climate change, snow, and winter pastures is increasingly included in research and climate change policy through, for example, the work of the Sámi Climate Council.

Extreme weather events are becoming more frequent, and reindeer herding communities in the Sámi Homeland are entering a new era of uncertainty. At the same time, pressure on reindeer pastures exerted by other land uses is growing. Development of local adaptation practices, assessment of cumulative impacts, and inclusion of TK in all pasture investigations and land use plans in the Sámi Homeland would be necessary actions in this complex situation.

In line with the few previous studies on the subject, this study showed that snow entails different cultural, recreational, and intrinsic values and mental health benefits that may be lost or altered as climate warming proceeds. We suggest that values, emotions, and meanings connected to snow, weather, and seasons should be given more attention in research addressing the impacts of climate change on the well-being of Sámi and other Arctic Indigenous peoples.

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