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How Reindeer Herders Cope with Harsh Winter Conditions in Northern Finland: Insights from an Interview Study

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ABSTRACT. Reindeer herding involves hard physical work carried out in a cold climate under variable weather conditions. In the fall and winter, herders' work in northern Finland includes collecting and moving reindeer herds to round-up sites, working in round-ups, slaughtering and processing meat as well as daily feeding and monitoring of the animals in the field. To study the experiences and perceptions of coping with cold among physically active herders in harsh winter conditions, we interviewed 22 herders from six herding districts of the central reindeer management area within the north boreal coniferous forest zone. We focused on behavioral and cultural strategies that accompany the physiological cold adaptations. Semi-structured interviews revealed that the main behavioral and cultural strategies used by herders to successfully carry out their duties while avoiding cold-related injury include clothing, physical activity, nutrition, and shelter as well as protecting vehicles and devices. Herders across sex, age, and herding district reported using modern layered clothing developed for extreme conditions, often combined with traditional footwear and clothes made of reindeer fur or woollen fabric. In addition, herders increase their physical activity; eat warm, energy-rich foods; make fires; stay overnight or take breaks in a house or a cabin, a car, or other protected places to reduce exposure to the harsh environment. Coping with extreme conditions not only requires flexibility, preparedness, and innovation from the herders but also thoughtful caution when approaching and managing unexpected situations. We conclude that modernization of reindeer husbandry, climate change, and rapidly increasing land use competition not only drive herders to modify their behavioral and cultural coping mechanisms for extreme weather conditions but may also create new, unexpected vulnerabilities.

Key words: reindeer herding; winter climate; coping strategy; adaptation; interview

RÉSUMÉ. L'élevage des rennes implique un dur labeur physique dans un climat froid assujetti à des conditions météorologiques variables. En automne et en hiver, dans le nord de la Finlande, le travail des éleveurs consiste à aller chercher les troupeaux de rennes et à les conduire dans des lieux de rassemblement, à travailler dans ces lieux de rassemblement, à abattre les bêtes et à transformer leur viande, ainsi qu'à faire manger les animaux se trouvant dans le champ et à les surveiller au quotidien. Afin d'étudier les expériences et les perceptions en matière d'adaptation au froid par les éleveurs physiquement actifs dans des conditions hivernales rigoureuses, nous avons interviewé 22 éleveurs en provenance de six districts d'élevage de la région centrale de gestion des rennes faisant partie de la zone forestière de conifères du nord boréal. Nous nous sommes concentrés sur les stratégies comportementales et culturelles qui accompagnent les adaptations physiologiques au froid. Les entrevues semi-structurées ont permis de constater que les principales stratégies comportementales et culturelles utilisées par les éleveurs afin de réussir à faire leurs tâches tout en évitant de se blesser à cause du froid concernent les vêtements, l'activité physique, l'alimentation et les abris, en plus de la protection des véhicules et des appareils. Sans égard à leur sexe, leur âge et leur district d'élevage, les éleveurs ont indiqué qu'ils portent des vêtements modernes à plusieurs épaisseurs conçus pour les conditions extrêmes. Souvent, ces vêtements s'accompagnent de chaussures et de vêtements traditionnels en fourrure de renne ou en tissu de laine. Par ailleurs, les éleveurs font plus d'activité physique, mangent de la nourriture chaude à forte valeur énergétique, font des feux, passent la nuit dans une maison, un chalet, une voiture ou d'autres lieux protégés ou prennent des pauses dans l'un ou l'autre de ces lieux afin de réduire leur exposition à l'environnement inhospitalier. S'adapter aux conditions extrêmes demande non seulement de la souplesse, de la préparation et de l'innovation de la part des éleveurs, mais aussi une grande prudence quand vient le temps de faire face à des situations imprévues et de gérer ces situations. Nous concluons que la modernisation de l'élevage des rennes, le changement climatique et l'augmentation rapide de l'utilisation concurrentielle des terres mènent non seulement les éleveurs à modifier leurs mécanismes d'adaptation comportementale et culturelle dans les conditions météorologiques extrêmes, mais qu'ils risquent aussi engendrer de nouvelles vulnérabilités inattendues.

Mots clés : élevage des rennes; climat hivernal; stratégie d'adaptation; adaptation; entrevue

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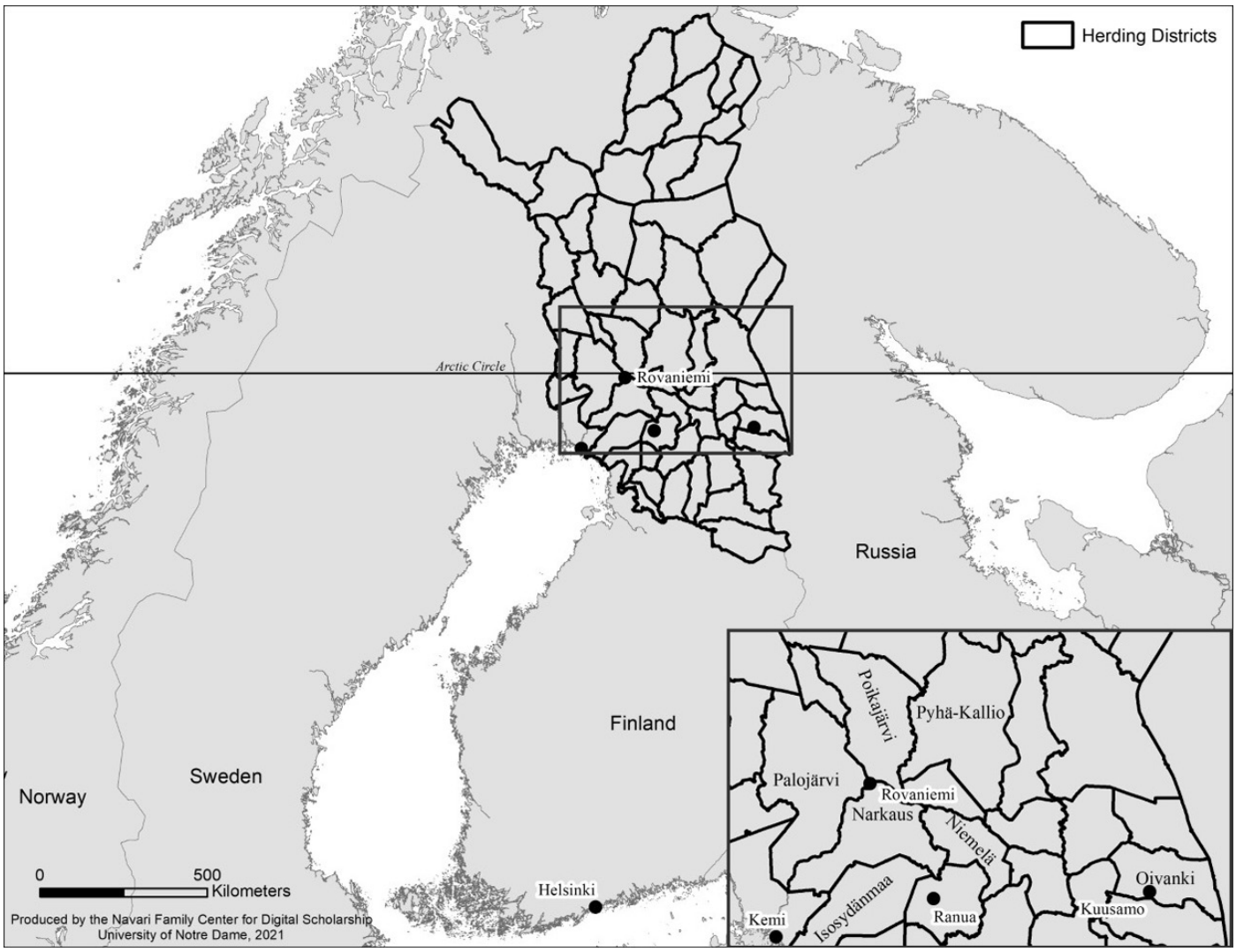

FIG. 1. Reindeer management area (RMA) of Finland, showing the herding districts (HDs): Pyhä-Kallio, Poikajärvi, Palojärvi, Niemelä, Isosydänmaa and Oivanki from which the herders were interviewed. Locations of the weather stations of the Finnish Meteorological Institute at Kemi, Rovaniemi, Ranua, and Kuusamo are also shown.

INTRODUCTION

In Finland, the reindeer management area (RMA) includes 54 herding districts (HDs) that cover 36% of the land (Fig. 1). All Finnish citizens (who live in this area) are eligible to practice reindeer husbandry in contrast to Norway and Sweden where the livelihood is mainly an exclusive right of the Indigenous Sámi population. In 2018–19, there were 188 190 reindeer and 4354 reindeer owners in Finland. About 70% of reindeer owners are males and 30% females (RHA, 2020a). Reindeer husbandry is based on free access of semi-domesticated reindeer (*Rangifer tarandus tarandus*) to pastures irrespective of land ownership (Reindeer Husbandry Act, 1990). In addition to meat production, reindeer husbandry creates employment in the meat processing industry, handicraft production, and tourism. It also has an important position in the cultural and social intercourse among residents in northern Finland (Soppela and Turunen, 2017). The term "reindeer husbandry" refers to reindeer as a resource as well as the related profits, breeding, and social mechanisms. "Reindeer management" refers to all of the practices pertaining to the keeping of reindeer, including governance. "Reindeer herding" is the day-to-day practice of the livelihood (Forbes, 2006).

Because of their outdoor work, reindeer herders in northern Finland are exposed to the combined effect of wind and low ambient temperatures during the winter months from October to April (Fig. 2, Appendix Table S1). Regardless of modernization in Fennoscandia over the past several decades, such as the shift from subsistence-based herding to a market economy, the transition to permanent housing, changed herding practices, and the introduction of new technology (Pelto et al., 1968; Forbes et al., 2006; Kortesalmi, 2007; Soppela and Turunen, 2017), reindeer herding still involves hard physical labor carried out under extreme climatic conditions. In the fall and winter, herders' work includes gathering and moving reindeer herds to the

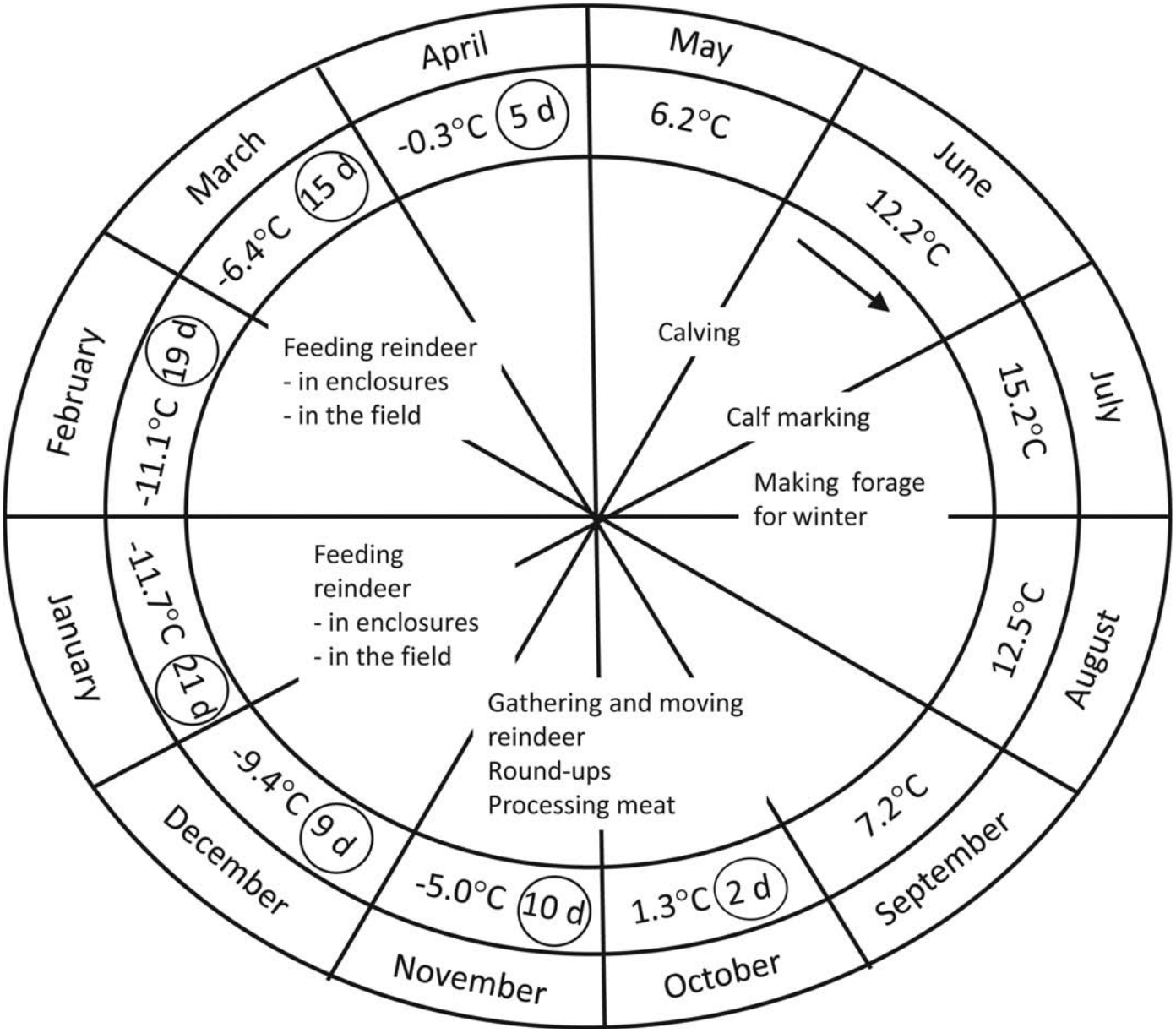

FIG. 2. Seasonal cycle of the reindeer herding work and the months when herders are exposed to low temperatures. Mean monthly temperatures and the number of days (d) in each month when the daily minimum temperature is below −10°C (circled) within the study site (Pirinen et al., 2012) are shown. The weather data are presented as mean values from the weather stations of Kemi, Rovaniemi, Ranua, and Kuusamo (see Fig. 1, Appendix Table S1; Pirinnen et al., 2012). The reindeer herding year (1st June to 31 May) starts in the beginning of June (→).

round-up sites as well as slaughtering and processing meat (Helle, 2015; Turunen et al., 2016) (Fig. 2). Herders also feed reindeer in the field or when taken into the enclosures (Turunen and Vuojala-Magga, 2014; Turunen et al., 2016). These are the main winter tasks, which regularly expose herders to harsh, cold conditions. The details of biocultural coping strategies such as physiological, behavioral, and cultural thermoregulation mechanisms needed to mitigate injuries caused by these conditions are not known.

With respect to physiological mechanisms of human cold adaptation, local and whole body adaptations are distinct from one another, though related. Local adaptations, for example, the lowering of skin temperature by vascular changes occur in the extremities such as hands, fingers, and toes. Whole body adaptations can be divided into metabolic, insulative, and hypothermic adaptation, and the simultaneous combination of the latter two (insulative-hypothermic), which is the most common mechanism (Daanen and Van Marken Lichtenbeltd, 2016; see also Launay and Savourey, 2009; Mäkinen, 2010). In metabolic cold adaptation, body heat production increases due to greater metabolic activity; in insulative cold adaptation, skin temperature is decreased by reducing peripheral blood circulation or by increasing the amount of body fat; and in hypothermic adaptation, heat loss to the environment is reduced by decreasing body temperature at rest (Daanen and Van Marken Lichtenbeltd, 2016).

In a cold climate, outdoor workers such as herders produce most of their body heat through muscular thermogenesis produced during physical activity (Rintamäki and Rissanen, 2006; Cheung et al., 2016; Ocobock, 2016). The body can produce additional heat through involuntary shivering thermogenesis of skeletal muscles, thermogenesis of brown adipose tissue, or both (Cheung et al., 2016). Heat loss from the body can be reduced by cold-induced vasoconstriction, though vasoconstriction works in concert with occasional vasodilation to prevent frostbite and loss of manual dexterity (Castellani and Young, 2016; Daanen and Van Marken Lichtenbeltd, 2016). However, even if these physiological mechanisms are enhanced as a response to repeated cold exposure, they are typically not enough to maintain core body temperature without forms of behavioral thermoregulation such as increased physical activity, clothing, or shelter (Stocks et al., 2004; Castellani and Young, 2016).

The effects of cold on humans are dependent on ambient factors (i.e., temperature, wind, and humidity), heat produced by physiological means, heat produced from physical activity (e.g., light or heavy work), heat loss from the body, and individual factors such as age and health status (Hassi and Mäkinen, 2001; Mäkinen, 2010). Depending on the interaction among these variables, cold stress may occur causing local or whole-body cooling (Hassi and Mäkinen, 2001). Cold exposure, especially with inadequate protection, can lead to physical discomfort, poor work performance, and a variety of injuries (Parsons, 2003; Hassi et al., 2005; Mäkinen and Hassi, 2009). Potential injuries include frostbite; cold environment-related injures such as sprains, slips, and falls; and an exacerbation of existing illnesses, especially those related to the cardiovascular and respiratory systems. Frostbite occurs when exposure to frost causes freezing of the skin or subcutaneous tissues (Hassi and Mäkinen, 2001). Hypothermia, a decrease of body temperature below 35°C, occurs when the body loses heat faster than it can produce it, causing a dangerously low body temperature (see also IUPS Thermal Commission, 2001).

Certain subsets of the population are more vulnerable to cold-related health effects: elderly people, those with existing complications or poor physical fitness, smokers, and alcoholics (Castellani and Young, 2016). However, physically active individuals, especially those who are active outdoors like reindeer herders, are also likely to have cold-related injuries and symptoms, which can hinder work performance and lead to greater economic burden in addition to the negative health impacts (Hassi et al., 2005; Mäkinen et al., 2006).

Human cold response and adaptation have been studied among a variety of people and settings, including Arctic populations, outdoor and indoor occupations, leisure activities, and laboratory-controlled cold exposures (Levine et al., 1995; Galloway et al., 2000; Snodgrass et al., 2005, 2006; Mäkinen et al., 2006; Mäkinen, 2010; Näyhä et al., 2011; Oksa et al., 2014; Oliveira et al., 2014; Fumagalli et al., 2015; Ocobock, 2017; Levy et al., 2018). The outdoor occupations involving significant cold exposure include employment in resource industries (e.g., forestry, agriculture, fishing, hunting, the mining industry, and petroleum extraction) and all-season occupations (e.g., construction, military) (Jeong et al., 2009; Oksa et al., 2014; Pearce et al., 2015; Cheung et al., 2016; Elgstrand et al., 2017). Given their high levels of physical activity and exposure to the environment, reindeer herders are put at greater risk for cold injury during herding work. Knowledge about health, wellbeing, and disease among reindeer herders in northern Fennoscandia is relatively limited (Näyhä and Hassi, 1993; Daerga et al., 2004; Hassler et al., 2004, 2008; Näyhä et al., 2011; Soininen, 2015). So far, only a few reports have been published about herders' responses (Virokangas et al., 1984; Pekkarinen et al., 1988; Ervasti et al., 1991) and physiological adaptations (Galloway et al., 2000; Ocobock et al., 2019a, b, 2020a, b) to cold. Furthermore, a concern has been expressed about preserving the traditional knowledge and skills of reindeer herders (see e.g., Helander-Renvall and Markkula, 2011; Magga et al., 2011), including the practices of coping with cold. To address this knowledge gap, we studied the experiences and perceptions of coping with cold among physically active reindeer herders in the harsh winter conditions of northern Finland. We focused on the herders' behavioral and cultural means and strategies to adapt themselves, their work, and their equipment to low temperatures, snowstorms, and other extreme winter conditions. The interviews of herders are part of the project "The metabolic cost of living among reindeer herders in northern Finland (2017–2020)," which aimed at studying physiological mechanisms (metabolic demands and brown adipose tissue activation) for adapting to cold among a physically active cold climate population—reindeer herders of northern Finland (Ocobock et al., 2019a, b, 2020a, b). Since the same individuals participated in both the above-mentioned physiological measurements and the interviews, we discuss some of the physiological results to provide context for the interview results.

MATERIAL AND METHODS

Study Sites

Herders from six herding districts (HD)—Pyhä-Kallio, Poikajärvi, Palojärvi, Niemelä, Isosydänmaa, and Oivanki—agreed to participate in this research on the recommendation of the Reindeer Herders' Association (RHA) (Fig. 1). The participants were from the HDs of the central part of the RMA of Finland. The salient characteristics of these HDs and their weather conditions are presented in Tables 1 and 2 and in the supplementary file Appendix Table S1. The total land surface area of these HDs represents 13% of the total land area of the RMA. The

TABLE 1. Characteristics of the herding districts (HDs) studied. Calf percentage = number of calves per 100 females at fall roundup. See Figure 1 for the location of the HDs and the weather stations.

HD	Pyhä-Kallio	Poikajärvi	Palojärvi	Niemelä	Isosydänmaa	Oivanki	Reference
Total land area (km^2)	3652	2415	3629	1104	2222	1281	Kumpula et al., 2019
Number of reindeer, 2018–19	5594	4423	4920	1712	1448	2358	RHA, 2020a
Reindeer/km^2	1.53	1.83	1.36	1.55	0.65	1.84	Kumpula et al., 2019; RHA, 2020a
Calf percentage (%)	57	57	59	56	68	47	RHA, 2020a
Number of reindeer owners	145	98	176	46	49	49	RHA, 2020a

TABLE 2. Weather characteristics in the study region. Temperature and precipitation data represent long-term mean values for the period 1981–2010 (Pirinen et al., 2012). Finnish Meteorological Institute publishes reports of climatological statistics for 30-year periods; the latest available report is for the period 1981–2010 (Pirinen et al., 2012). No wind speed values are available for Kemi and Ranua. See Figure 1 for the location of the weather stations.

Weather station	Kemi	Rovaniemi	Ranua	Kuusamo
Mean annual air temperature, 1981–2010 (˚C)	1.6	0.9	1.0	0.1
Mean October–April air temperature, 1981–2010 (˚C)	−5.2	−6.1	−6.0	−7.0
Mean January air temperature, 1981–2010 (˚C)	−10.8	−11.3	−11.6	−12.8
Absolute minimum air temperature (˚C)	−42.6	−38.1	−42.3	−45.2
Year of absolute minimum air temperature	1999	1999	1999	1985
Mean number of days with minimum air temperature below −10˚C per year, 1981–2010	21	21	21	22
Mean July air temperature, 1981–2010 (˚C)	15.8	15.2	15.3	14.6
Mean annual precipitation, 1981–2010 (mm)	580	618	622	615
Mean wind speed (m s-1)	–	3.9	–	2.6
Mean thickness of snow cover on 15 March 1981–2010 (cm)	67	76	72	74

sum of the largest permissible number of reindeer of the studied HDs represents 11% of that in the RMA (Table 1).

All six HDs are located in an area characterized by a cold and snowy forest climate (Köppen climate type: Dfc) (Peel et al., 2007) and high annual variability. The eastern part of the area is affected mostly by continental air masses resulting in lower temperatures and thicker snow cover whereas the western part is affected by the Gulf of Bothnia. The landscape consists of northern boreal coniferous forests and mires (SYKE, 2019). The mean annual temperature measured from 1981 to 2010 ranged from 0.1˚C – 1.6˚C (Pirinen et al., 2012). The mean monthly temperature was the lowest in January (range: −10.8 to −12.8˚C). Annual precipitation was 609 mm, about half of which is snow that accumulates to a depth of 72 cm (Pirinen et al., 2012; FMI, 2019; Table 2, Appendix Table S1). Wind conditions within north boreal coniferous forests are not harsh (Table 2) and major storms are not common (Pirinen et al., 2012).

Seasonal Work of Reindeer Herders

Reindeer herding follows a seasonal cycle (Fig. 2, Helle, 2015; Turunen et al., 2016, 2020; RHA, 2020b). The reindeer-herding year starts in June with calving. In free-ranging calving, reindeer give birth to their calves in their natural calving regions, for example, forested areas. Calving is followed by calf earmarking, which is carried out from midsummer onwards. Each reindeer must be marked with the owner's reindeer earmark (Reindeer Husbandry Act, 1990). In enclosure calving, pregnant hinds are separated into a space of their own within the enclosure from March – April until the end of May. In this case, the calves are earmarked immediately after birth, and hinds with a calf are let free thereafter (Turunen et al., 2016, 2020; RHA, 2020b). Herding work in the summer until August includes haymaking for supplementary feeding during the following winter.

In autumn, herders start collecting their herds and moving them to the round-up sites either on foot or with the aid of ATVs (all-terrain vehicles), motorbikes, snowmobiles, or helicopters. In round-ups, the reindeer are counted, the animals to be spared are separated from those to be slaughtered, calves not marked in summer are earmarked, and the reindeer of other HDs are taken to their proper owners. The reindeer to be spared often receive medication to prevent parasitic infection. Reindeer slaughtering takes place either in the field or at a slaughterhouse. Meat processing includes skinning, cutting, washing, weighing, and packing. After the round-ups, reindeer are herded onto winter pastures or taken into pens (Turunen et al., 2016, 2020).

The animals are given supplementary feed (hay, grass silage, pellets, or a combination thereof) in the pens or their natural foraging areas (e.g., forest areas). Feeding is usually conducted from the snowmobile, tractor or storage, or reindeer feed freely on bales of hay or silage left in the area. Herders' winter work may also include moving reindeer with the aid of hay to the feeding places, monitoring the reindeer health and movements, and taking animals in poor condition to home care (separate pens). In spring, depending on weather and snow conditions, supplementary winter feeding is finished, and reindeer are released from the pens to natural pastures. Herders' annual work also includes herding to protect reindeer from predators, searching for the remains of reindeer lost to predators, fence repair,

driving reindeer away from human settlements and fields, planning meetings, and bookkeeping (Helle, 2015; Turunen et al., 2016, 2020; RHA, 2020b).

Interviews

Our study was a qualitative, descriptive study based on 22 semi-structured interviews of reindeer herders. Herders were selected through purposive sampling, in which the RHA advisors provided the researchers' contact information of the HD managers. Selection of herders for the interviews and physiological measurements was based on the location of the HD within a reasonable distance (max 200 km) from Rovaniemi; as well as herder's potential interest, willingness, and availability to participate. Researchers then contacted the HD managers and sent further information on the project. All managers agreed and notified other herders from their HD about the opportunity to participate in this research (snowball method). The interviews were conducted either immediately before or after the physiological measurements.

We interviewed six herders from Pyhä-Kallio, five from Poikajärvi, four from Palojärvi, two from Niemelä, one from Isosydänmaa, and four from Oivanki HD. Of them, 16 were males (73%) and six were females (27%) (Appendix Table S2). The age of the informants ranged from 21 to 64 years, with a mean of 44 years; mean age for males was 49 years and that for females was 29 years. The lack of older female herders accurately represents northern Finland herder demographics. About 80% of the informants were born into and grew up in a reindeer-herding family, whereas 20% of them were newcomers, being either married to a herder or employed by one of the studied HDs. For half of the interviewed herders, reindeer herding was a principal source of livelihood, and for other half (and for almost all females) it was a subsidiary occupation. Other jobs besides herding included meat-processing, tourism, land measurements, building, and research. Herders were given codes H1-H22, followed by the name of the herding district.

The semi-structured interviews consisted of questions about working in and coping with harsh weather conditions in the present and past. We were interested to know what kind of outdoor work herders do, what their means and strategies for coping with low temperatures and snow storms are, and if there is a low temperature limit at which they suspend work. We asked what kind of clothes herders use in low temperatures and snowstorms, their history of potential frostbite injury and how they avoid frostbite, and how they protect their vehicles and devices in harsh conditions. We were also interested in herders' perception of their acclimatization to cold as winter progresses. Finally, we asked how the informants' parents and grandparents used to cope with similar conditions. Herders were given time to freely describe their experiences and perceptions of coping with harsh condition. In this study, a temperature below 0˚C was considered "a low temperature," a range of −25 to −35˚C, "a very low temperature" or "a hard frost" and −35˚C or lower as "an extremely low temperature" or "an extremely hard frost." This classification was based on both herders' interview responses and modification of the classification by the Finnish Meteorological Institute (FMI, 2020b).

The interviews were conducted by Minna Turunen and Päivi Soppela during 18–25 May in 2018 and 15–24 January in 2019, either at the Arctic Centre of the University of Lapland in Rovaniemi, herders' homes, or the facilities of the participating HD (cabin, slaughterhouse, etc.). The herders were able to see the interview questions either beforehand or, at the latest, in the interview situation. The interviews were conducted in Finnish, recorded with the permission of the participants, and transcribed in full. Sufficient material was gathered after 22 interviews (Eskola and Suoranta, 2000); only one complementary interview of an elderly male herder (born in 1956) with a life-long experience of reindeer herding was conducted 30 March 2020 by phone. This interview focused on past coping strategies, particularly herders' traditional clothing (H100, Oivanki).

The interview material was organized according to the questions and the responses from the herders, which in combination formed the themes within the Results section. Our qualitative method was thus not a strict thematic analysis (see e.g., Creswell and Creswell, 2018). Despite the small sample size, the interview material was analyzed by using potential response attributes including sex, age (< 30 years, 31–40 years, 41–54 years and > 55 years), and HD to explore possible patterns in the data.

This study was conducted with Institutional Review Board approval from the University at Albany (17-E-165) and with the approval of the Ostrobothnian Health Care District from the University of Oulu (EETTMK: 4/2018). Prior to the interviews, we informed the participants about the purpose of the study and how the interviews were going to be used. Participants were provided with an information sheet about the study, and informed written consent (in Finnish) was obtained from all participants (Kohonen et al., 2019).

RESULTS

Herders' Exposure and Responses to Cold

The interviewed herders are exposed to daily minimum temperatures below −10˚C for 86–99 days during October–April (Fig. 2, Appendix Table S1). This period includes two major physically demanding working phases of reindeer herding: (1) gathering and moving reindeer to the round-up sites from mid-September to January-February, often taking 8–12 hours per day, and (2) feeding reindeer both in the pen and field from November to March, which takes usually 1–4 hours per day (H1–H22, Fig. 2). The herders indicated that working days are the longest and the work is most physically demanding during the period of gathering and moving reindeer to the round-up sites, round-up work, and meat processing. Round-ups

and slaughtering in the field have been conducted in temperatures as low as −30˚C to −45˚C, which is clearly lower than the optimal temperature (0 to −10˚C) and not preferable for herders since working conditions become inconvenient and carcasses easily freeze (H9, H11, Poikajärvi; H21, Oivanki).

Our parallel measurements with the interviewed herders showed that their daily energy expenditure was at a very high level during the round-up (Ocobock et al., 2019a). The average total energy expenditure was 4155 kcal d^{-1}; a mean of 3390 kcal d^{-1} for females and 4484 kcal d^{-1} for males. During the herd round-up, herders expended approximately 500 kcal d^{-1} more than office workers and 700 kcal d^{-1} more than Yakutian reindeer herders (Snodgrass et al., 2006).

The interviewed herders reported that cold exposure has changed during the past 100 years because of drastically changed herding practices in northern Fennoscandia (H6, Pyhä-Kallio; H13, Palojärvi; H100, Oivanki; see also Pelto et al., 1968; Forbes et al., 2006; Kortesalmi, 2007). Previously, herders stayed away from their homes for several weeks for the gathering and rounding-up of reindeer and stayed overnight in houses and later in cabins, which is not as common today. They also spent more time in the forest and made fires there more often. Reindeer were herded and gathered in winter mostly on skis, foot, or by driving trained (sledge) reindeer instead of snowmobiles or ATVs (H1 – H22; H100, Oivanki). This meant that when gathering and moving reindeer, herders did not get cold so easily, since they were more physically active, and extremely warm clothes were not needed. One of the herders explained, "In olden times when reindeer were gathered on skiis, the risk for getting frostbite was smaller due to lower speed than today when snowmobiling" (H6, Pyhä-Kallio). Another herder agreed: "It is possible that 100 years ago the herders were not freezing as much as today, because ATVs and snowmobiles are cold vehicles… it is the speed and wind [causing that]" (H1, Pyhä-Kallio).

The interviewed herders did not, in general, find harsh winter conditions problematic for conducting their work. Approximately 70% of the interviewed herders across sex, age, and HD reported that they have experienced occasional cold discomfort, such as frostbite on fingers, toes, ears, nose, or cheekbones, impaired manual functioning (dexterity), or excessive cooling during outdoor herding work. According to the herders, frostbite has not been severe enough to require medical treatment; the injuries were most likely superficial, with only the skin frozen. Herders reported that cold injuries are greatly exacerbated by moisture such as when their shoes, socks, or mittens get wet.

Our results are in agreement with studies conducted over 30 years ago in northern Finland, which reported that frostbite associated with driving snowmobiles occurred among 68% of participants (Virokangas et al., 1984; Näyhä and Hassi, 1993). The maximum allowed speed of a snowmobile in the field is 60 km h^{-1} and 80 km h^{-1} on ice-covered waterbodies (Finnish Road Safety Council, 2016). Herders reported that depending on snow conditions and the work in progress, their average snowmobile speed in forest areas is 30 km h^{-1} and 50 km h^{-1} in open areas (e.g., water bodies, mires, and cutting areas) (H1 – H22). Ambient temperature and air velocity are key environmental factors determining cold exposure among herders. Wind chill calculations, which can be used for estimating heat loss from the skin due to the combined effects of ambient air temperature and air velocity (FMI, 2020a), show that a snowmobile speed of 50 km h^{-1} in −10˚C results in a wind chill exposure of −21.8˚C and, in −20˚C, a wind chill of −35.4˚C (FMI, 2020a). Developments such as a heated bench or large windscreen on snowmobiles may however reduce the driver's cold exposure (see section *We Dig Our Snowmobiles into Snow*).

Traditional and Modern Clothing Combined

All herders across sex, age, and HD reported that they cope with cold primarily by having warm, layered clothing, most often an innermost layer of woollen underwear, a windproof outermost layer and, depending on temperatures and wind, insulating clothing between the inner and outer layer. Female herders in particular (age range 21 – 37 years) stated that instead of one-piece snowmobile overalls (*kelkkahaalari*) (Fig. 3a), which were common from the 1980s until the past decade, they now favor two-piece snowmobile suits (Fig. 3b). All herders reported that they use fur caps during low temperatures (H1 – H22; H100, Oivanki; Fig. 3c). The caps were most commonly made of seal, but also fox, wolf, or mink leather. In very low temperatures, herders used big fur or leather mittens or gloves or windproof winter working gloves together with woollen mittens. Many herders used rubber boots sometimes combined with felt lining when the temperature is near zero. During frosts, herders used oversize boots or snowmobile boots with a separate felt lining, often with two pairs of woollen socks. In extremely low temperatures, herders used thermoboots (Fig. 3d) or footwear made of reindeer fur (Fig. 3e). Herders strongly stressed the importance of keeping shoes and boots dry. They accomplished this by using shoes and boots that were big enough for air to circulate and by ensuring a woollen sock was the only layer in direct contact with the skin. Chemical "heat pads" that can be placed inside the footwear or mittens to stay warm were used by only a few herders interviewed (e.g., H20, Oivanki). The most common type of reusable heat pad requires bending a metal disk; a plastic bag then releases heat associated with the crystallization of a supersaturated solution of a salt (e.g., sodium acetate).

All herders emphasized the importance of regulating the amount and type of clothing according to the prevailing weather conditions and their physical activity level. They also pointed out that clothing should not be too warm during high physical activity, and unnecessary physical work and sweating should be avoided as moisture from sweat can be dangerous in combination with cold. Most herders also reported that it is important to take a change

FIG. 3. Modern and traditional clothes and footwear used by herders in their work in northern Finland: a) one-piece snowmobile overall (*kelkkahaalari*), (b) a two-piece snowmobile suit, (c) a cap made of seal and blue fox fur, (d) thermoboots. Photos 3a–d: Sanna-Mari Kynkäänniemi.

FIG. 3 – *continued*: Modern and traditional clothes and footwear used by herders in their work in northern Finland: (e) a footwear made of reindeer leg leather (*nutukas* from Kuusamo), (f) a warm-up coat (modern *peski*), (g) a closed hooded cloak made of woollen textile (*luhka*), (h) a long coat closed from the front with wolf fur outside (*peski* from Inari), (i) and pants made of reindeer leg leather and fur from Kuusamo (*säpikäshousut*). Photos 3e and 3g–i: Sanna-Mari Kynkäänniemi, Photo 3f: Aliisa Pokka.

of clothes in case they do get wet, either from sweat or accidentally falling into a body of water. Almost one-third of the herders (mean age 40 years) stated that they use "a modern *peski*," a long windproof warm-up coat (*varikkotakki*, *kaamasen peski*) (Fig. 3f) to be on the safe side during the low temperatures, wind, and low physical activity (e.g., when driving a snowmobile): "We saw them in snowmobile races and in sport events and thought that it could be good for us too" (H16, Niemelä).

All herders said that they feel colder and need more clothes in the autumn when temperatures start getting lower. When winter advances, after one or more harsh frost periods and the temperature lowers, herders said they don't feel as cold and less clothes are needed. One of the herders explained: "One could compare that at −5˚C in the autumn in wind and sleet one needs at least the same amount of clothes as what you need to have at −35˚C in winter" (H1, Pyhä-Kallio). The herders thought that the reason for this could either be that they have gradually adapted to low temperatures or that the more humid-cold air in autumn feels colder than dry-cold air later in winter, further emphasizing the dangers of damp conditions in low ambient temperatures.

Herders across sex, age, and HD reported that clothing for snowstorms is quite similar to that for low temperatures, but when driving a snowmobile it is particularly important to use warm, windproof and waterproof clothing (outer layer), driving goggles, a scarf, buff or face mask to protect the face, and to take a change of clothes and footwear if they get wet (H1–H22). The herders also reported that during snowstorms one should have layered clothing but fewer layers compared to the amount needed for hard frosts. For headwear, the earflaps of a fur cap laid down protect ears from the wind, and a coat with a hood protects the head and neck during the snowstorms. Snowmobiles equipped with a high windscreen also improve coping during snowstorms (H7, Poikajärvi; H13, Palojärvi).

Herders interviewed still use some of the traditional clothes and footwear that were used for centuries in herding work. Fifty percent of all herders, and almost all female herders reported that they use shoes with a curled leading (*nutukas*) (Fig. 3e) or gaiters (*säpikäs*) made of reindeer leg leather (e.g., H5, Pyhä-Kallio; H9, Poikajärvi; H13, Palojärvi) (Itkonen, 1948; Anneberg, 2010). Herders had experiential knowledge of the pros and cons of using *nutukas*. They are typically used in dry, frosty winter conditions, after ATV season is finished, or when driving a snowmobile. *Nutukkaat* prevent foot cramps as they are breathable, soft, and flexible. Herders pointed out, however, that they are not practical when driving a car because the bottoms of these shoes easily get wet. They are also not good in round-up work: "If you draw a reindeer from its antlers [in enclosure during the round-up] and have *nutukkaat* on your feet, then you just go with the reindeer, because their bottoms do not have a grip" (H9, Poikajärvi).

A few herders also mentioned that they use *luhka* (H5, H6, Pyhä-Kallio; H13, Palojärvi; H20, Oivanki) (Fig. 3g), which is a closed hooded cloak used to warm the shoulders and avoid getting wet from the falling snow, for example, from the canopy in a dense forest when snowmobiling. Furthermore, the *luhka* is easy to take off before going into the cabin or house. *Peski* (Fig. 3h) is a long coat closed from the front with fur outside and made of 5–7 skins of reindeer calves or wolf skin, for example (Anneberg, 2010). It is now used by herders only rarely during the roundups because it is not practical when conducting round-up work (H3, Pyhä-Kallio; H13, Palojärvi; H100, Oivanki).

Revitalization of Traditional Handiwork?

The oldest reindeer herders used more culture-specific coping strategies against cold than did young herders or newcomers to the livelihood (e.g., H100, Oivanki). This became apparent from their rich traditional knowledge base about the past use of clothes and footwear, transmitted from their grandparents, other relatives, or more experienced colleagues. Besides traditional footwear (e.g., *nutukas*, *säpikäs*) and clothes (e.g., *luhka*, *peski*) (see Fig. 3) some herders said that their parents and grandparents, as well as themselves when they were children, used a Lapp costume of traditional color and decorations encompassing both coat and pants, which were made of dense, woollen textile (*verka*) (H9, Poikajärvi; H13, Palojärvi; H100, Oivanki). Many herders used to have two Lapp costumes, one for herding work and another better one for formal occasions, such as funerals and birthday parties. Herders used Lapp costumes commonly until the 1970s within the study area. Some of the herders were related to Sámi and some were not (H13, Palojärvi). One of the herders said: "Clothes made of thick woollen textile (*sarka*) were preferred clothes some decades ago. Even today they are good in many respects. They are not windproof. It is a weakness, and they get wet, but otherwise they are very comfortable, when you have to be active, because they are of breathable material. Much better than modern Gore-Tex goods/supplies in that respect" (H6, Pyhä-Kallio). Also used were pants made of reindeer leather (*säpikäshousut*) (H1, Pyhä-Kallio; H9, Poikajärvi; H100, Oivanki) (Fig. 3i).

Rubber boot production started in Finland at the end of 19th century (Nokian Footwear, 2020), and they became common among residents after WWII in the 1940s; until that time, leather boots or fur shoes were used. Two young female herders used pieces of newspaper in fur shoes as a form of inherited, traditional knowledge: "My grandmother has taught that newspapers are to be placed into shoes [*nutukas*] or boots, a woollen sock on bare foot. It is good because it dries moisture from the sock and the newspaper is always moist when I take it out after using it. And in earlier times dry hay [sedge] was placed in the shoe or boots" (H7, H8, Poikajärvi).

It became evident that the means for coping with hard and extremely hard frosts are still much the same as they used to be decades ago. Layered clothing was also used in the past, for example, *raappahousut*, long johns made of

thick cotton, were commonly used between underwear and outermost pants until a few decades ago (H12, Palojärvi). One of the herders reported that similar woollen pants and fur shoes (*nutukas*) (Fig. 3e) are still used in addition to felt boots, fur caps, and fur mittens. He continued: "In principle nothing has changed…when it is time of hard frosts, I also wear fur pants (*säpikäshousut*). They have been used in olden times, but also at present. The modern Gore-Tex suits are not even close to the same what fur pants are…. Fur pants have such kind of advantage, that when you drive snowmobile you have to be a lot on bended knees and reindeer fur does not let anything through them. It is possible to see the difference between fur pants and modern pants. They [fur pants] are still even better" (H1, Pyhä-Kallio) (Fig. 3i). Two elderly herders mentioned sledge fur coats (*rekiturkki*) used by their parents (H2, Pyhä-Kallio; H100, Oivanki). Sledge fur coats were long, heavy, and made of wolf fur or sheep fur with fabric lining, and they were used in a sledge when driving a trained reindeer or a horse, but not as much in herding work. In the past, trained reindeer were used to gather other reindeer to the round-up sites, and distances were long because round-up sites could be located far away. The herder pointed out that these coats are too big and heavy to be used in today's herding work (H2, Pyhä-Kallio).

Interviews revealed that herders were worried about the disappearance of the use and skill needed to make a reindeer herder's traditional clothes and clothing accessories. However, there were signs that young people are interested in revitalizing these traditions and have participated in workshops for making traditional garments (H1, Palojärvi; H20, Oivanki). "During recent years my generation in our location don't wear Lapp costume (*verkatakki*) anymore…and they are not so much made any more (as handiwork), like fur shoes (*nutukas*). It has started disappearing…my grandmother did not make fur shoes, but my grandaunt, grandfather's sister made fur shoes…. My sister has recovered those skills back.... We want to keep that skill alive, because when I sometimes used fur shoes I realized that when you use them more and more, how useful they are… Feet feel better and skin is better. And they are light. They don't change the position of feet. Walking is more natural, because the bottom is not thick" (H5, Pyhä-Kallio).

Activity, Shelter, and Food to Stay Warm

In addition to clothing, approximately 70% of herders mentioned that they cope with cold through additional physical exercise such as jumping, walking, or running when needed (see Rintamäki and Rissanen, 2006). Much of herding work in winter includes daily feeding of the reindeer, which also provides exercise for the herders. The herders pointed out that to stay warm, it's important to alternate passive/immobile and active/mobile work phases, for example, taking notes of reindeer numbers and drawing animals during the round-up (H5, Pyhä-Kallio). Herders also stated that one should always take matches and dry kindling along for making a fire in the forest to cope with cold (to warm up themselves, to dry their back and clothes, and to make warm food and drinks). When gathering and moving reindeer to the round-up sites and during round-ups, some herders avoid cold by staying overnight in a cabin, and many take breaks from their work in a cabin, car, or other place protected from wind. All study HDs have reindeer herder cabins, but they are not available at all round-up sites (H19, H20, Oivanki). One of the herders reported that in a very extreme situation he would make a shelter by digging a hole into the snow pack (*lumikieppi*), stay there or under the very thick branches of a big spruce tree that extend to the ground, and wait there for the storm to end (H9, Poikajärvi).

Herders also mentioned that being prepared for low temperatures by eating warming, energy-rich food with hot drinks makes it possible to work almost nonstop for the whole day. Many herders pack lunches composed of food that does not freeze easily (e.g., dry bread, chocolate, and nuts) and hot drinks (e.g., coffee, cacao, tea, and mulled wine), preferably in a vacuum-sealed container. One of the herders described the traditional diet as follows: "The diet during the cabin life has been always like this: sautéed reindeer in the morning and [reindeer meat] soup in the evening. With these one gets well along. But it is not exactly like this anymore" (H17, Niemelä). Data from herders' food journals during the annual round-up in 2018 indicated that especially male herders preferred sautéed reindeer or other reindeer products and fatty sausages as main food (Ocobock et al., unpubl.). Dietary intake of the interviewed herders ranged from 854–3638 kcal/day (Ocobock et al., 2020b). Given the high level of physical activity and often cold conditions during the round-ups, it is unsurprising that herders are consuming much higher percentages of fat and lower amounts of protein and carbohydrate than are recommended (WHO, 2020).

"We Dig Our Snowmobiles into the Snow"

The interviews showed that particularly male herders across age and HD had developed a number of methods to keep their vehicles and other useful technologies functioning even in extreme conditions. During hard frost, snowmobiles are used more often than cars for herding work because they are easier to start in the cold. Cars are usually heated during the hard frosts by using an electronic cable, a fuel-powered heater, or an electric-powered generator if there is no electricity available. Old-fashioned two-cycle snowmobiles are simpler than the modern four-cycle ones (which entered the market in the mid-2000s) because they are equipped with a drawstring and the motor is visible and easily accessible. Herders reported several methods for starting this kind of snowmobile, for example by using a blanket or electric fan, making a fire in the yard by the cabin and driving the snowmobile over it, or even driving the snowmobile inside the cabin to get the motor

heated. Most of the herders are satisfied with the modern four-cycle snowmobiles, however, because they can be easily started even at extremely low temperatures (below −35˚C). Two herders said that they started the snowmobile at temperatures as low as −43˚C. Another herder pointed out: "Present-day four-cycle snowmobiles don't have a drawstring…if they ran out of batteries that's it. Then you can try to activate it by hair-dryer etc. to get it warmer, I got the snowmobile started even in −35˚C. Some have a log heater as extra equipment. Two-cycle snowmobile can be started because it has a draw string" (H3, Pyhä-Kallio).

Herders, except the youngest ones (born in 1990s), recalled the extremely low temperatures of −38.1˚C, −42.3˚C, −45.2˚C, and −42.6˚C in January 1999 (Table 2), measured at different weather stations in the study region (Pirinen et al., 2012; FMI, 2019). At the very least, herders had to feed the animals within the enclosures every day during the winter months no matter the temperatures, even when it was lower than −50˚C locally. During this period of extremely low temperatures, herders struggled to start motors and get vehicles moving. Some herders reported that they had to dig their snowmobiles into the snow and cover them at the end of the day to get them started the next morning (H2, Pyhä-Kallio). A car had to be heated through a cable and started several times per day, even during the night so that the motors would not freeze. There was always a fear of power loss and heating system failures (H2, Pyhä-Kallio). During hard frosts, the reindeer required more supplemental feed due to higher metabolic energy expenditure; in addition to a regular feeding, the animals were given an additional feeding (H7, Poikajärvi). When herders were asked about the condition of reindeer during the frost period, one of the herders reported: "In the pen conditions some calves died. Calves are the lightest of the reindeer, and they have the least muscle and fat mass. They were the first to start fading away. The period of extremely low temperatures lasted at least two weeks. It was a long period" (H1, Pyhä-Kallio).

Technical developments related to vehicles, such as larger than normal windscreens (snowmobile), heated running boards and benches, and thumb heaters (snowmobile, ATV) are helpful in coping with low temperatures. In Finland, herders are not required to use helmets when driving a snowmobile or ATV. Herders emphasized that using helmets in connection with herding work make hearing, using headphones, and continuous monitoring of the animals and the environment challenging (H13, Palojärvi).

All the herders reported that they protect their smaller devices such as mobile or radio phones during the hard frosts by keeping them as close to their body as possible (e.g., in a pocket or a leather or fur mitten) or attached to a charger connected to a modern snowmobile or ATV while driving. Herders reduced power consumption of their mobile and radio phones by keeping the power off when not in use, keeping internet and extra applications off, and reducing the screen brightness of the phone. Some herders still use old-fashioned mobile phones since they are more durable and equipped with longer-lasting batteries than modern ones.

TEK and New Technology Used for Navigation

A herder's traditional ecological knowledge (TEK)—particularly detailed experiential knowledge of the landscape (vegetation and usage patterns) where his or her reindeer range—is a fundamental requirement of reindeer herding. One of the herders described the importance of experiential learning of landscape TEK: "You remember well the lands where you have roamed since your childhood. Old men used to be angry, if someone had a map. So that one does not learn to roam by following a map. Topography and such, one must get them driven into your head, so that you know them even in darkness. In darkness and in foggy weathers and in all conditions, it is based on this (H9, Poikajärvi). TEK is still transmitted from older to younger generations, as one of the herders described how her father taught her the local landscape: "There are wet places in the forest, where one can easily sink. Today I know that when we approach juniper stands, or alike, one has to be a bit careful [because of water]… But luckily in that round-up I had a change of clothes in the car. I felt shame when I was going to change my clothes (H20, Oivanki).

Only approximately 10% of the interviewed herders admitted that they have been lost. Even the herders who are familiar with the landscape in which they herd reindeer can lose their sense of direction and get lost when driving snowmobiles in poor visibility due to snowstorms, fog, or darkness within the vast open areas (e.g., lakes and clear-cutting areas), on land which is not their usual working area, or when intensively monitoring the movements of reindeer. If the landscape changes rapidly because of different land use activities such as forestry measures or new infrastructures, TEK no longer applies (see Axelsson-Linkowski et al., 2020). Therefore, the herders indicated that it is important to have a compass, GPS, navigator, or a mobile phone map application for checking the shortest route if one's location becomes uncertain. By relying too much on only the device, however, one never learns to know the landscape and increases the risk of getting into an accident or lost (H1, Pyhä-Kallio). One of the herders said: "Everybody has a compass in a backpack though they don't necessarily admit it. Older generation herders particularly…. And they may go around if they don't have it. They don't admit it either. Sometimes during a thick fog or a snowstorm, you cannot see anywhere. One just has to keep the right direction. Very easily one starts going in a wrong direction" (H5, Pyhä-Kallio).

Emergency Preparedness

Herders reported that emergency preparedness—properly and carefully planning the herding work and route for unexpected situations (such as getting lost in darkness

or snowstorm or sinking into a weakly frozen or unfrozen water body in winter)—is of vital importance. They emphasized that one should always inform friends and family about any trip plans. A change of clothes, matches, knife, and extra food should be a fundamental part of their preparations for work trips (H1, Pyhä-Kallio). Herders also pointed out that no additional risks should be taken and that for example, in extreme conditions, it is always safer to choose a route through a protective forest instead of vast open places.

Herders' require innovation and improvisation in order to develop methods and strategies to cope with cold. Innovation has often taken the form of experience-based technical know-how such as keeping vehicles and other technologies functioning despite extreme conditions (see section *We Dig Our Snowmobiles into the Snow*), or warming their field lunch by using heat from the exhaust gas of the snowmobile, for example (H1, Pyhä-Kallio). This know-how is often gained through personal experience (learned by doing and through trial and error; i.e., improvisation) and transmitted across generations.

Particularly the most experienced herders (males) across all studied HDs were well aware of the importance of either inherited or acquired characteristics, which help herders cope with harsh or unexpected conditions. In addition to flexibility for using a wide variety of means to adapt, herders emphasized the importance of proactive planning and preparing, as well as being considerate, careful, and calm in unexpected situations. One has to first consider whether freezing or stormy conditions are suitable for working outside at all. As one of the herders stated: "It is dangerous if one catches cold, it is a bad situation. One has to know his/her limits, when it is time to seek warm shelter" (H15, Palojärvi). And another female herder pointed out: "Particularly if you go alone into the forest. Then I'm very careful, so that I won't get into such kind of difficult places, because in the wilderness there is not necessarily service for mobile phone. Then if something happens, one can sink into something. For example, my father was alone [in the forest] driving by snowmobile, and it was January. It was −30˚C, and he had sunk with the snowmobile into an unfrozen ditch or it was a boghole. He was wet from the waist downwards" (H5, Pyhä-Kallio).

DISCUSSION

In this study, we explored the experiences and perceptions of the behavioral and cultural mechanisms that reindeer herders employ to cope with harsh, cold conditions. These mechanisms work in conjunction with physiological cold-climate adaptations. Our earlier physiological measurements among the interviewed reindeer herders in northern Finland have shown that herders are well adapted to cold by the time of round-up and mid-winter. The herders had relatively high resting metabolic rates and activity levels (Ocobock et al., 2019a, b, 2020a). High resting metabolic rates, the minimum number of calories burned to maintain life, are thought to play an important role in keeping individuals of cold-climate populations warm despite their extreme environment (Galloway et al., 2000; Snodgrass et al., 2005). In addition, the individuals can get extra heat by activating brown fat when exposed to cold (Levy et al., 2018). The herders in this study exhibited an increased metabolic rate and higher surface temperatures at their shoulder during experimental cold exposure, which was likely due to activation of brown adipose tissue (ca. 10˚C) (Ocobock et al., 2019b, 2020a). Thermogenesis in brown fat is associated with an increase in metabolic rate (more calories used) and higher skin temperatures where brown fat is located—typically in the neck and on top of the shoulders in humans (Cypess et al., 2009; Virtanen et al., 2009). However, physiological cold adaptations are not enough on their own for one to successfully survive and thrive in a harsh, cold climate.

The present study demonstrates that the interviewed herders also have a number of behavioral and cultural mechanisms that complement their physiological cold adaptations (Ocobock et al., 2019a, b, 2020a, b) in order to successfully carry out their duties while avoiding exposure to extreme cold and cold-related injury. The overall patterns of these mechanisms (clothing, physical activity, nutrition and shelter, as well as protecting vehicles and devices) were strikingly consistent across the sex, age, and HD of the interviewed herders. A lack of major differences between the HDs is likely due to the relative similarity in geography, climate, and culture of the small study site (14 303 km^2) within the central RMA of Finland (Tables 1 and 2). Herding practices, which greatly impact the herders' exposure to and coping strategies for cold, differed only slightly among the studied HDs. For example, in Pyhä-Kallio, where helicopters or small airplanes are used in addition to ATVs for gathering and moving the herds to round-up sites, the herder exposure to extreme conditions is likely shortened, and thus there isn't as great a need to cope with cold. Shelter accessibility also differed among the studied HDs. All HDs have cabins for herders, but, for example, in Oivanki, there are no cabins available at all round-up sites. Both exposure to and coping with cold would vary more between the herders of the present study and herders from the Saami home region in northernmost Finland where the climate is colder and windier. HDs in the Saami home region are larger, distances longer, fells are more numerous and higher, and herders' work is based more on traditional herding and less on feeding reindeer in the pen.

Despite the small sample size (22 interviews), we found herders' responses varied depending on age and sex. For example, the most experienced herders (all males) had a richer traditional knowledge of cultural coping strategies transmitted from their grandparents and other relatives than did young herders or those who are newcomers to the livelihood or employed by others. These strategies include detailed knowledge about the means for protecting vehicles and devices, use of traditional clothes and footwear

(Fig. 3e, g, h, i), and having shelters such as houses and cabins in harsh winter conditions.

Clothing, which can be considered an adaptive strategy both behaviorally and culturally, was the principal means through which herders minimized heat loss. Both male and female herders successfully combined modern clothing with traditional clothing to cope with harsh winter conditions. Herders are concerned about losing the knowledge and skills for making traditional clothes as only some young female herders are interested in making and using them. Know-how for making traditional clothing does not seem to be transferred effectively from generation to generation (Berkes, 1999). Some knowledge and skills may have been lost, some are being transmitted incompletely, and others are novel knowledge and skills. Traditional skill revitalization, particularly that related to clothing and footwear, is challenging not only due to the required knowledge of nature-based materials, but also to the long-term commitment and dedication to the craft. The fact that traditional clothes and footwear are in use gains visibility on a public level, which greatly improves the preservation of this skill. There was, however, a growing interest among female herders in such practices, most likely connected to a new phenomenon of more young females coming into the livelihood. All interviewed females were enthusiastic about herding as an occupation, and most of them had a wide range reindeer husbandry education. The role of the different educational institutes is significant in the revitalization of traditional reindeer herding handiwork. The short courses are usually taught by skilled artisans, who pass on their knowledge to students. For example, the adult education centers in the study area offer both contact and online teaching in traditional handiwork such as making fur shoes (*nutukas*, *säpikäs*), leather boots (*lapikas*), belts, ribbons (*paulat*), caps or *luhka* (AEC Ranua, 2020; AEC Rovaniemi, 2020).

Herders' work and their exposure to and ability to cope with harsh winter conditions have been modified by modernization of reindeer husbandry through both mechanization and digitization since the mid-20th century (Pelto et al., 1968; Kortesalmi, 2007; Turunen and Vuojala-Magga, 2014). Modern technology has greatly facilitated the herders' work and reduced their exposure to low temperatures. Instead of working for weeks out in the forests, herders with snowmobiles are now able to return home after a working day. New technologies such as ATVs and GPS units play a crucial role in hazard avoidance and facilitate adaptation to changing conditions, but their use can create new exposure sensitivities and exacerbate existing ones (Pearce et al., 2015). As our interviewees indicated, delicate electronic vehicles and devices have also increased herders' vulnerability to harsh conditions. For example, a modern high-speed four-cycle snowmobile equipped with heated running-boards and bench, thumb-heaters, and a high windscreen is helpful in coping with cold. At the same time, there is an increased risk of cold discomfort among herders, such as frostbite due to the combined effect of high speed and low temperatures, which can greatly increase heat loss from the body (Ervasti et al., 1991; Näyhä and Hassi, 1993; FMI, 2020a). In extreme conditions, there is a risk of failing to get a modern four-cycle snowmobile started if it runs out of battery power (as it does not have a pull string for manual start). Interestingly, in some locations, driving by snowmobile has decreased compared to the past decades because the movements of reindeer equipped with satellite collars can be monitored from the screen of a mobile phone, tablet, or computer.

The present and previous studies (Ocobock et al., 2019a, b, 2020a, b) focused on studying the adaptation of reindeer herders in harsh winter conditions, which is much less studied than adaptation, coping strategies, and adaptative capacity of herders and herding communities to climate change (e.g., Magga et al., 2011; Risvoll and Hovelsrud, 2016; Turunen et al., 2016; Rasmus et al., 2020). We have earlier shown that weather conditions impact not only reindeer and herding pastures in northern Finland, but also herders' seasonal working practices (Turunen and Vuojala-Magga, 2014; Turunen et al., 2016; Rasmus et al., 2018, 2020); these results are comparable to those from Sweden and Norway (e.g., Tyler et al., 2007; Furberg et al., 2011; Magga et al., 2011; Risvoll and Hovelsrud, 2016). For example, herders' work related to moving and gathering reindeer to the round-up sites has increased since the herds are more scattered because of warmer and longer autumns. In addition, the use of terrestrial vehicles, particularly ATVs, has partly replaced snowmobiles due to lack of snow or thin or non-uniform snow cover (Turunen et al., 2016; Rasmus et al., 2020). Also, supplementary feeding of reindeer has increased due to more difficult snow conditions, which decrease the availability of natural forage for reindeer. In Northern Finland, feeding reindeer in enclosures has largely replaced feeding the animals in the field (Turunen and Vuojala-Magga, 2014; Turunen et al., 2016; Rasmus et al., 2018, 2020).

Climate change will continue to greatly modify herders' working conditions in the future. Increasing winter temperatures and decreasing frost periods as well as earlier snowmelt (Rasmus et al., 2014, 2020; Kivinen and Rasmus, 2015; Lépy and Pasanen, 2017) may reduce herders' exposure to cold, which means that herders may require fewer coping mechanisms. However, there will be unprecedented challenges in these rapidly changing subarctic environments related to adverse weather conditions for which no proper coping strategies yet exist, such as precipitation in severely cold weather, drastic temperature variations over short periods of time, heavy storms, catastrophic ice formation on vegetation, or extreme snow cover (Peltonen-Sainio et al., 2017; Furberg et al., 2018; Markkula et al., 2019). These challenges mean that the innovation and improvisation skills herders already have will be essential for developing new coping strategies in a rapidly changing and unpredictable environment.

Greater unpredictability of weather patterns and seasons may hinder the utility of traditional knowledge transmitted

from generation to generation as that knowledge may no longer correspond with the changing conditions, and there are no existing coping strategies or knowledge available (Peltonen-Sainio et al., 2017; Axelsson-Linkowski et al., 2020) The situation has become even worse because of increased weather variability. Thus, in rapidly changing conditions, TEK related to these issues may lose its relevance, as the typical weather signs are no longer reliable. For example, uncertain timing of ice formation and melt in water bodies may increase the risk of falling and drowning accidents of both reindeer and herders. It may also become increasingly common that herders' TEK no longer applies as the environment is strongly modified by rapid land use (e.g., forestry cuttings, new infrastructure; roads, railways), climate change (e.g., snow conditions, vegetation) or their combined impacts (Axelsson-Linkowski et al., 2020). Conversely, lesser-used traditional knowledge may find new relevance during this time of fast-paced change, revealing coping mechanisms that could improve upon environmental, social, and political coping capacities (Turunen et al., 2016; Soppela and Turunen, 2017). Consequently, reindeer herders' preparedness for and ability to modify their actions to cope not only with a rapidly changing climate and unpredictable weather events but also increasing land use competition are of vital importance, and both traditional and new knowledge are required for further adaptation.

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