# Global Health Action

## CLUSTER: VULNERABLE POPULATIONS IN THE ARCTIC

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Interest in the Arctic has grown significantly in recent years. The Arctic environment is unique and highly sensitive to disturbances. Temperatures have already risen twice as quickly in the Arctic as elsewhere on Earth. Glaciers and sea ice are melting more extensively than in the past. This is already putting a great strain on communities and ecosystems. As ice withdraws, technological advances are creating opportunities to open transport routes across the Arctic Ocean and exploit the natural resources of the Arctic. These developments must be managed in a responsible and sustainable manner so that they do not lead to undesired effects.

The Arctic Council is the cooperation forum of the Arctic states, in which we work together for a responsible development of the region. The work of the Arctic Council has, since its inception, built on a close cooperation between scientists, researchers and policymakers. From 2011 until 2013, Sweden has the privilege of chairing the Arctic Council and leading its work.

Around 4 million people live north of the Arctic Circle, many of them are indigenous people. For the inhabitants of the Arctic, the developments in the region are a source of both challenges and opportunities. Climate change affects their health, their access to good quality food and water as well as their traditional activities such as reindeer husbandry, hunting, and fishing. At the same time, the business community's increasing interest in Arctic areas is creating opportunities for economically more advantageous living conditions. A high priority of the Swedish Chairmanship of the Arctic Council is to give more focus to the human dimension of the rapid changes that are occurring in the Arctic.

Another Swedish priority is to raise the profile of Arctic issues in international forums where climate change is discussed, with a view to achieving more ambitious global emissions reductions of greenhouse gases. At the same time, we need to shed more light on how we can strengthen the capacity of natural and social systems to adapt to future change. Research is a key issue in this context. It is also important to take advantage of the knowledge that exists among the people living in the region.

This volume is an excellent and timely contribution of such research-based evidence that highlights the effects of climate change on human health and living conditions in the Arctic region. While emphasising the need for more research on the subject, it also discusses what can and should be done to strengthen the capacities of societies to manage and overcome disturbances. It is, thereby, creating an important link between scientific findings and practical decision making and policies. The findings and recommendations herein will be an important source of information and inspiration for the Swedish Presidency of the Arctic Council. I trust that it will also initiate discussions between health researchers and policymakers on a global level, helping to build consensus on effective climate policies to protect vulnerable populations around the globe.

Gustaf Lind
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FOREWORD
Vulnerable populations in the Arctic

Earth’s average surface temperature is rising unusually fast. This global warming process is deemed by international scientific assessment to be predominantly due to human economic activities (1). Recent research indicates that, globally, the rate of emission of greenhouse gases is increasing (2), as is the rise in sea level and the loss of summer Arctic sea ice (3). Currently, the warming trend is ‘tracking’ at the top of the range of the previously modelled forecasts (4). Meanwhile, concerns are growing that, as higher temperatures are reached, reinforcing (‘positive’) feedback systems in nature will accelerate the process.

The warming is occurring more rapidly in the higher latitudes of the northern hemisphere than in the rest of the globe. Already, since mid-twentieth century, an increase of 1-2 °C have occurred within the Arctic region. By later this century, for ‘medium’ global emissions scenarios, the temperature increase in the Arctic is likely to be in the range of plus 4-7 °C, approximately double the global average warming. Such a rise, occurring so rapidly, would place extraordinary stress on ecosystems and would disrupt many geophysical processes (including precipitation patterns, ice cover, river flows and ocean currents).

Indeed, various ecosystems are already being influenced by the warming. In consequence, and more generally, life in the high-latitude north for all living beings is beginning to be affected by the direct and indirect effects of climate change. However, so far, research into the impacts of climate change has paid little attention to the risks to human health. Instead, concerns have been focused on the consequences for economic conditions, the vulnerability of human health, both physical and mental, will be affected by climate change. Those human health impacts, predominately adverse, will result both directly from altered climatic conditions (e.g. more severe heat waves and more frequent extreme weather events) and from the diverse environmental, ecological, economic and social impacts of climate change (5).

Indigenous peoples live in closer contact with nature than others and have valuable knowledge of ongoing biophysical and ecological processes. They have also, as the legacy of a long-standing nomadic lifestyle, both an adaptive capacity and knowledge of adaptation strategies that can be of great value for the wider, more urbanised, population.

In this special issue of Global Health Action, contributions from researchers from all over the Arctic address different aspects of these climatic and environmental changes, with a focus on how they affect human health. We can also read about insights and opportunities. Indigenous peoples have been interviewed about what they have recently observed in nature, and their conclusions from these observations. They provide insights into how important their cultural identity and social context are for their continued well-being. They have also been asked how these factors influence their choices about moving or not.

There is no doubt that both the everyday life and health status of many indigenous groups are already undergoing rapid change, some of them because of climate change. This includes a higher level of mental ill-health and the health consequences of a change of diet to a more western way of eating (including a much higher intake of processed foods), causing overweight, type 2 diabetes and an increase in cardiovascular diseases. Reports of research and intervention programmes among indigenous groups in Alaska describe that risks of injury, mental stress and non-communicable diseases are increasing. Mortality rates for Alaska Natives exceed that of ‘all races’ in the USA.

Interviews with reindeer herders among the Swedish Sami indicate that they are approaching the limit of resilience. Thinner ice on rivers and lakes increases risks for injuries and losses of animals, as do extreme and unpredictable weather and altered seasons. ‘Everything has been regeared’ with longer, wetter and warmer autumns, warmer winters and spring coming suddenly and earlier than before changing the traditional type of herding and making it more difficult to migrate the herds. The tree line is rising and the vegetation is changing, resulting in a shrinking of grazing lands.

Other businesses, including wind power, hydropower, forestry and mining, are increasingly competing for traditional indigenous pastoral space. All this threatens the sustainability of a traditional life style, including reindeer herding. The resultant sense of grief and loss of control threaten the identity of the Sami. On the other hand, the interviewed herders also speak about the long-tested adaptive capacity and of opportunities. Yet, even so, the feeling of constantly being ‘left out in the cold’ by authorities persists in their answers.

Other research presented here shows that various animals, including mammals, insects and parasites, are moving their habitats in response to climate change. This, in turn, makes it possible for microorganisms to expand their territories. Hunters in northern Sweden, for example, have noticed that their dogs are being infested by more ticks, year by year. Researchers from Russia describe, for example, a recent 50-fold increase in the prevalence of tick-borne encephalitis (TBE) in the northwestern part of the
country. In Sweden, the number of human cases of tularaemia has increased in the north recently, and TBE is now also occurring over a widened region in southern Sweden. Effective surveillance of these changes in the range and seasonality of various infectious diseases, and their health consequences, is needed to minimise future risks for humans and animals.

Environmental risks to health from chemical contaminants in the environment have been of particular concern in the Arctic, due to long-range transportation (atmospheric and ocean transport) from lower latitudes as well as from local sources. Examples of such contaminants are persistent toxic substances, including mercury and lead, and persistent organic pollutants such as polychlorinated biphenyls and pesticides. These hazardous chemicals are of particular concern for the unborn. Surveillance of contaminants in the environment and in food and water has been ongoing for some years, and some encouraging evidence is presented here showing that, consequently, situations can sometimes improve.

Times of change, as we now experience with climate change, present not only more problems but also more opportunities – especially opportunities to change, even transform, methods of production, consumption and energy generation and use. However, without well-functioning surveillance systems for different health aspects and without adequate research and appropriate research funding, the problems will overwhelm the opportunities.

Food security is a central concern – and an important example. Food security requires that all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active healthy life. However, with the advent of climate change, climatic conditions and seasonal timetables will change in ways that affect food yields. Other more specific problems will result. For example, underground ice cellars traditionally used to store whale meat frozen all year round no longer function safely due to thawing of the permafrost. Such climate-related changes in long-standing customs and ways of living ultimately lead to stress, mental disorders and suicides.

Water security means having access to water of good quality. Without access to food and water of good quality, health is threatened and living conditions are impaired. Data reported in this issue show, that in Alaska in areas with declining access to water, there is an increase in respiratory and skin infections resulting in more cases of hospitalisation. A surveillance of the quality of food and water, and of access to them, is of particular importance in the Arctic, especially now that, in addition to longer standing and more localised environmental problems, the climate is changing so rapidly (6).

The Arctic Council has a number of working groups, and the Sustainable Development Working Group (SDWG) has recently formed an expert group on human health together with representatives of the indigenous peoples in the north. The Arctic Human Health Expert Group (AHHEG) is responsible for framing the SDWG human health agenda, proposing priorities and projects, and assessing proposals for actions that will contribute to the advancement of a knowledge base on circumpolar human health.

This special issue is an initiative from the AHHEG to raise awareness and knowledge of the effects of ongoing climate change on the health of humans in the Arctic and adjoining north. The rest of the world should question whether it is reasonable that some human groups and their cultures should pay so high a price for activities performed by populations elsewhere – including, now especially, activities that contribute to climate change. Indigenous peoples are the most vulnerable humans in this context, but further, all humans and animals in the north are exposed to these climatic and environmental changes. Ethical perspectives must, therefore, be brought to the conference table as well as into academic environments. The media’s awareness of the significance and urgency of this great modern threat and challenge should also increase thereby contributing to wider public understanding of the need for action.

Further research on the effects of climate change on human and animal health and activities in the north will provide essential knowledge. This requires more funding for scientific research, the result of which will be more secure data for decision makers to shape the best possible future for a planet on which the conditions for life are ever changing, albeit now much more rapidly than when nature acts alone.

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References


Climate change and health effects in Northwest Alaska

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This article provides examples of adverse health effects, including weather-related injury, food insecurity, mental health issues, and water infrastructure damage, and the responses to these effects that are currently being applied in two Northwest Alaska communities.

Background: In Northwest Alaska, warming is resulting in a broad range of unusual weather and environmental conditions, including delayed freeze-up, earlier breakup, storm surge, coastal erosion, and thawing permafrost. These are just some of the climate impacts that are driving concerns about weather-related injury, the spread of disease, mental health issues, infrastructure damage, and food and water security. Local leaders are challenged to identify appropriate adaptation strategies to address climate impacts and related health effects.

Implementation process: The tribal health system is combining local observations, traditional knowledge, and western science to perform community-specific climate change health impact assessments. Local leaders are applying this information to develop adaptation responses.

Objective: The Alaska Native Tribal Health Consortium will describe relationships between climate impacts and health effects and provide examples of community-scaled adaptation actions currently being applied in Northwest Alaska.

Findings: Climate change is increasing vulnerability to injury, disease, mental stress, food insecurity, and water insecurity. Northwest communities are applying adaptation approaches that are both specific and appropriate.

Conclusion: The health impact assessment process is effective in raising awareness, encouraging discussion, engaging partners, and implementing adaptation planning. With community-specific information, local leaders are applying health protective adaptation measures.

Keywords: climate change; health impact assessment; health effects; Arctic health

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observation that synthesizes complex climate and health causal chains, and combines both indigenous and western knowledge systems (6). Development of the process and the implementation was funded by the US Indian Health Service and the US Environmental Protection Agency. This article provides examples of climate health effects related to injury, infectious disease, food security, mental health, and sanitation infrastructure. It also provides examples of adaptive strategies that are being applied in two communities: Point Hope and Kivalina.

Present investigation

Regional characteristics
The Northwest Arctic region crosses the Arctic Circle and covers an area of about 63,000 square kilometers. Bordered by the Brooks Mountain Range to the north and the Chukchi Sea to the west, the area is underlain by ice-rich permafrost and is in the transition zone between taiga forest in the south and tundra in the north. It is also a transition zone between Arctic, maritime, and continental climate regions. In the hub community of Kotzebue, temperatures range from −46°C to +29°C. Total annual precipitation averages 23 cm with an average annual snowfall of about 101 cm (7). Between 1949 and 2006, the average annual temperature increased by 1.8°C (8), with the greatest increase occurring during the winter months. A comparison of monthly average air temperatures suggests a trend of increasing temperature in every month of the year (9).

About the people
There are a total of 12 communities in the Northwest Arctic region, the largest of which is Kotzebue with a population of about 8,000 residents. The region is remote and isolated with no connecting roads between communities or with the rest of the state. Eighty-five percent of residents are Inupiat Eskimos and many are engaged throughout the year harvesting caribou, seal, fish, whale, moose, berries, birds, and edible plants. Employment related to education, health, government, mining, transportation, fishing, and construction contribute to the economy. Unemployment is about 15.6%. The median household income is $45,976.00 and about 17.4% of the population is below the poverty level.

In 1950, the average life expectancy for Alaska Natives was 46.6 years. By 2001, life expectancy at birth for both sexes had risen to 70.3 years, largely due to decreases in mortality from infectious disease and unintentional injuries (10). Still, mortality rates for Alaska Natives exceed that of “all races” in the USA, for all causes except heart disease. Rates for most chronic diseases are increasing. Age-standardized rates of cancer are up by 12%, chronic obstructive pulmonary disease up by 191%, and diabetes is up by 262%. These general trends also apply in the Northwest Arctic where the leading causes of death – cancer, heart disease, unintentional injuries, cerebrovascular diseases, and suicide – are all increasing (11).

Climate impacts, health effects, and adaptation

Injury
Extreme and unpredictable weather, altered seasons, and poor water, snow, and ice conditions are climate impacts that can cause injury. A leading concern in the Northwest is falls through ice. During the past two decades, thick multiyear sea ice has been replaced by thinner first-year ice over large areas of the Arctic (12). There is anecdotal evidence that sea ice conditions are increasing the risk of injury.

“The ice is no good for hauling out bowhead. Too thin. This spring it was so bad people were falling through the ice all over the place. It was very dangerous.” (Ray Koonuk Sr., Environmental Program Director)

On May 8, 2008, three Point Hope whaling crews were cast adrift when shore-fast ice broke free, resulting in helicopter rescues. Diminishing river ice is also a concern for many communities. Northwest Arctic residents rely on river ice roads to hunt, travel between communities, and transport fuel and supplies. But many rivers now have a shorter ice travel season. The Kobuk River is breaking up more than a week earlier than when records began in the early 1900s resulting in ice conditions that are more unpredictable and unsafe, even in mid-winter (13). Concerns about ice safety were expressed by residents in all of the communities surveyed.

“A few years ago freeze-up was late. We had three or four snow machines go through the ice. Two machines were lost.” (Andrew Baldwin Jr., Public Safety Officer)

Adaptation responses are merging traditional knowledge with modern technology. In Point Hope, emergency response time has been improving with the distribution and broader use of personal emergency locator beacons. The beacons are provided on loan to hunters and travelers by the local fire department. These are tracking transmitters that aid in the detection and location of people in distress.

“The storms have been very bad. Lots of wind and blowing snow. Hunters are using locator beacons that are tracked by Search and Rescue in Barrow. These result in rescues and saved lives.” (Willard Hunnicutt, Fire Chief)

Infectious diseases
The Northwest Arctic region has high rates of respiratory infection. In 2005, pneumonia was the leading cause of hospitalization, accounting for over 55% of hospital discharges. Poor sanitation is an important causal factor.
Alaska Native homes without running water experience far higher rates of respiratory and skin infections (14). Climate change can indirectly increase the risk of infectious disease by damaging and disrupting water and sanitation infrastructure.

“When the washeteria freezes up, the number of people visiting the clinic with infections goes up.” 
(Isabelle Booth, Community Health Aide)

In October 2004, the development of shore ice in the village of Kivalina was delayed because of unusually mild temperatures. Shore ice is important as it provides a buffer between powerful storm waves and the fragile Arctic coastline. Storm surge that month (see photo 1) caused extensive erosion and damaged the sewage drain field at the washeteria, the only facility in Kivalina that provides public toilet, laundry, and shower facilities. The damage closed the washeteria for five consecutive months in 2005 and continued to contribute to declining days of washeteria operation over the next few years. Extended periods of closure raised concerns about the potential for increased rates of skin and respiratory infection.

A preliminary review of clinical patient visit codes by the Alaska Native Tribal Health Consortium suggests that increasing washeteria closure days correspond with increasing rates of skin infection. Between 2004 and 2007, the total number of skin disease-related clinical visits to the Kivalina Clinic more than tripled: from 44 visits per year in 2004 to 140 per year in 2007. An epidemiological evaluation has been initiated by the US Centers for Disease Control and Prevention to evaluate the potential relationship between washeteria closure and incidence of infectious disease. Adaptation activities in Kivalina include the construction of a new washeteria waste water system and an engineering feasibility study to look at other possible water and sanitation improvements.

Food insecurity
A traditional lifestyle and diet helps to prevent many chronic diseases, but climate change is decreasing access to some healthy traditional foods. In Point Hope and Kivalina, thawing of the permafrost in traditional underground ice cellars is decreasing food security (15). Harvested bowhead and beluga whale is stored in underground food cellars, (see photo 2). The cellars until recently were frozen year round. Today, they typically thaw in the summer, resulting in meat and blubber that can be unsafe or inedible.

“We used to have frozen whale meat and maktak all year round, winter and summertime too. But it is not frozen anymore.” (Joe Towksjhea, Retired Whaling Captain)

Warming temperatures may also be increasing risk of food-borne, gastrointestinal diseases. Adaptation responses have included monitoring the cellar temperatures and humidity. A review of traditional sigíl’uqas design, construction, and methods of use is also being performed. Interdisciplinary teams, including traditional users, permafrost scientists, and engineers are meeting to identify potential adaptation options for these coastal communities.

Mental health
Alaska Natives are experiencing stress related to rapid cultural change and the loss of social, cultural, and environmental conditions. Climate change can also generate stress and fear related to safety and security. Flooding in the fall of 2007 resulted in evacuation of the entire village of Kivalina. On-going vulnerability to storm events puts residents at higher risk for behavioral health problems. Local health workers report heightened stress, fear, and anxiety among residents during the storm season.
Community water infrastructure

Climate change is a new challenge for water utilities already struggling with high operating costs. Warming and permafrost thaw is impacting water availability and water quality, and causing some surface water systems to operate outside their design parameters. The active thaw layer of the permafrost is increasing, and even the deep permafrost is warming, as much as 2°C over the past 20 years (17). A review of satellite imagery by the US Geological Survey suggests that the size of the lakes in the vicinity of Point Hope is undergoing rapid change. Point Hope acquires water from a small tundra lake situated on top of permafrost. From late June until early September operators work 24-hour shifts to have enough stored water to last through the winter. But high summer temperatures in recent years has increased algae and permafrost thaw, and permafrost thaw is impacting water availability and causing some surface water systems to operate outside their design parameters. The active thaw layer of the permafrost is increasing, and even the deep permafrost is warming, as much as 2°C over the past 20 years (17). A review of satellite imagery by the US Geological Survey suggests that the size of the lakes in the vicinity of Point Hope is undergoing rapid change. Point Hope acquires water from a small tundra lake situated on top of permafrost. From late June until early September operators work 24-hour shifts to have enough stored water to last through the winter. But high summer temperatures in recent years has increased algae and other biological growth in the lake, decreasing water quality and fouling filters at the water plant.

“...There have been lots of mosquitoes and mosquito larvae. They plug up the bag filters and we have to change them every five minutes.” (Andrew Frankson, Water Operator)

Typically, water plant operators clean water system prefilters four times per day. In 2008, the number of required cleaning events rose to as much as 50 times per day, significantly decreasing productivity. Periods of increased filter change correspond with periods of high air temperature. Adaptation responses have included baseline testing of water quality and active monitoring of lake water conditions.

Conclusion

In Northwestern Alaska, climate change is increasing vulnerability to injury, disease, mental stress, food insecurity, and water insecurity. Northwest communities are applying adaptation approaches that are specific and appropriate. Satellite technology is helping to reduce risk of injury by quickly locating hunters in distress. Improved shore revetment walls not only prevent erosion and protect infrastructure but also help reduce mental stress. In communities concerned with changes to source water quality, improved monitoring is helping engineers to design more resilient and condition appropriate water systems. Community-scale health impact assessment is an approach that is helping communities in Northwestern Alaska identify and address their local climate challenges. Understanding the connections between climate change and human health is the first step toward effective adaptation planning.

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Facing the limit of resilience: perceptions of climate change among reindeer herding Sami in Sweden

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Background: The Arctic area is a part of the globe where the increase in global temperature has had the earliest noticeable effect and indigenous peoples, including the Swedish reindeer herding Sami, are amongst the first to be affected by these changes.

Objective: To explore the experiences and perceptions of climate change among Swedish reindeer herding Sami.

Study design: In-depth interviews with 14 Swedish reindeer herding Sami were performed, with purposive sampling. The interviews focused on the herders experiences of climate change, observed consequences and thoughts about this. The interviews were analysed using content analysis.

Results: One core theme emerged from the interviews: facing the limit of resilience. Swedish reindeer-herding Sami perceive climate change as yet another stressor in their daily struggle. They have experienced severe and more rapidly shifting, unstable weather with associated changes in vegetation and alterations in the freeze-thaw cycle, all of which affect reindeer herding. The forecasts about climate change from authorities and scientists have contributed to stress and anxiety. Other societal developments have lead to decreased flexibility that obstructs adaptation. Some adaptive strategies are discordant with the traditional life of reindeer herding, and there is a fear among the Sami of being the last generation practising traditional reindeer herding.

Conclusions: The study illustrates the vulnerable situation of the reindeer herders and that climate change impact may have serious consequences for the trade and their overall way of life. Decision makers on all levels, both in Sweden and internationally, need improved insights into these complex issues to be able to make adequate decisions about adaptive climate change strategies.

Keywords: climate change; indigenous peoples; Sami, reindeer herding; perception; resilience

Global climate change is unequivocal and the Arctic regions are experiencing the most rapid increase in temperature on the planet, at approximately twice the global average rate, most pronounced changes occurring during winter and spring (1). The impacts of climate change have been evident in many Arctic societies with detrimental consequences in some places, especially for the indigenous populations (2). The northern part of Sweden contains a small area above the Arctic circle, but the main part in the subarctic region might also be affected by early climate impacts, influencing the people in this region. The indigenous peoples of Sweden, the Sami, live here. The traditional Sami land, called Sápmi, covers four countries: Northern Norway, Northern Sweden, the northernmost part of Finland in Scandinavia and the Kola Peninsula in Russia, see Fig. 1. There are approximately 100,000 Sami in these four countries of whom 20,000 Sami live in Sweden (3).

A group of people in this population, the reindeer herders, live very close to nature and are hereby exposed to the potential effects of climate change more than others. Sami reindeer herding represents a tightly intertwined human-environmental system in which indigenous people interact closely with an ecosystem upon which they depend for their way of life. The regions in the Nordic countries where reindeer herding is practised are sparsely

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populated though rich in infrastructure, transport and electronic communication networks, compared to other circumpolar regions. The Sami traditional trades include hunting, fishing, handicraft and reindeer herding. Around 10% of the Swedish Sami are involved in reindeer herding. The majority of Swedish Sami are integrated in the Swedish society, for example in terms of occupations and schooling.

According to Hassler et al. (4), the Sami overall health status shows generally small differences in risk of major diseases and causes of death compared with the non-Sami population. The overall life expectancy of Sami people equals that of the rest of the Swedish population: 74.9 years for Sami men compared to 74.6 years, 80.0 years for Sami women compared to 80.3 years (4). In comparison with other indigenous peoples, the successful epidemiological transition of the Sami population is globally unique. It is attributed to a gradual integration of traditional and modern life styles, high living standards and a high educational level. In terms of socioeconomic standards, the overall annual medium net income for Sami between 1970 and 2000 shows small differences compared with the non-Sami population, although the income for reindeer-herding Sami men was considerably lower. In fact, in reindeer herding Sami households, the majority of the family’s net income today comes from women being employed outside the household (5).

Approximately 2,500 Swedish Sami in 51 Sami villages have their main income from reindeer herding, and the number of reindeer has fluctuated around 250,000 in the last 5 years (6). Reindeer herding is practised on 52% of Sweden’s surface, and the conditions for the trade vary to a great extent in different regions of the country. Reindeers are principally managed in a Nordic manner, rich in tradition; there are two annual migrations moving the animals between geographically separate summer and winter pastures. Reindeer herding in Sweden is entirely based on the sustainable and free exploitation of natural pastures. The main income in reindeer herding in Sweden comes from commercial trade with reindeer meat and from economic compensation for predation losses. Reindeer predators in Sweden include brown bear (*Ursus arctos*), lynx (*Lynx lynx*), wolf (*Canis lupus*), wolverine (*Gulo gulo*) and golden eagle (*Aquila chryseatus*) (7).

The weather patterns covering reindeer pastures are highly complex and display a large degree of regional, local and temporal variation. Changes in temperature, weather and precipitation can affect vegetation and the animals’ possibility to access grazing. Especially, where climate change affects the freeze-thaw cycle, powerful impacts can be expected (2).

**Aim**

The aim of this study was to explore the experiences and perceptions of climate change among reindeer herders in the Swedish indigenous population: the Sami.
Method

Study design
The study was a qualitative, descriptive study, based on in-depth semi-structured interviews using open-ended questions. Individual interviews were considered the most appropriate method to gain an in-depth understanding of the reindeer herder’s views and perspectives on climate change. Individual interviewing might enable the reindeer herders to express emotions or discuss sensitive issues more easily. In addition, it was also considered the most suitable method, as a geographical dispersion of the interviewees was regarded as very important due to the large range and variation in conditions for reindeer herding in different parts of Sweden. The reindeer herders work all week long in constant readiness for the needs of the herd, and it would have been very complicated and difficult to gather a group of herders from different parts of northern Sweden at a specific time and place. Individual interviews also met the reindeer herders’ need for flexibility.

The study obtained consent from the Sami Parliament and was approved by the Research Ethics Committee at Umeå University (dnr 09–193 § 48/09).

Sampling of informants
The sampling was purposive, aiming at maximum variation with an effort to include reindeer herders of different sex and age, active as well as retired herders and opinions from different regions in Swedish Sápmi. The initial two interviewees were recruited during the Jokkmokk Winter Conference 2009. After that, the heads of different Sami villages were contacted to reach potential interviewees. Some of the participants were found through the so-called snowballing technique, where informants were asked to suggest other relevant participants. The informants were contacted by phone and if they agreed to participate, asked to choose the time and place for the interview.

Study population
The interviewees were 14 reindeer herders from all over Swedish Sápmi, 3 women and 11 men, representing 11 different Sami villages. The median age was 56, age ranging between 16 and 75. The two youngest participants were still students but were brought up in reindeer-herding families and worked with reindeer herding during holidays. Both planned a future as reindeer herders. One of these young interviewees worked with a reindeer herd situated in Norway, not far from the Swedish border but had experiences in reindeer herding in both Sweden and Norway. Seven of the interviewees were still full-time herders, four were retired full-time herders and one person had another occupation and worked part-time. The average number of years with reindeer-herding experiences among those working as reindeer herders was approximately 39 years. The geographical distribution of the participants in this study is shown in Fig. 1.

Data collection
The interviews were conducted during 3 months in the spring of 2009.

All interviews were performed by Maria Furberg in Swedish, which together with Sami is the native language of the interviewees. The interviews were conducted at places chosen by the participants themselves and most of them took place in the homes of the interviewees. The interviews were digitally recorded and lasted between 30 and 80 min. An interview guide was used and the participants were asked to reflect upon

- what they knew about climate change
- experiences of changes in their environment over time
- their thoughts about these changes
- the future for reindeer herding

Throughout the process of interviewing, the interview guide was evaluated and developed further several times using an emergent design. Maria Furberg wrote brief research notes to preserve reflections and thoughts emanating during the interviews. After having performed 14 interviews, it seemed that the range and variation in experiences and perceptions of climate change had been captured and that saturation was reached.

Data analysis
The interviews were analysed using qualitative content analysis as described by Graneheim and Lundman, a method similar to the one described by Krippendorff (8, 9). In the systematic analysis, both the manifest content and the latent meaning of the text were captured, aiming at an understanding of the reindeer herder’s experiences and perceptions of climate change. Each interview was transcribed verbatim, five of them by Maria Furberg herself. To start with, all interviews were read several times to obtain a sense of the whole. The analysis then proceeded with detailed analysis of each interview and an open coding process with the use of the Open-Code software (10, 11). The text was divided into meaning units that were then labelled with codes capturing the contents of the units. A meaning unit comprises words, sentences or paragraphs containing aspects related to each other through their content and context (8). After all interviews had been coded once, a second round of coding took place, refining codes to make sure that the latent meaning would be captured. The codes were carefully evaluated so that they did refer to the same aspects in-between interviews. The coding was done also by another researcher to ensure

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concordance in the interpretations and thereby increase trustworthiness.

Codes with a similar content were grouped into sub-categories. These sub-categories formed five main categories. The process of analysis hereby developed from organising the data to organising ideas generated from the data, as described by Starrin (12). A continuous development of the codes, sub-categories and categories was carried out throughout the whole process by constantly moving backwards and forwards in the material: from the whole to parts of the text. Finally, one theme emerged that brought the five main categories together. An example from the analysis process is presented in Fig. 2 showing a meaning unit, codes, sub-categories and a category.

Results

In the interviews, the herders talked about their everyday lives, impacts of changes in their environment and how different circumstances affect their work and restrict their ability to adapt. Based on the codes and developed categories, one core theme emerged that characterises how the reindeer herders viewed their current situation, especially in the light of climate change: reindeer herding is facing the limit of resilience. The five categories describe how everyday life as a reindeer herder has changed over time, especially during the last 10 years and the impacts these changes, including climate change, have had on reindeer herding. In the following text, each section is titled with the category, the sub-categories are indicated in bold and quotations are included to illustrate how the interpretations are grounded in the data. Fig. 3 gives an overview of the findings illustrating the relationship between the key concepts in the interview guide, sub-categories, categories and the emerging theme.

It is like the seasons have been disturbed

The last 30 years have seen major changes in the natural environment and the weather. The interviewees were worried about the impact these changes have had and may have on reindeer herding. The herders in our study pointed out that, although changes have always occurred in the natural environment, the current changes are not ones they recognise. These environmental changes included the following:

The interviewees felt the weather and the seasons have changed and described a feeling of the year having been ‘regearred’, rearranged in some way with the seasons being disturbed. The autumns are longer, wetter and warmer with the temperature hovering around zero degrees (°C) for an extended period of time. The herders described a delay in the onset of autumn, and some had also noted a shift in the oestrus of the reindeer a few days later than previously, which means animals can be slaughtered later than they were before. If there is no autumnal night frost, then the mushrooms do not freeze and die and that makes it more difficult to herd the reindeer for slaughter. During normal migration, both the reindeer and herders must cross frozen bodies of water. However, according to the interviewees, the waters freeze over much later, which affects the migration to the winter-grazing lands especially for Sami villages that have large rivers along their migration routes.

Herder 3: when we moved down in the past, the waters froze in the autumn, there was a bit of snow, it was cold, it started in October already. The waters froze in October, so we used to move, sometimes we’d move a month before Christmas and we’d use all the lakes. There are lots of lakes along our migration routes and they used to be frozen over then but now they’re not.

The interviewees described how snow can come very early but then disappear again and then it can keep on raining and snowing right up until Christmas. As a result, the lichen freezes in a sheet of ice close to the ground forming ‘ice bark’; the pasturage becomes ‘locked’, thus making it impossible for the animals to reach. In early autumn, sleet can also stimulate the reindeer to start migrating too early. The resulting slushy, wet and unstable autumns were a source of considerable worry to the interviewees as pastures that freeze over early can remain frozen the whole winter preventing the reindeer from grazing properly.

Herder 13: Yes, but it’s as if everything has been regearred, the whole year has kind of changed gear . . . When I started reindeer herding, you could drive a snowmobile in the middle of October and it...
was already winter then. By the first Sunday in Advent it was always winter, and snow, and it was cold, and the winter finished around the tenth-fifteenth of May, you couldn’t drive a snowmobile any longer. It was always like that. But now the snow doesn’t arrive until Christmas, it doesn’t go cold, and it sleet and it rains and it browls and goes on in November-December and it’s not proper winter and then it’s winter until Midsummer instead...

According to the interviewees, the long, stable cold periods often do not occur at all and the winters feel much warmer. Sudden thaws in the winter are today commonplace, which can lead to good pasturage becoming locked. In general, the interviewees felt that the winter weather is more unstable than it used to be. They had noted that precipitation can occur even at severely cold temperatures. This completely new and previously unknown phenomenon is quite distressing to the herders.

The spring comes early and suddenly, as early as March, 2–3 weeks earlier than normal and the interviewees could see an advantage in this for reindeer herding. Those who have summer pastures in the Norrbotten mountains said, however, that spring in the mountains comes later today or suddenly stops and is followed by a very cold May, which can have a very negative impact on the sensitive calving period. Early spring with high temperatures also means that no proper snow crust forms during the night, making migration more difficult and requiring more energy both from the reindeer and the herders.

The interviewees gave varying pictures of the summers. Some felt that the summer season is warmer, whereas others thought the really hot summers have disappeared. Some had noted that in the mountains there are fewer ‘nival patches’—patches of snow that remain for longer than the rest of the snow, sometimes even right through the summer—than there used to be. The warmer summers can also bring more insects causing a nuisance for the
reindeer. The interviewees described how the mushrooms arrive earlier, sometimes as early as in July, which means the herders have to finish tagging the calves earlier as the calves begin to disperse in search of mushrooms.

More of everything
Most climate scenarios predict more extreme weather events. None of the interviewees mentioned this but they did talk about the everyday weather becoming more extreme, everything is getting more intensive and they perceived the weather to be more unstable. Sun, rain and snow alternate and the interviewees described how the variations in temperature can be severe, which can lead to rapid changes in pasturage.

The herders perceived the sun to be hotter and to burn more, especially in the spring. The reindeer herders get sunburnt as early as February, something they have not experienced before. When it rains, there are huge amounts of rain; when it snows, it snows intensely.

Herder 13: what I react a lot to is weather that gets so bloody extreme. If the sun starts to shine, it shines incredibly brightly and it’s warm for a long time, and if it starts to rain, it never stops, and if its starts to snow, it never stops snowing either. It gets so, kind of very extreme and I’ve not seen that before, when I was younger.

Herder 5: ‘It’s like this (demonstrates huge waves with the hand) up and down all the time. In recent years, we’ve also started to say that when we’ve had a cold snap of say –15 degrees (°C), that’s been a lot. And we know that it’s now 2 days later and it’s above zero. This is what it’s been like in recent years.’ … One evening it was suddenly plus two degrees (°C). It went like from –20 to +2 degrees (°C) in just a few hours, but then it went back down again. This kind of uneven temperature is something that you think has started to occur more recently—these sudden shifts in temperature I mean.’

The tree line is rising rapidly and the interviewees described how they find tree plants high up on the bare mountain (above the tree line) and that areas that were completely bare before are now afforested. They felt that there has been a general increase in forest growth and they had also noticed that the annual spruce tree shoots have increased substantially in size. The changes have happened rapidly over the last 10 years.

Herder 9: Since I was a kid, you can see quite clearly that there’s now more vegetation. That there are more bushes and more brushwood and that the tree line is moving further and further up. Spruce forest is growing where it actually shouldn’t. And it’s going fast. You can see the annual shoot can be 50 cm on a spruce, for example.

The interviewees were seeing obvious changes in the vegetation in the reindeer-grazing lands, which was something that worried them. Forestry activities have led to a considerable reduction in the occurrence of tree-hanging lichen, but the interviewees also described how reindeer lichen has decreased and has been replaced by grass and other vegetation. Several also said that they believe the lichen is growing more slowly than it used to. They described that denser vegetation with bushes and brushwood are becoming more prevalent.

The traditional knowledge of the reindeer herder has developed over a long time, and many of the interviewees had the impression that this knowledge no longer corresponds with reality, also expressed by elders in their surroundings: they do not recognise themselves any longer. New, previously unknown phenomena such as precipitation in severely cold weather and drastic temperature variations over short periods of time are occurring and the old weather signs are no longer reliable. Herders are now being forced to do the opposite of what old, unwritten rules have always said, such as staying out on the mountains all winter or migrating to the summer-grazing lands at the wrong time.

Herder 5: And then we realized that so as not to destroy our winter grazing lands we had to leave, although it was only the end of March. And then we said that our father would turn in his grave if he knew that we were on the mountains at this time of year, it would be unthinkable!

The pressure on reindeer herding is increasing
The reindeer herders described how their room for manoeuvring has constantly decreased over the years as a result of outside pressure and restrictions. The grazing lands are continuously shrinking. The lands are being rendered useless for reindeer grazing as a result of exploitation for hydropower, forest roads, logging operations, wind farms, tourist resorts, etc. and no new lands are being made available.

Many Sami villages now move their reindeer by truck in contrast to traditional migration over land, where they herd the reindeer between the summer- and winter-grazing lands by night and let them rest and graze by day. The interviewees described how migration over land is becoming more difficult and is even impossible today for certain villages as their migration routes have been blocked by large water reservoirs that either do not freeze over at all or the ice on them is too thin when it is time for autumn migration. For some villages, there is no longer anywhere for the reindeer to graze when en route; the land has perhaps already been grazed or forestry has led to the disappearance of tree-hanging lichen – an important additional source of pasturage. There were several reasons why some herders started to move their reindeer by road, but the changes mentioned here have led herders in some village to realise that they no longer
have another option but to use trucks to transport the animals, despite the high costs involved.

Loss of traditional skills and knowledge worried the interviewees. Shrinking grazing lands and the need for larger reindeer herds in order to survive financially mean that not all those who want to can work as reindeer herders. These people take their skills and knowledge with them into other industries. In villages where traditional land-based migration is no longer possible, the new generation will never learn how to herd reindeer en route and traditional knowledge will be lost forever.

Herders described how the number and extent of competing business activities are increasing all the time and how the reindeer industry must always take a back seat in favour of interests from other industries such as wind power, hydropower, mining, forestry and tourism. They have neither the time nor the energy to spend working on all these issues.

Activities in the mountains and in the forest are expanding all the time and cover an increasingly greater part of the calendar year. According to the interviewees, this has led to the reindeer being disturbed for much more of the year than before by hunters, snowmobile enthusiasts, recreational activities, skiers, hikers, adventure tourists, etc. More and more activities are being offered to more and more tourists in the mountains, exerting greater pressure on the reindeer industry. The herders felt that everyone should have access to the mountains but they asked for greater respect from the general public for the needs of the reindeer and felt that this should be regulated in some way.

The interviewees emphasised the poor financial conditions for reindeer herding and the fact that they are nowadays totally dependent on state subsidies for their livelihoods. Examples of such subsidies include those for supplementary feeding, predator compensation and slaughter support. The reindeer industry is finding it difficult to survive financially on its own, and the vast majority of herders need to have another job on the side. The interviewees saw the poor financial prerequisites as yet another threat to regeneration among reindeer herders as today’s youth are not attracted to an industry in such dire financial straits.

The predator policy was seen as a major threat by the interviewees and a cause of a great deal of worry, anguish and sorrow. According to the reindeer herders, the predator compensation nowhere near covers the costs incurred by Sami villages when predators attack their animals, and they were convinced that the threat posed by predators has increased considerably over the last 20 years or so. Predators also cause the herders a great deal of mental stress. They feel for their animals and suffer when they find their remains, not only because of the financial loss they incur but also because they know all the individual animals in the herd and their histories.

The interviewees described how intermittent grazing by dispersed herds and the absence of deep snow favour the predators as this makes it easier for them to move around and attack their prey. They said that the reindeer industry will not be able to withstand the even greater pressure from predators that the climatic changes may create. The interviewees felt that the current Swedish predator policy does not consider the reindeer industry at all and that the general public is more or less ignorant of the facts.

As the financial situation deteriorates for the reindeer industry, all herders must have larger herds. With large herds and constantly shrinking grazing lands, the pasturage is being grazed too intensively and has too little time to recover. The interviewees perceived a lack of sustainability in today’s reindeer-herding activities, and they ascertained that they also had contributed to this development by starting to use trucks, helicopters, snowmobiles and motorbikes to a greater extent, which is very expensive and leads to costs that the industry is finding difficult to bear.

The reindeer herders pointed out that the poor and patchy pasturage is very labour intensive as the dispersed reindeers have to be more intensely watched and herded together more often. There is a need for supplementary feeding almost every winter. Today’s large herds in combination with the scattered pasturage make it virtually impossible to herd reindeer without the use of snowmobiles, and the interviewees ascertained that the reindeer herders’ traditional methods are not compatible with today’s climate.

Herder 8: And then I can think about past winters. It wouldn’t have been possible to use skis to keep the reindeer herd together.

Using snowmobiles is costly and is, according to some interviewees, detrimental to the reindeer herders’ health, causing work-related musculoskeletal disorders and pain. The interviewees also said that the climate change predictions they have received from researchers and authorities have caused considerable mental stress among herders. The predictions have been difficult to contend with and having them confirmed on a daily basis has further contributed to the stress and worry about the future, perhaps even more than the changes themselves.

Constantly left out in the cold

The herders described how the reindeer-herding Sami have always had to adapt and yield to a number of decisions taken by the authorities. They pointed out that the mountains were originally the Sami’s own country, where they were completely alone. When other interests in utilising this land emerged, the government intervened and claimed it as its own and the Sami had no say in the matter. The herders interviewed felt that the Sami were basically ‘steamrolled’ when the Reindeer Grazing...
Constitution came into force in 1972. The introduction of the 1993 law on hunting for small prey is seen as a similar decision that was taken without their consent and conflicted with their views and interests. Feelings of resignation and powerlessness in the face of authorities’ decisions and the regulatory framework were expressed during the interviews. The interviewees felt that they were being ignored and that they had no say in the decision making.

Herder 6: And I remember we really took the gloves off when we were negotiating about the 1972 convention but we still got shafted. However much we objected, we were just brushed aside.

The interviewees expressed that reindeer herding has always been ‘up against it’, and that the value generated by the reindeer industry counts for little in comparison to the ready cash produced by other industrial sectors: that reindeer herding is not valued in Sweden today, not considered important.

The interviewees were aware that, as a land-based industry, theirs is vulnerable to the effects of climate change and they felt that they are the first to be affected. They didn’t feel, however, that Sweden is participating in research into climate change and its effects on reindeer herding as actively as the other countries in the Arctic region. The interviewees called for a more active approach to research and more powerful measures to combat climate change. They believe that the government only proposes detailed measures and these also affect the reindeer industry. The increased taxes on fuel prices, for example, is making snowmobile and truck transport much more expensive and is having a serious financial impact on the industry, according to the study herders.

The interviewees painted a picture of the individual having great responsibility in the Sami reindeer-herding collective. Many herders are trying to be active and to take responsibility for their own livelihood and existence, for example, using less motorised vehicles, avoiding helicopter herding, taking better care of their waste and using ecological fuel. But, some of the interviewees nevertheless felt that they should get more involved in what is happening in the world around them, protest more against the encroachment by others into the environment on which they depend. At the same time, the interviewees felt that they do not have the time and this gives rise to a feeling of resignation. They felt the fact that they are ‘first in the firing line’ of climate change is unjust as the reindeer herders themselves don’t think they have contributed to it as much as others have. The interviewees felt that society in general should be assuming a greater level of responsibility for the costs associated with climate change.

According to the study herders, the Sami consider themselves a peaceful people and throughout history they have always adapted and backed down, not taken issue and protested – a strategy they are now starting to perhaps regret.

The Chernobyl nuclear disaster in 1986 hit the reindeer industry hard and constituted an elusive and invisible threat. The interviewees described feelings of being alone, powerless and left to fend for themselves after what happened and they had to deal with the problems caused by other people. Several of the herders spontaneously referred to Chernobyl when talking about climate change.

Herder 9: Look at Chernobyl for instance. Overnight things could change so much and affect so many people. So we’ve always got that in the back of our minds. And it’s not certain … that we’ll be able to still herd reindeer in fifty years time.

Chernobyl brought sorrow. According to those interviewed, herders had to go against their own values in terms of the respect they have for all living things. Everything changed overnight; apparently healthy animals were slaughtered and the meat had to be discarded. All Sami villages were adversely affected by the drop in demand for reindeer meat, but only villages with extremely high radiation levels in their meat received compensation.

The accident illustrated just how vulnerable reindeer herding is and with Chernobyl still fresh in memory, the interviewees expressed no faith in the governments’ support in terms of climate change impacts on the reindeer-herding industry.

Changing without losing the identity

Throughout the interviews, there is a sense of grief for the future. The herders did not consider climate change in itself to be the major threat to reindeer herding but rather to be yet another stressor on an already heavily burdened industry and culture. The interviewees described how fantastic their work as reindeer herders was, with a high quality of life. But, they also talked about reindeer herding as hard work, with a lot of worries and anguish as well. These worries focused primarily on the toll of predators on the herd, the weather, the availability of pasturage and the general financial considerations of the occupation. Several of the interviewees expressed relief at the thought of retiring. The pressure to be positive and always look for opportunities in order to have the strength to carry on with the job clearly came out in the interviews.

The interviewees emphasised that that they have always been able to adapt before, that they have to think of new solutions, a different form of reindeer herding, perhaps start to feed the animals, utilise new grazing land, etc. They think they can see opportunities in climate change, not just threats. If climate change results, for example, in snow-free winters, this would be a good thing for the reindeer industry. An extended growing season may
Facing the limit of resilience: Sami perceptions of climate change

provide the reindeer with better pasturage during the summer and they would be able to survive more serious winters, if they were shorter than they are today. Despite the interviewees talking a lot about the obstacles and difficulties caused by climate change, they also emphasised their own local benefits in the form of undulating grazing lands, access to nature reserves, better winter pasturage than other villages, etc.

One of the interviewees talked about a feeling of relief at not having had any children because of the stress and worry one suffers as a reindeer herder.

Herder 5: The fact that I don’t have any children, I see as an advantage in certain situations, honestly, when I think of what’s ahead . . .

Several of the interviewed herders have children who want to continue herding reindeer and they try to take a positive outlook so as not to destroy their children’s hopes for the future.

Herder 9: The future of reindeer herding, yes, I hope it’ll survive. And I have youngsters who believe in it. And I try to think positive for their sake as well. And for my own sake. But that’s the thing: I can’t be negative and pessimistic because then I’d undermine their hopes, beliefs and future prospects. Yes, so you just have to grin and bear it.

The interviewees described how they want to believe in the future for reindeer herding but at the same time they could see that it has already gone through major changes and that the adjustments needed to combat climate change in the future risk becoming overwhelming when combined with all the other stressors. They described how motorisation, profit maximisation, unsustainable grazing and feeding are all unwelcome developments and that a resistance movement has begun where herders are trying to revert to more traditional methods. However, this has been made more difficult by the climate changes on the environment.

Supplementary feeding is a reluctant emergency solution that has recently become necessary almost every winter because of frozen pasturage. Even though the interviewees did not like the idea of feeding, they were grateful that the option is available to them as their historical emergency pasturage in the form of tree-hanging lichen has now virtually disappeared. Supplementary feeding is costly, and the interviewees also described many other problems and difficulties it causes, including poorer tasting meat, a different fat consistency in the meat and a different and heavier workload with more herd supervision and feed management, compared to free grazing. Financial subsidies also come up in this context, the herders pointed out the risk of fenced reindeer gaining a competitive advantage over traditional reindeer herding: the reindeer do not need to be monitored, the costs for snowmobiles and motorbikes are avoided, the animals do not need to be transported and fed reindeer are bigger and weigh more when they are slaughtered. All the interviewees were against the trend towards keeping reindeer in enclosures, which, they said, increases the risk of disease among the animals and is against their nature. The interviewees described how the greater need for feeding, the trend towards keeping reindeer in enclosures and the hopeless financial conditions for reindeer herding are threatening the very professional identity of reindeer herders. Thus, the profession of herding is at risk of becoming just a hobby. In the past, the reindeers were the focal point of reindeer herding; the reindeer steers what the herder does, not the other way round. However, the interviewees described how the profession is today more and more governed by outside circumstances instead of by the reindeer. For example, the animals are slaughtered when the herder manages to book an abattoir truck or on the day the vet is available. Herders make sure they do not arrive in the mountains until after Easter so that they do not have to ask for a ban on snowmobiles and come into conflict with tourists. The herders must move the animals when they can get hold of a truck, etc.

Herder 9: You are controlled in a different way by dates, like when we get the abattoir truck. We’re a bit controlled from the outside as well. You can’t just decide that now we’ll take the reindeer in when the timing and conditions are ultimate.

The interviewees described the difficulties in combining traditional reindeer herding with today’s society: reindeer herders and their families also want to go on holiday, the children want the same material standards as their friends, value is seen only in terms of ready money. The interviewees found it difficult to see how the reindeer industry can bear such costs with the conditions it faces today, and several could not see a solution to the problem and asked themselves whether they are the last generation of traditional reindeer herders.

Discussion

The core theme that emerged during the analysis was ‘facing the limit of resilience’. In resilience theory, the concept of resilience refers to the capacity of a system to absorb disturbance and reorganise while undergoing change, so as to retain essentially the same function, structure, identity and feedback (13). The categories in this study are examples of such disturbances. Climate change poses additional challenges, and the reindeer herders no longer believe in their ability to adapt, leading towards the limit of resilience.

A lack of control is apparent in the whole data set. Most of the study reindeer herders have actual experiences of vulnerability directly connected to nature by living through the impacts of the Chernobyl accident. The interviewees described these events with strong
feelings of vulnerability, exposure and resignation; emotions increased by the dependency on decisions made by others. These experiences seem to affect how the reindeer herders view and handle the future and the prospects of climate change as described by the categories: grief for the future, trying to revert back to more traditional methods and being the last generation.

The study interviewees’ experiences of delayed autumns, bodies of water freezing over later in the year than usual, warmer winters, earlier springs, rising tree levels and changes in vegetation are all changes reported and/or predicted in the Intergovernmental Panel on Climate Change (IPCC) climate change assessments (1). In the Snowchange project 2001-2004, indigenous voices of climate and ecological change from all over the circumpolar North were heard and their statements also confer with the ones in this study (14). The reindeer herders in this study described both earlier spring and also longer lasting snow cover depending on location, giving the impression of later spring. These reports could be conceived as a contradiction, but this scenario has been described as a possible climate change impact by Hogda et al. (15). They posited that the impact of climate warming might result in an earlier onset of spring in areas where snow cover has been blown away by stronger winds, whereas spring will come later in areas with a thicker snow cover where the snowmelt will take longer (15).

A greater variability in the climate in form of more frequent storms or other extreme weather events has also been predicted (16). Although more extreme and unstable daily weather has not been identified in the projections, the reindeer herders in this study emphasise those phenomena. Whether these daily phenomena represent a so far unknown feature of climate change effects on weather systems remain unclear, future research is required to be able to make this determination.

Russian reindeer herders, the Nenets, as reported by the anthropologist Stammmer-Gossman, share the Sami reindeer herders’ concern about limitations in the adaptive capacity to handle climate change. Stammmer-Gossman claimed that for the Russian Nenets ‘changes to the natural environment induced by human activities are seen by the community as the main disturbing factor, whereas changes due to the “natural course of nature” may be accepted in the broader context of the autonomy and self-organization of nature’ (17). From the present study, it is not possible to say whether the Swedish reindeer herders share this cultural acceptance for natural environmental changes, but if they do, it could explain their lack of reports of more extreme weather events. Extreme weather events such as storms and flooding would then be considered a natural part of nature, as opposed to more extreme daily weather such as rapid fluctuations in temperature. Reindeer herders, in Sweden as well as in Russia, are experts in adapting to a dynamic landscape and changes in weather and environmental factors. This capacity for adaptation is based on traditional skills and knowledge and when this knowledge is no longer applicable or valid, it adds a new dimension of insecurity.

The Swedish reindeer herders in the present study are less concerned about the issues caused by climate change, but much more about their ability to adapt to those changes because of several other stressors and limitations. The interviewees argue that nature always changes and that they can handle climate change effects providing they have the means to do it. In the present study, issues such as decreasing grazing lands, poor economy, competing businesses and the Swedish national predator policy stand out as major threats to the adaptive capacity of reindeer herding.

The IPCC’s third assessment report defines vulnerability as the degree to which a system is susceptible to, or unable to cope with, adverse effects or stress (16). Many of the contemporary additional concerns for Arctic indigenous peoples, such as poverty, substance abuse, inadequate housing and substandard infrastructure, are not valid for reindeer herders in Sweden (2). Even so, based on the results in this study, Swedish reindeer herders are, according to the IPCC’s definition, highly vulnerable to climate change effects.

In Sweden’s 1994 national report to the IPCC, the evaluation of vulnerability to climate change includes only a few words about reindeer herding, mentioning larger quantities of snow, the formation of ‘ice bark’ and increased vulnerability to traffic death of reindeer, as problems. In comparison, the section about fishing is 3.6 times longer, although there are fewer professional fishermen than reindeer herders in Sweden today (18, 19). In the second report from 1997, there is no evaluation of vulnerability for reindeer herding (20). This might reflect the interviewees’ experiences of not being recognised in the Swedish society.

The Swedish Sami reindeer herders share their grief for the future and their fear of being the last generation to carry on traditional occupations such as reindeer herding, with many other indigenous peoples over the world. According to the UN, indigenous peoples face systemic discrimination and exclusion from political and economic power in many places of the world and the interviewees in this study describe the same notion.

Keskitalo’s comprehensive work on vulnerability assessments in the Arctic focusing on several nature-based industries also includes interviews with three Swedish reindeer herders and these participants likewise emphasized that the operating conditions for the sector must be improved to enable adaptation to further changes. Keskitalo summarised the sectors’ vulnerability as the result of multiple factors such as a poorly developed market, national regulation, climate/weather conditions.
and limited recruitment into the livelihood due to declining income (21). The Keskitalo participants, interviewed in 2004, also brought up that they were close to the limit of adaptation. This study, performed 5 years later, suggests that the reindeer herders now even closer to that limit: in the light of climate change, they are facing the limit of resilience.

**Conclusion**

The results of this study illustrate the reindeer herders’ vulnerable situation. The climate change impacts add additional pressure on the reindeer-herding industry that might have detrimental consequences for the trade, the culture, the historical traditions and the people involved. Swedish decision makers on a national level, as well as regional and local levels, need to have an increased insight into the various pressures affecting the reindeer-herding industry to be able to make adequate decisions on climate change adaptation strategies. This article provides a framework for improved decision making based on the reindeer herders’ own perceptions and experiences.

**Conflict of interest and funding**

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**References**


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What is known about the health and living conditions of the indigenous people of northern Scandinavia, the Sami?

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**Background:** The Sami are the indigenous ethnic population of northern Scandinavia. Their health condition is poorly known, although the knowledge has improved over the last decade.

**Objectives:** The aim was to review the current information on mortality, diseases, and risk factor exposure in the Swedish Sami population.

**Design:** Health-related research on Sami cohorts published in scientific journals and anthologies was used to compare the health condition among the Sami and the majority non-Sami population. When relevant, data from the Sami populations in Swedish were compared with corresponding data from Norwegian and Finnish Sami populations.

**Results:** Life expectancy and mortality patterns of the Sami are similar to those of the majority population. Small differences in incidences of cancer and cardiovascular diseases have been reported. The traditional Sami lifestyle seems to contain elements that reduce the risk to develop cancer and cardiovascular diseases, e.g. physical activity, diet rich in antioxidants and unsaturated fatty acids, and a strong cultural identity. Reindeer herding is an important cultural activity among the Sami and is associated with high risks for accidents. Pain in the lower back, neck, shoulders, elbows, and hands are frequent among both men and women in reindeer-herding families. For men, these symptoms are related to high exposure to terrain vehicles, particularly snowmobile, whereas for women psychosocial risk factors seem to more important, e.g. poor social support, high effort, low reward, and high economical responsibilities.

**Conclusions:** Although the health condition of the Sami population appears to be rather similar to that of the general Swedish population, a number of specific health problems have been identified, especially among the reindeer-herding Sami. Most of these problems have their origin in marginalization and poor knowledge of the reindeer husbandry and the Sami culture in the majority population. It is suggested that the most sustainable measure to improve the health among the reindeer-herding Sami would be to improve the conditions of the reindeer husbandry and the Sami culture.

**Keywords:** review; Sami; reindeer herding; health; mortality; cancer; cardiovascular diseases; physical and psychosocial risk factors; dietary habits; marginalization

*The Sami people are the indigenous ethnic group of northern Scandinavia and the Kola Peninsula. Taking advantage of the receding Fennoscandian ice sheet 10,000–7,000 years ago, they migrated from Western Europe through Eastern Europe, up to Northern Scandinavia via Finland and the coastal areas of Norway (1). Phylogenetic reconstructions based on DNA markers have shown that the Sami descended from a small and distinct subgroup of Western Europeans rather than from indigenous Siberian populations (2, 3).

The size of the present Sami population in the Scandinavian countries is not well known due to lack of ethnic markers in national population records and censuses. Different estimates suggest the total population to consist between about 80,000 and 110,000 Sami (4, 5). The Norwegian Sami population is largest (a high...
The health and living conditions of the indigenous people of northern Scandinavia

The majority of the Sami still inhabit the northern parts of the Scandinavian countries. The highest density is found along the valley of the Tana River where they constitute the ethnic majority in two Norwegian municipalities (Karajok and Kautokeino) and in one Finnish municipality (Utsjoki) (5). From this core area, the relative frequency of Sami gradually declines with distance, particularly toward the eastern and southern parts of the Scandinavian countries. In Sweden, about 50% of the total Sami population inhabits the northernmost county (Norrbotten) and about 15% inhabits the second northern-most county (Vasterbotten) (6).

Today, most Sami have adopted an ordinary western way of living, with, e.g. modern professions and similar food habits as in the general population. Only small groups are still holding on to a more traditional lifestyle based on fishing, hunting, and reindeer herding. In Sweden and Norway, the legal right to breed and herd reindeer for commercial purposes is restricted to inhabitants of Sami heritage. There are approximately 2,000 Sami in each of Norway and Sweden who are economically dependent on reindeer husbandry (7).

The political situation of the Sami has improved over the last decades. In Norway, Finland, and Sweden, the Sami have been acknowledged as the original inhabitants of northern Scandinavia, and a National Sami Parliament has been established in each of the three countries. However, the mandates of these parliaments are weak and important parts of the national legislations and social structures are not adjusted to meet the rights and needs of the Sami.

Like other ethnic minorities, the Sami people have suffered from centuries of discrimination and marginalization. The sociocultural vulnerability of the Sami, together with their genetic origin (8–10), suggests deviating disease and mortality patterns between the Sami and the majority populations in the Scandinavian countries. It might therefore appear a bit surprising that the knowledge of the health condition of the Sami is still quite poor, particularly regarding the condition of the Russian Sami.

In a research review published in 2005, we concluded that most of the published researches on health and diseases among Sami were fractionated, unsystematic, and anecdotal (11). However, the situation has improved over the last years. An increasing number of research initiatives have been taken in the Scandinavian countries, particularly in Norway where substantial governmental resources have been assigned to research on the health condition of their Sami population.

Our current knowledge on health and diseases in the Swedish Sami population rests to a large extent on studies conducted by me and my coworkers at the Southern Lapland Research Department in Vilhelmina. The results have previously been reviewed in Swedish and in Sami with the primary objective to disseminate the knowledge among national authorities, health-care organizations, and within the Sami community (6, 7).

The aim of the present article is to review the current knowledge on the health and living condition of the Swedish Sami. When relevant, data from the Swedish Sami population are compared with corresponding data from Norway and Finland.

Ethical considerations
All studies conducted at the Southern Lapland Research Department have been approved by the regional ethics committee at the University of Umeå, and conform to the principles of the Declaration of Helsinki, the International Ethical Guidelines for Biomedical Research Involving Human Subjects, and the International Guidelines for ethical review for epidemiological studies.

The research question always emanated from health concerns posed by Sami organizations, Sami communities, or individual Sami. The risk for stigmatization was always thoroughly discussed with Sami representatives before a research project was commenced, and whenever the Sami thought the stigmatization risk was too large in relation to potential gain in knowledge, the project was canceled or substantially modified.

In all research projects, Sami representatives were guaranteed continuous information and participation as well as large possibilities to influence the research process, i.e. during the entire process from planning to interpretation of results and dissemination of results. Through web pages, newsletters, and meetings, the research has always been fully transparent toward the Sami society, and efforts to disseminate the research results within the Sami society and among relevant national and regional authorities have been strongly prioritized.

Methods and study populations
Different methods for data acquisitioning and selection of study populations have been used. Several studies are based on data from national and regional registers of causes of death, diagnoses, lifestyle, and socioeconomic conditions. In other studies questionnaires, medical examinations and interviews have been applied in the process of collecting data. An overview of methods for data acquisition and selected study populations of original studies in collaboration with me and my coworkers at the Southern Lapland Research Department is presented in Table 1.

In order to enable epidemiological research on large cohorts of Swedish Sami, a database was created from several sources, adopting generous inclusion criteria to
### Table 1. Health-related studies in the Swedish Sami population performed at the Southern Lapland Research Department during the last decade

<table>
<thead>
<tr>
<th>Reference</th>
<th>Research topic</th>
<th>Data source/method of data collection</th>
<th>Year of data collection/ follow-up period</th>
<th>Sami cohort</th>
<th>Reference population</th>
<th>Characteristics of reference population</th>
</tr>
</thead>
</table>
 n = 34,239 (non-reindeer-herding Sami) | n = 144,930 | Non-Sami matched by age, gender, and area of living |
| Ahlm et al. 2010 (17) | Causes of fatal, work-related accidents, and suicide | The National Causes of Death Register, autopsy records at the National Board of Forensic Medicine, police reports, and medical records at the County Council | 1961-2001                                | n = 7,482 (reindeer-herding Sami) | None | Non-Sami matched by age, gender, and area of living |
 n = 1,988 (reindeer-herding Sami, 1980) | n = 8,132 (1961) 
 n = 7,952 (1980) | Non-Sami matched by age, gender, and area of living |
 n = 34,239 (non-reindeer-herding Sami) | n = 144,930 | Non-Sami matched by age, gender, and area of living |
 n = 11,449 (non-reindeer-herding Sami) | n = 71,550 | Non-Sami matched by age, gender, and area of living |
| Edin-Liljegren et al. 2004 (32) | Clinical, psychosocial, and behavioral risk factors for cardiovascular diseases | The Regional Preventive Cardiovascular Diseases Program Register of the County of Västerbotten | 1990-2001                                | n = 170 (reindeer-herding Sami) 
 n = 441 (non-reindeer-herding Sami) | n = 1,222 | Non-Sami matched by age, gender, and area of living |
| Ross et al. 2009 (39) | Nutrient and food intake                                 | The Regional Preventive Cardiovascular Diseases Program Register of the County of Västerbotten | 1990-2001                                | n = 145 (reindeer-herding Sami) 
 n = 450 (non-reindeer-herding Sami) | n = 1,000 | Non-Sami matched by age, gender, and area of living |
| Nilsson et al. 2011 (31) | Dietary habits and lifestyle 50-70 years ago in relation to present day | The Regional Preventive Cardiovascular Diseases Program Register of the County of Västerbotten and interviews | 1990-1996, 2008 (interviews) | n = 81 (reindeer-herding Sami) 
 n = 226 (non-reindeer-herding Sami) | n = 1,842 | Non-Sami matched by age, gender, and area of living |
<table>
<thead>
<tr>
<th>Reference</th>
<th>Research topic</th>
<th>Data source/method of data collection</th>
<th>Year of data collection/ follow-up period</th>
<th>Sami cohort</th>
<th>Reference population</th>
<th>Characteristics of reference population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kaiser et al. 2011 (37)</td>
<td>Symptoms and predicting factors of depression and anxiety</td>
<td>Questionnaire</td>
<td>2007</td>
<td>$n = 319$ (reindeer-herding Sami)</td>
<td>$n = 1,393$</td>
<td>Non-Sami, from rural and urban areas of northern Sweden</td>
</tr>
<tr>
<td>Daerga et al. 2011 (49)</td>
<td>Confidence in health-care organizations</td>
<td>Questionnaire</td>
<td>2007</td>
<td>$n = 356$ (reindeer-herding Sami)</td>
<td>$n = 1,441$</td>
<td>Non-Sami, from rural and urban areas of northern Sweden</td>
</tr>
<tr>
<td>Sjölander et al. 2008 (45)</td>
<td>Prevalence and relative risk for musculoskeletal symptoms and perceived psychosocial work strain</td>
<td>Questionnaire</td>
<td>2003-2007</td>
<td>$n = 74$ (male reindeerherders)</td>
<td>$n = 53$ (adult females in reindeer herding families) $n = 194$ (non-reindeer-herding men in blue-collar occupations)</td>
<td>Non-Sami men in construction, industry, and transportation occupations</td>
</tr>
<tr>
<td>Daerga et al. 2004 (30)</td>
<td>Causes of musculoskeletal pain and impact of interventions</td>
<td>Questionnaire and medical examinations</td>
<td>2001-2003</td>
<td>$n = 51$ (reindeer-herding Sami)</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>Zabel et al. 2011 (50)</td>
<td>Carnivore-induced stress</td>
<td>Questionnaire</td>
<td>2009</td>
<td>$n = 401$ (reindeer-herding Sami)</td>
<td>None</td>
<td></td>
</tr>
</tbody>
</table>
minimize the risk of excluding Sami who satisfied only one out of several Sami definitions. People with Sami ethnicity were identified in electoral registers of the Sami Parliament, registers of reindeer-breeding companies held by the Department of Agriculture, and the registers of the population censuses administrated by Statistics Sweden. Their relatives, i.e. forefathers, siblings, and children, were identified in the National Kinship Register, administrated by Statistics Sweden, and added to the Sami database.

The database could be perceived as a reconstruction of the Swedish Sami population between 1941 and 1997 (kinship relations were available from 1941 and forwarded at the time of the construction of the database). A total of 41,721 Sami individuals were identified over the time period, and for a given year, e.g. in 1998 the number of Sami totaled 36,000 individuals.

By electronic data linkage of the Sami database with high-quality national and regional registers on health and diseases, it became possible to study the health condition on the entire or subgroups of the Sami population, and to relate it to various demographic, geographic, and socioeconomic factors. For comparison with the non-Sami majority population, a reference population was compiled, at a 4:1 ratio, from the population register by Statistic Sweden. The reference population was matched with the Sami cohort regarding age, gender distribution, and area of residency.

A detailed account of the Sami database and the reference population, together with results from validation studies, has been presented previously (12, 13).

In the following sections, I will briefly review the current knowledge on different health-related areas, with comparisons to relevant data reported from the Sami populations in Norway and Finland.

Mortality and diseases

Causes of death

The Swedish Causes of Death Register was used to examine life expectancy and specific causes of death among reindeer-herding and non-reindeer-herding Swedish Sami over the period 1961–2000 (14–17). No difference in life expectancy was observed between the Sami and the non-Sami population of the same geographic region. The incidence of specific causes of death was also quite similar among Sami and non-Sami. These results are basically in agreement with mortality studies conducted in the Norwegian and the Finnish Sami populations (18–20).

Beyond the similarities in mortality patterns, it was found that reindeer-herding Sami men had significantly lower relative risks compared with non-Sami men to die from cancer, cardiovascular diseases, and gastrointestinal diseases (15, 16, 21). However, the reindeer-herding men also showed significantly higher risk for fatal accidents and suicide, risk elevations that increased over time (15). The incidence of fatal accidents was 6–10 times as high among the reindeer-herding men as among farmers and construction workers, two occupations known to show high relative rates of severe accidents in Sweden. It was concluded that commercial reindeer management is one of the most dangerous occupations in the country.

Detailed analyses of all unnatural death that occurred among reindeer-herding men between 1961 and 2001, using autopsy records at the National Board of Forensic Medicine, police reports, and medical records at the County Council, showed that suicides contributed to 23% of all deaths, road traffic accidents to 16%, and snowmobile fatalities to 11% (17). Half of the victims tested positive for alcohol, and alcohol abuse was documented in 15% of the victims. The accident pattern reflects an outdoor lifestyle and working conditions characterized by high socioeconomic pressure and extensive use of off-road vehicles (15, 17).

An increased risk of suicide among Sami men in Sweden is in agreement with findings from Norway and Finland (20, 22). Although the elevated risk is small in relation to the non-Sami majority populations, the excess risk is probably a consequence of marginalization of the Sami culture and lifestyle in the Scandinavian countries (14, 15).

Among the reindeer-herding men, the incidence of suicide increased by 75% between periods 1961–1980 and 1981–2000 (14). In three-fourth of all suicides, the causes of death were gunshot wounds and hanging (17). The geographic distribution showed that the incidence of suicide is significantly larger in the southern part of the reindeer-herding district of Sweden (results in preparation). A conceivable reason for this is that the reindeer husbandry is more in question in the southern parts, and is put under larger pressure from the majority population to use grazing land for other purposes than reindeer herding (i.e. forestry, tourism, energy, and mineral production).

Cancer

Our knowledge on the incidence of various diseases in the Swedish Sami population is based on data from national health and diagnosis registers, and is largely confined to information on cancer and cardiovascular diseases. Cancer is the disease that is most thoroughly studied in the Sami population. In Sweden, a significantly lower cancer incidence among Sami men has been observed (23–25). The occurrence of prostate cancer was considerably lower among Sami than among other Swedes of the same region. Sami women have been observed to have an increased risk of gastric and ovarian cancer, while Sami men had an increased risk for stomach cancer. A general trend in all Scandinavian countries is
that the cancer risk is lower among Sami men than among Sami women (for review, see (26)). In Sweden, the lowest cancer incidence has been observed among reindeer-herding Sami men, and the highest among non-reindeer-herding Sami women (25).

Northern Scandinavia received considerable amounts of radioactive fallout from nuclear weapon tests in northern Russia during the 1950s and 1960s as well as from the nuclear power plant accident in Chernobyl in 1986. As the diet of the reindeer-herding Sami to a large extent is based on locally produced meat, i.e. from reindeer, moose, and fish, they have been exposed to relatively high levels of radioactive radiation for several decades. However, an increased risk of particular radiation-sensitive cancers (leukemia and thyroid cancer) has not been observed among the Sami, neither in Sweden nor in Norway and Finland (27, 28).

The relatively high levels of physical activity (29–32), in combination with high intake of antioxidants and unsaturated fatty acids and low intake of dairy products, have been suggested as the main reasons for the low risk of cancers of the colon and the prostate among the reindeer-herding Sami (24, 27, 28). Thus, the traditional Sami lifestyle may contain behaviors and habits that protect them from developing cancer. This conclusion is supported by the fact that reindeer-herding Sami who leave the traditional Sami lifestyle by migrating to urban regions develop a similar risk of prostate cancer as that in the general Swedish population (25).

The temporal trend of cancer diagnoses shows an increase in incidence in the general population as well as in the Sami population (25). However, for some cancer sites, the risk has increased faster among the Sami than in the majority population. Over the time span 1961—2003, there was a relatively larger increase in incidences of breast cancer among Sami women, and leukemia among Sami men (25). The reduction of incidence of stomach cancer observed in the general non-Sami population was not observed in the Sami population, in which the incidence was nearly constant.

**Cardiovascular diseases**

There are only small differences between the Sami and other Swedes regarding the risk to develop cardiovascular diseases (16, 32). In both Swedish and Norwegian studies, it has been found that the reindeer-herding Sami show lower incidences of cardiovascular diseases than other Sami (16, 33). Another consistent observation is that the relative risk to contract cardiovascular diseases is higher among Sami women than Sami men. The risk of stroke is increased among women in reindeer-herding families and Sami men not involved in reindeer herding. Women from reindeer-herding families also showed a significantly lower risk to develop myocardial infarction, while the reindeer-herding men were observed to have a lower risk for stroke.

An analysis of income development in relation to mortality from and incidence of cardiovascular diseases suggest that the differences in incidence of stroke between herding and non-herding Sami men, and between Sami women and non-Sami women, are caused by behavioral and psychosocial risk factors rather than by traditional socioeconomic ones (16). It was also indicated that the elevated mortality rates from myocardial infarction rather than stroke explain the excess mortality for cardiovascular diseases previously shown among Sami women (15).

**Other somatic diseases**

There is no published information on the frequency of other somatic diseases in the Swedish Sami population. However, preliminary results among approximately 15,000 Sami in Sweden indicate that they showed the same incidence of diabetes as the majority population between 1985 and 2002 (results in preparation).

Among Sami children and adolescents in northern Norway, asthma and allergies are more common compared to aged matched non-Sami in the same geographic setting (34, 35). It was also found that between 1985 and 1995, there was a faster increase in prevalence of asthma and allergy among Sami children. The causes of these differences are not known.

**Mental health**

There are a few studies where mental problems have been investigated among Sami children and adolescents in northern Norway (for review, see (36)). It appears as the mental health conditions are equally good among the Sami and the non-Sami youth. Yet, some interesting differences have been noted. The Sami adolescents showed less frequent risk-taking behavior and eating disturbances, and they more often expressed satisfaction with their body. The mental health condition was better among Sami living in a strong Sami cultural context than that of Sami children growing up in areas where the Sami culture was weak. Moreover, the mental health of young Sami men was more affected by ethnocultural factors than that of young Sami women.

The findings of Kvernmo and coworkers might explain, at least partly, why the incidence of suicide is higher among Sami men in the southern parts of the Swedish reindeer-herding district, where the Sami culture is relatively weak, as compared to those living in the northern areas (see above). In a recent study, reindeer-herding Sami men and women were identified as being at particular risk for suicidal expressions, and it was suggested that specific attention should be paid to young and middle-aged reindeer-herding men with hazardous alcohol consumption and symptoms of anxiety (37).
Lifestyle, health behavior, and socioeconomic conditions

Diet
The traditional Sami diet was characterized by high intake of proteins and fat, especially from fish and reindeer meat, and low consumption of carbohydrates, fibers, and certain vitamins (31, 38). This dietary pattern persists to some extent among today’s reindeer-herding Sami, although the differences compared with the western diet have decreased, which means that the meat and fish consumption has decreased, whereas the intake of fruit, vegetables, bread, and sugar has increased (31, 38, 39).

In studies of Sami living in the Swedish county of Västerbotten, lower blood levels of HDL cholesterol and lower systolic and diastolic blood pressure have been found but no differences in BMI, total cholesterol, and triglycerides compared with non-Sami in the county (31, 32, 39). Lower levels of cholesterol have also been reported from elderly Norwegian Sami in comparison to age-matched non-Sami (40). These findings support the suggestions that a high intake of reindeer meat and wild-caught fish is a contributing factor behind the relatively low risk of cancer and cardiovascular diseases among reindeer-herding Sami (16, 25, 27, 39).

Tobacco and alcohol
The tobacco and alcohol habits appear to be roughly the same among the Sami and non-Sami Swedes, and between reindeer-herding Sami and other Sami (31, 32, 39). In a recent study, it was found that, although the level of consumption of alcohol was similar, subgroups among reindeer-herding Sami men might have a somewhat more hazardous drinking pattern compared with non-Sami (41). Similar results have been reported among Norwegian and Finnish Sami (42, 23, 55).

Young Sami in northern Norway consume less alcohol than young non-Sami Norwegians (for review, see (43)). Interestingly, the lowest consumption was found among Sami with a strong Sami identity.

In a study on health-related quality of life among Swedish reindeer-herding Sami, it was found that poor mental quality of life was positively related to the consumption of alcohol for women but not for men (44). Among the men, however, low quality of life was positively connected to feelings of guilt about one’s alcohol habits.

Physical activity
There seem to be no major differences in physical activity between Swedish Sami and non-Sami (32, 39), except for reindeer-herding men who execute physically strenuous work more often than other Sami and non-Sami (31). Another interesting exception is that non-reindeer-herding Sami women seem to be significantly less physically active in comparison to their men (32, 39). This could contribute to the observed gender differences in incidences of cardiovascular diseases and some cancers among non-reindeer-herding Sami (16, 25).

Socioeconomic condition
It has been shown that the increase in income has been similar among Sami and non-Sami between 1970 and 2000, except for the reindeer-herding men who show a significantly lower income and slower increase in income compared with non-Sami men (45). While the women of reindeer-herding families have the highest formal education, the reindeer-herding men had the lowest (16, 45). Non-reindeer-herding Sami, both men and women, appear to have approximately the same level of education as other Swedes in the same geographic setting.

Risk factors and health in the reindeer husbandry

Accidents
As mentioned above, there is a high incidence of fatal accidents among reindeer herders (see, Causes of death). Due to frequent work in a harsh environment and cold climate, it is not surprising that this occupation and lifestyle is associated with a high risk for accidents, frostbite, musculoskeletal pain, and vibration injuries. This has been verified among both Swedish and Finnish reindeer herders (45, 46, 56–60). Accidents are to an important extent related to the use of off-road vehicles (snowmobile, motorcycles, and all-terrain vehicles). Collisions with rocks and trees are common, often causing injuries of the head, wrists, hands, neck, and back. Other common accidents occur during handling of the reindeer, e.g. cut by reindeer antler, cut by knives during slaughter, and marking of calves, and squeeze or pulled over during gathering or transportation of reindeer.

Musculoskeletal disorders
The occurrence of musculoskeletal symptoms is high among both men and women in the reindeer-herding families. Pain and discomfort in the lower back, neck, shoulders, elbows, and hands/wrists are frequent (45–48, 46, 49). Among reindeer-herding men, there is a significantly higher prevalence of pain in the hands, elbow, and lower back as compared to other blue-collar occupations with high prevalence of musculoskeletal pain, i.e. industry, construction, farming, and transport (45).

Although the accidents are frequent, about three-fourth of the reported musculoskeletal pain conditions have another origin, such as long-term exposure to static, repetitive work, or work in awkward body postures (45, 49). For men, the symptoms are most likely related
to physical risk factors, with high exposure to snowmobile and motorcycle driving, while the women’s symptoms are more influenced by psychosocial risk factors such as poor social support, high effort, low reward, and a feeling of being disconnected from the daily reindeer-managing activities (32, 45, 49). Reindeer herders are also heavily exposed to vibration when driving snowmobiles, all-terrain vehicles, and motorcycles (46). Consequently, a large proportion of the reindeer-herding men show clear-cut clinical indications of vibration damages of the nerves and blood vessels in hands and arms.

**Psychosocial and socioeconomic working conditions**

The conditions for the Sami to breed and herd reindeer have changed dramatically over the last decades. Historically, reindeer herding was a Sami lifestyle and is still a culturally very important activity. In the 1970s, the Swedish government imposed regulations and control systems in order to transform reindeer husbandry to an economically profitable business. Today, a successive reindeer-herding business needs a large livestock, good grazing areas, four-wheel driven cars, and different kind of terrain vehicles (and a good portion of skills and luck). One consequence of the extensive motorization is that the modern reindeer husbandry requires continuous income in order to pay for the continuous operating costs.

The legal right of the Sami to use large areas for reindeer herding is increasingly questioned in large areas of the reindeer-herding areas of Sweden. A growing competition from exploiters who intrude on their traditional grazing land has certainly had a negative impact on the psychosocial and socioeconomic conditions of the reindeer-herding Sami. Together with the governmental goals to tolerate a given size of the populations of predators (i.e. bears, wolves, wolverines, lynxes, and eagles), the accumulated demands from various land exploiters generate a serious threat to the sustainability of the reindeer husbandry and the Sami culture (6, 16, 44, 45, 50).

The working conditions for many reindeer-herding Sami are characterized by high job demands, low control over external factors influencing the reindeer-herding conditions (e.g. national rules and legislation), and low level of social support (32, 45, 49). In comparison with both women of reindeer-herding families and Swedish men in other blue-collar professions, the reindeer-herding men not only experienced higher demands but also larger opportunities to influence how and when daily working activities should be executed (45). Reindeer-herding women also experienced higher demands than Swedish women from urban areas in the northern part of Sweden, but not in comparison with non-Sami women living in the same area. A tendency toward increased job demands and reduced decision latitude could be observed over the period 1990-2007 among both men and women of reindeer-herding families (32 and results in preparation).

The work organization within the Sami communities (‘Sameby’ or ‘Sámi by’) has been reported as unsatisfactory by many reindeer herders (results in preparation). Almost, 70% of the reindeer-herding Sami indicated that the workload was dissatisfaction in that it was unevenly distributed and that the communication was too poor. A large proportion of the women reported a shortage of appreciation, help, and support from others in the Sami community. These findings are probably related to the complex organization and social structure of the Sami communities. Within a Sameby, the herders and their families compete about having successful reindeer-breeding companies, which implies possessing the largest possible part of the total number of reindeer allowed by the Sameby. At the same time, the reindeer herders are coworkers and depend on each other in many collective tasks, e.g. building and maintaining collective infrastructure such as fences and cottages, gathering, and transportation and slaughtering of reindeers. Furthermore, close kinship is common among members of different reindeer-herding families within the Sami communities.

Reindeer-herding men showed a significantly lower income than Swedish men in general, and the differences in income have increased slightly over the past decades, probably as a result of declining profitability of the reindeer husbandry (16). Today, women of reindeer-herding families demonstrated larger average income compared with their men, and they often have a regular employment in addition to their duties in the reindeer-herding work (16, 32, 45). The increased financial responsibility, together with the fragmented working situation, is thought to be important factors associated with the women’s relatively low quality of life, poor social support, decision latitude, and intellectual discretion (32, 44, 45). Many women also report low degree of involvement in the reindeer-herding work compared with the men as well as less appreciation, assist, and reward for the work they are doing (32, 44, 45).

Most reindeer herders experience that they have small possibilities to influence national and regional decisions and regulatory frameworks of importance for the reindeer husbandry. Price trends for reindeer meat, vehicles, and fuel, and the national policy regarding the size of the predator populations are determined by complex systems beyond the control of the reindeer herders. The reduced size of the grazing lands that is fragmented into smaller unconnected areas due to the expansion of forestry, mining, and energy production
decreases the possibility of the reindeer-herding companies to maintain a reasonable economic return.

In light of the psychosocial and socioeconomic conditions of the reindeer husbandry, it is not surprising that members of reindeer-herding families report low social, physical, and mental quality of life, high prevalence of symptoms of depression and anxiety, and poor confidence in national institutions and authorities (45, 49, 51).

Conclusions and suggested actions
In comparison with other indigenous people in the circumpolar region, the health and living conditions of the Sami are exceptionally good. For instance, there are no evidences of low-life expectancy, of significantly elevated incidences of common diseases, or of increased prevalence of alcohol and substance abuse that are serious health problems among other indigenous populations (52, 53). Although the health condition of the Sami population appears to be similar to that of the general Swedish population, a number of specific health problems have been identified, especially among the reindeer-herding Sami. Most of these problems have their origin in marginalization and poor knowledge in the majority population of the reindeer husbandry and the Sami culture. Thus, the most sustainable measure to improve the health among the reindeer-herding Sami would be to improve the conditions for the reindeer husbandry and the Sami culture. The key issue is to strengthen the legal rights of the Sami people to use their traditional homeland for reindeer herding and other culturally and economically important activities. For this to happen, there have to be alterations of laws and radical changes of the majority population’s and its institutions attitudes toward the Sami people.

A concrete way of improving the health condition for reindeer-herding Sami is to establish occupational health-care centers as an integrated part of the reindeer husbandry (6, 7, 54). Their health condition would also benefit from a system of appointed health coordinators with specific assignment to facilitate the relationships between the reindeer-herding Sami and existing occupational health-care services and various health-care institutions and clinics (6). The coordinator’s main responsibility should be to guide the reindeer-herding men and women within the health-care system and to inform and educate the health-care professionals about the reindeer-herding lifestyle, the working conditions, and the Sami culture.

This review implicitly shows that the available information on the health condition of the Swedish Sami population is limited. There are several reasons for that. The most important, in my opinion, is that the different needs and possibilities of ethnic minorities are neglected in Sweden as a consequence of our effort to treat all citizens equal. In the absolutistic interpretation of the equality principle, there is little room for specific actions directed toward ethnic minorities as they should be treated as everybody else. As a result, Sweden lacks a national health policy for the Sami people, and there have been no resources allocated to research focused on their health conditions (6, 7). Another reason for the shortage of information in some health-related domains, e.g. mental and inherited health problems, is that some research questions have been rejected by the researchers and/or Sami organizations to avoid unnecessary stigmatization, or due to a lack of attentiveness within the existing health-care organizations to meet potential medical needs exposed by such studies.

There is a need to examine a wide range of diseases that hitherto have not been studied among the Sami, how various diseases are connected to different risk factors, and how diseases and risk factors develop over time. It would also be a great asset to have comparable data on different subpopulations of Sami, e.g. reindeer-herding and non-reindeer-herding Sami, men and women, and different age groups. Another topic of importance is to elucidate health consequences of climate changes.

To obtain long-term, sustainable, and coordinated information about the health condition of the Sami, the Swedish government has been recommended to establish a national center for research on Sami health (6, 7, 54). In Norway, such a center was established a decade ago, which significantly has increased the available knowledge on the health and living conditions of the Norwegian Sami.

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Infant mortality of Sami and settlers in Northern Sweden: the era of colonization 1750–1900

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The study deals with infant mortality (IMR) that is one of the most important aspects of indigenous vulnerability.

Background: The Sami are one of very few indigenous peoples with an experience of a positive mortality transition.

Objective: Using unique mortality data from the period 1750–1900 Sami and the colonizers in northern Sweden are compared in order to reveal an eventual infant mortality transition.

Findings: The results show ethnic differences with the Sami having higher IMR, although the differences decrease over time. There were also geographical and cultural differences within the Sami, with significantly lower IMR among the South Sami. Generally, parity has high explanatory value, where an increased risk is noted for children born as number five or higher among siblings.

Conclusion: There is a striking trend of decreasing IMR among the Sami after 1860, which, however, was not the result of professional health care. Other indigenous peoples of the Arctic still have higher mortality rates, and IMR below 100 was achieved only after 1950 in most countries. The decrease in Sami infant mortality was certainly an important factor in their unique health transition, but the most significant change occurred after 1900.

Keywords: infant mortality; indigenous; Sami; seasonality; parity; demography; vulnerability

The improvement in health and life expectancy among Swedish Sami represents one of the few encouraging examples of a positive indigenous health transition. Even with documented threats such as high suicide rates among young reindeer herders, the Swedish Sami of today experience standards of living, life expectancy, and health equal to those of non-indigenous Swedes (3). The scenario was different 150 years ago when life expectancy was considerably lower among the Sami as compared to the settler population (4, 5). However, it is still unclear how the Sami health transition came about.

Systematic longitudinal information about health, morbidity, and mortality among the world’s indigenous populations is generally hard to find. Infant mortality rates (IMR) are one of the most used indicators to understand a population’s health status, especially if it is possible to examine them over an extended period of time. The contemporary evidence that does exist of indigenous peoples’ IMR suggests that poor living conditions and nutrition along with high rates of infectious diseases result in an IMR much higher than among non-indigenous populations (1, 6–8).

In an effort to increase our understanding of the demographic transition in northern Sweden, the present study aims to examine the IMR during the period...
of intensified colonization in a Sami and non-Sami population.

Historical background
Research indicates that many Sami became reindeer herders in the early 17th century, as a response to a population crisis (9). Their economy was previously based on hunting and gathering. This transition coincided with the Swedish state’s increased interest in Sápmi, the distant regions of the north which were the Sami’s traditional lands. Churches were built with the ambition to convert the Sami to Christianity. Courts were held annually, market places were built, and the first printed books in the Sami language appeared (10). Further interest in the area was stirred in the late 17th century by the discovery of silver, but the mining epoch lasted for only 50 years. The Sami remained very isolated, not only because of their economy and culture but also because of the great distances between households and the intense cold of the region for most of the year. At the end of the 17 century, the state also tried to encourage settlers to move to the area, offering free land, and 15 years free from taxes. This had, however, a limited impact on immigration, a trend that did not change until the mid-18th century. During the following 100 years, the ethnic balance in Sápmi changed, turning the Sami into a position as minority in their own lands. Their culture and society underwent major changes as well (11).

Data and research methods
Omran’s essay on the epidemiological transition, modeling societies change from high mortality due to infectious diseases to low mortality caused by chronic diseases, has had a great impact on the public health community and stirred research in a variety of disciplines (12, 13). Indigenous peoples were not mentioned in his work, but few researchers would dispute that the indigenous populations of the world experienced demographic transitions much later than non-indigenous populations. However, although an indigenous demographic or health transition is generally acknowledged, due to lack of longitudinal data, it is rarely examined (14, 15).

The main source material used for the present study is a set of data files from the demographic dataBase (DDB) at Umeå University, one of the world’s most information-dense historical population databases. A recent addition to the DDB are 18th and 19th century parish records from Sápmi. The longitudinal database includes every individual in the parishes during the period when the area was colonized, largely by Swedish settlers, and the Sami population changed from a majority to a minority. The source material separates the Sami and the settler populations and contains information on, for instance, sex, age, cause of death, migration, and fertility. Each individual can be followed from the cradle to the grave allowing the reconstruction of life biographies and family composition based on ethnic categorization (Table 1).

Because data quality is poor in the earlier years, the time period has been restricted to 1750–1895. Only infants born within the study area and with a known birth day have been included. The total working sample comprises 18,801 births in three different parishes.

Infant mortality is calculated by the number of deaths within the first year of life during a time period divided by the number of live births during the same period. When calculating infant mortality and making comparisons with Swedish national data, 10 year intervals were used (16).

The risk of infant mortality is modeled as a Cox proportional hazard model with ethnicity, sex, parity, birth season, and birth period as the explanatory covariates. Separate models are estimated for the three different parishes. The statistical package used was SPSS, version 19 (Fig. 1).

Sápmi, the traditional Sami area, is culturally very complex. Sami live in four countries, speak nine different languages, and are diversified by reindeer-herding techniques, social organization, and economic resources. Until the early 19th century, Sami land rights were legally protected, but then a more repressive state policy replaced the Sami traditional division and use of land with a national administrative system (17).

The present study includes three parishes where Sami were in a great majority around 1750. The church registers of Jukkasjärvi and Jokkmok in the North Sami area contained both Sami and Swedish settlers, whereas Föllinge Sami parish in the South Sami area was an administrative construction exclusively for the indigenous population in the area. There was also a corresponding parish register for the settlers of Föllinge.

The magnitude and timing of colonization differed between the parishes. In the northernmost parish of Jukkasjärvi, Sami were in majority throughout the period 1750–1900. Until 1850, there are around 400 non-Sami and 1000 Sami, and both groups experienced a population increase from 1880, settlers more than the indigen-
ous. We believe that the parish of Jokkmokk is more representative of the Sami parishes in general, where an ethnic majority shift occurred around 1830, moving in a frontier wave from the south to the north. In the parish of Föllinge, the ethnic majority shift came earlier: from the late 18th century, there were more non-Sami than Sami in the area, and the change accelerated so that at the end of the period there were almost 10 times as many Swedes as Sami. Conflicts between reindeer herders and settlers were intensive in the area.

Previous research has to a large extent exclusively counted the reindeer herding nomads in the Sami group. There was, however, an ethnic complexity in the north already during the early stages of colonization, and not all Sami were nomadic reindeer herders; large groups were hunters or farmers, and during the period, many Sami took up residence in settlements, becoming settlers but still Sami, sometimes recorded as 'Sami-settlers' [lappnybyggare] in the parish registers. All these groups are included as Sami in our study, resulting in a Sami population larger than normally stated. This has been done to create a more ‘in situ’-oriented demography (18).

We have combined the ethnic markers in the sources using a system designed by the historian Gabriella Nordin in her dissertation on marriage patterns in Sápmi 1750–1900 and also presented in Sköld and Axelsson (5, 11).

A complementary source of information about infant mortality is the annual reports of the district physicians in the area. However, the doctors were not well acquainted with the conditions among the Sami, and the reports often give laconic and judgemental descriptions of Sami health.

Previous studies of Sami mortality have revealed considerably higher rates from 1750 to 1900 compared with non-Sami, both in Sápmi and in Sweden generally (4, 5, 19). By contrast, the second half of the 20th century shows no ethnic mortality differences (3). This is consistent with the occurrence of a delayed indigenous demographic and epidemiologic transition (20), and because infant mortality is one of the early indicators of intensified change, our study aims to find evidence for declining IMR among the Sami before 1900 that could be interpreted as a forerunner of a general transition. Long-term infant mortality trends are analyzed to compare Sami and non-Sami groups in the three parishes. Using both northern and southern Sami areas, the cultural complexity of the Sami society is recognized. Infant mortality generally has shown great geographic variations (21). Sex differences and seasonality are included parameters that are interpreted in terms of the varying work intensity of the reindeer nomads. Parity, causes of death, and change over time are additional variables that complete the study together with an estimation of the impact of health care programs. The results are discussed from the perspective of data quality, methodological issues, and the general demographic transition in Sweden.

Northern cultures
The Sami have lived in Sápmi for thousands of years and have learned to adapt to the extreme conditions there. Nevertheless, the nomadic Sami lifestyle, the hazardous character of reindeer herding, and a shifting food resource resulted in a high mortality, including infant mortality. The Sami were devoted parents with strong

Fig. 1. Map of Sweden, including the parishes of Jukkasjärvi, Jokkmokk, and Föllinge. Source: Demographic database, Umeå University.
emotions and traditions attached to their children, and had developed customs for reducing risk during pregnancy, delivery, and child care. Traditionally, pregnant women were recommended to stay mobile but not to work hard. Birth was given in a standing or knee-heeling position. Men were considered excellent midwives because of their experience with reindeer. The child was believed to be endangered by evil spirits and other threats, and a newborn child was put in a skin from a newborn reindeer calf, with a piece of steel close to the infant to protect it (22).

Breast-feeding was the only option for Sami mothers. It is universally reported by the clergy, physicians, travelers, politicians – and later also expressed by the Sami themselves – that Sami children were breast-fed for at least 2 years, and sometimes for as long as four years. During the first days after birth, before the mother produced milk, the infant was given a piece of sugar or reindeer fat in a small napkin. This might have caused a risk of infections, especially during summer. Some Sami women consumed alcohol during pregnancy but not during the last days before birth giving. However, when the infant was born, the woman was encouraged to drink quite a lot of alcohol (22).

The non-Sami settlers were mostly from other parts of Sweden, but sometimes from Finland or Norway. Colonization was promoted by the state from the late 17th century, but the great explosion of in-migration occurred in the second half of the 19th century, when mining, railroads, and improved agricultural techniques offered new opportunities.

The medical health care organization
From the mid-18th century, the Swedish health care system tried to reduce the very high infant mortality in the country. In Stockholm and other urban areas, sometimes more than half of the newborn children died within their first year of life. Medical instructions were published concerning the care of infants, and district doctors were employed, even though in the 1870s it was still a rare event for someone in northern Sweden to have a visit by the doctor (23).

In earlier times, the clergy were given responsibility for health care, but during the 19th century they became less and less involved. They were officially released from health duties in 1830, and after this, their participation in medical issues in the parish was greatly reduced, although many clergy continued to assist with medical advice. From this time, midwifery services increased, although economic difficulties caused many parishes to resist official requests to employ a midwife (24).

Infant mortality in Sápmi
In the early 19th century, the northern parishes had among the highest infant mortality in Sweden. The region around Stockholm also suffered from extremely high death rates for the youngest. The IMR declined over the 19th century, as a result of improved hygiene, and increased breast-feeding. In many places in Sweden, it had not been common to breast-feed babies. Instead, there was a widespread culture of artificial feeding, where undiluted and unboiled cow milk, often sour and of bad quality, replaced breast-feeding. Different sorts of diarrhea were common in those areas, especially during the warm summer months. The combination of hard agricultural work that often prevented mothers from breast-feeding their infants, and the difficulties in preserving fresh milk, resulted in repeated mortality peaks from June to August. Previous research has shown that high levels of artificial feeding of infants lead to higher mortality during the summer months. Nevertheless, many areas in northern Sweden experienced a great reduction in infant mortality during the 19th century. In some parishes, it dropped from over 50% to below 18% 50 years later (23).

Swedish observers in the 18th century believed that Lapland, as Sápmi was then known, was one of the healthiest places someone could live. It was thought that the fresh air guaranteed a long and strong life. Although some clergy were afraid that the nomadic life that began soon after the birth was harmful, as were the drinking habits of the women, the Sami were generally described as healthy: children were given frequent baths and infants were breast-fed for several years (25). It was not until Hellstenius in 1884 published an article on infant mortality in the counties of Jämtland and Härjedalen, including the South Sami area, that the extremely high infant mortality among the Sami was revealed. However, Hellstenius offered no explanation other than vague ideas about racial differences. Later, Wahlund showed a similar infant mortality among Sami parishes in the northern area, twice as high as the settlers. Children and adults

Infant mortality in Sápmi
In the early 19th century, the northern parishes had among the highest infant mortality in Sweden. The

Fig. 2. Sami infant mortality in Jukkasjärvi, Jokkmokk, Föllinge, and Sweden in 1751–1895.
showed no corresponding increased mortality (26, 27) (Fig. 2).

Registration before 1780 is often incomplete and the IMR is unreliable. At the end of the 18th century, Sami infant mortality was at the same high level as the rest of Sweden, and occasionally even higher, but when the IMR declined generally in Sweden from 1810, the Sami in Jukkasjärv and Jokkmokk stayed at high rates. The Sami parish of Föllinge shows considerably lower rates than the Sami in the other two parishes, and until 1850 Sami infants in Föllinge had much lower mortality than in the rest of Sweden. The trend appears to continue with only six infant deaths of 93 births during the period 1850–1895. Due to the low overall number of births and deaths, we have excluded 10 year averages for Föllinge parish (Table 2).

There is a general trend of decreasing Sami infant mortality in 1750–1899. In the northern parish of Jukkasjärv, Sami have consistently higher IMR than the rest of Sweden, but the difference decreases over time. Until 1850, they also have higher rates than the non-Sami in the parish, but during the second half of the century, the situation is the opposite. The non-Sami in Jukkasjärv experience increased infant mortality over time. Before 1850, their IMR is lower than in Sweden, thereafter higher. The non-Sami in Jokkmokk also have lower IMR than Sweden until the mid-19th century. They have an increasing IMR trend over time, nevertheless their rates are lower than the Sami throughout the period. In Föllinge, there are insignificant IMR differences between Sami and non-Sami, and both groups are well below the Swedish average. There is an excess infant mortality for males in all three parishes, and for both Sami and non-Sami (except for non-Sami in Föllinge). The sex difference was greater among the Sami (Table 3).

The higher male IMR is significant for both Sami and non-Sami in Jukkasjärv and in Jokkmokk, but in Föllinge only for Sami. There is, however, no reason to believe that these differences have any explanatory value for the demographic transition in Sápmi.

### Parity: the impact of birth order

It was often claimed that Sami families were smaller than non-Sami families in the area (28). This was often based on an assumption that a large family was an obstacle to the nomadic life of the reindeer herders (Table 4).

In all three parishes, Sami infants born as child number five or more suffered from the highest risk of dying. Although we cannot control for the number of older siblings that were actually alive, it seems clear that large families were less able to avoid infant mortality. The mothers who gave birth for the fifth time or more were also older than those giving birth for the first time. The health status of the mother is an important determinant of infant survival, especially during the first week. Among the Sami, first-born infants had the second largest risk of dying, whereas among the non-Sami they experienced the greatest risk. The settlers may have lacked the well-developed traditional knowledge needed for dealing with the cold climate and other risks specific to their environment.

### Table 2. Infant mortality (per 1000) in Jukkasjärv, Jokkmokk, and Föllinge in 1750–1899

<table>
<thead>
<tr>
<th>Year</th>
<th>Jukkasjärv</th>
<th>Jokkmokk</th>
<th>Föllinge</th>
</tr>
</thead>
<tbody>
<tr>
<td>1750-1799</td>
<td>Sami 64</td>
<td>206</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>Non-Sami 47</td>
<td>95</td>
<td>79</td>
</tr>
<tr>
<td>1800-1849</td>
<td>233</td>
<td>175</td>
<td>110</td>
</tr>
<tr>
<td>1850-1899</td>
<td>136</td>
<td>161</td>
<td>71</td>
</tr>
<tr>
<td>Total</td>
<td>152</td>
<td>176</td>
<td>74</td>
</tr>
<tr>
<td>N</td>
<td>4,803</td>
<td>3,245</td>
<td>808</td>
</tr>
</tbody>
</table>

Source: Demographic database, Umeå University.

### Table 3. Male and female infant mortality (per 1000) in Jukkasjärv, Jokkmokk, and Föllinge 1750–1899

<table>
<thead>
<tr>
<th></th>
<th>Male</th>
<th>Female</th>
<th>Total</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jukkasjärv</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sami</td>
<td>165</td>
<td>139</td>
<td>152</td>
<td>4,800</td>
</tr>
<tr>
<td>Non-Sami</td>
<td>146</td>
<td>130</td>
<td>138</td>
<td>1,738</td>
</tr>
<tr>
<td>Jokkmokk</td>
<td></td>
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<td></td>
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<tr>
<td>Sami</td>
<td>190</td>
<td>163</td>
<td>176</td>
<td>3,242</td>
</tr>
<tr>
<td>Non-Sami</td>
<td>118</td>
<td>104</td>
<td>111</td>
<td>3,321</td>
</tr>
<tr>
<td>Föllinge</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sami</td>
<td>84</td>
<td>66</td>
<td>74</td>
<td>799</td>
</tr>
<tr>
<td>Non-Sami</td>
<td>75</td>
<td>75</td>
<td>75</td>
<td>4,875</td>
</tr>
</tbody>
</table>

Source: Demographic database, Umeå University.

### Table 4. Infant mortality (per 1000) after parity in Jukkasjärv, Jokkmokk, and Föllinge 1750–1899

<table>
<thead>
<tr>
<th></th>
<th>1-4</th>
<th>5+</th>
<th>Total</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jukkasjärv</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sami</td>
<td>151</td>
<td>120</td>
<td>192</td>
<td>152</td>
</tr>
<tr>
<td>Non-Sami</td>
<td>166</td>
<td>105</td>
<td>156</td>
<td>138</td>
</tr>
<tr>
<td>Jokkmokk</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sami</td>
<td>184</td>
<td>156</td>
<td>200</td>
<td>176</td>
</tr>
<tr>
<td>Non-Sami</td>
<td>151</td>
<td>97</td>
<td>99</td>
<td>111</td>
</tr>
<tr>
<td>Föllinge</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sami</td>
<td>71</td>
<td>56</td>
<td>113</td>
<td>74</td>
</tr>
<tr>
<td>Non-Sami</td>
<td>82</td>
<td>61</td>
<td>90</td>
<td>75</td>
</tr>
</tbody>
</table>

Source: Demographic database, Umeå University.
to the northern inland area. Both ethnic groups in all parishes had the lowest risks for mortality for infants born as number two, three, or four in the birth order of the mother.

1800–1899: a dynamic century
The period of study includes great social, political, economic, demographic, and environmental changes. Due to the unreliability of the data during the 18th century, the cox regression analysis is based on results from the period 1800–1899 (Table 5).

The results show geographical differences between the three Sami groups. In Jokkmokk with an ethnic majority shift around the 1830s, a pronounced Sami excess infant mortality remains throughout the 19th century. This is also the only parish with the highest mortality risk among the first born infants in 1850–1899. The northern parish Jukkasjärvi experiences a dramatic shift from twice as high Sami infant mortality in 1800–1849 to slightly lower IMR compared to the non-Sami during the second half of the century. The more balanced the ethnic proportions became, the less differences occurred in infant mortality. In the southern parish of Föllinge, Sami were a minority from the 18th century, but nevertheless they showed higher IMR over the entire period. Generally, a modest male excess mortality is found and less risk for parity 2–4. There are no noteworthy seasonal differences, except in Föllinge where higher IMR appeared among infants born during the winter months January to March. The sample from this parish is too small to include separate analyses for different periods of the 19th century.

Conclusion
The Sami in the northern parishes of Jokkmokk and Jukkasjärvi had a high IMR between 1750 and 1900, whereas the southern Sami in Föllinge experienced considerably lower levels. If infant mortality is used as an indicator of a positive shift in the demographic, epidemiologic, and health transitions, it can be concluded that by 1900 these transitions had not begun in the northern parts of the area. The non-Sami in the area

Table 5. Cox regression of infant mortality in Jokkmokk, Jukkasjärvi, and Föllinge, 1800–1899

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>Ethnicity</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Sami</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Sami</td>
<td>1.88 0.000</td>
<td>1.42 0.000</td>
<td>1.98 0.000</td>
<td>0.87 0.157</td>
<td>1.66 0.002</td>
</tr>
<tr>
<td><strong>Sex</strong></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Female</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Male</td>
<td>1.06 0.598</td>
<td>1.21 0.036</td>
<td>1.40 0.001</td>
<td>1.13 0.185</td>
<td>1.08 0.446</td>
</tr>
<tr>
<td><strong>Birth order</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>1</td>
<td>1.09 0.583</td>
<td>1.40 0.004</td>
<td>0.75 0.032</td>
<td>1.12 0.345</td>
<td>0.89 0.360</td>
</tr>
<tr>
<td>2–4</td>
<td>0.76 0.055</td>
<td>0.89 0.027</td>
<td>0.63 0.000</td>
<td>0.72 0.004</td>
<td>0.65 0.000</td>
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<td>&gt;5</td>
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<td>1.00</td>
<td>1.00</td>
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</tr>
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<td><strong>Birth season</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>January–March</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
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<tr>
<td>April–June</td>
<td>0.94 0.689</td>
<td>0.90 0.405</td>
<td>1.09 0.521</td>
<td>1.04 0.757</td>
<td>0.72 0.017</td>
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<tr>
<td>July–September</td>
<td>0.98 0.892</td>
<td>0.96 0.777</td>
<td>0.90 0.438</td>
<td>1.03 0.801</td>
<td>0.70 0.013</td>
</tr>
<tr>
<td>October–December</td>
<td>1.02 0.909</td>
<td>1.08 0.547</td>
<td>0.95 0.682</td>
<td>1.02 0.883</td>
<td>0.80 0.113</td>
</tr>
<tr>
<td><strong>Birth period</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1800–1849</td>
<td></td>
<td></td>
<td></td>
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<td>1.00</td>
</tr>
<tr>
<td>1850–1899</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.14 0.277</td>
</tr>
<tr>
<td>Deaths (n)</td>
<td>288</td>
<td>479</td>
<td>433</td>
<td>445</td>
<td>374</td>
</tr>
<tr>
<td>Likelihood ratio</td>
<td>29.2</td>
<td>37.7</td>
<td>55.6</td>
<td>18.4</td>
<td>31.5</td>
</tr>
<tr>
<td>DF</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Overall p-value</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.010</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Note: \(e^b\) is the relative risk, \(p\) is the \(p\)-value for each parameter in the model.
show increased IMR over time, and did not follow the decreasing IMR in Sweden from the 1820s. The indigenous people of northern Sweden experienced a delayed process, and at the end of the 19th century, their IMR were still above the national average. On the other hand, the trend shows decreasing IMR, and we know that the gap between the Sami and the rest of Sweden was closed around 1950.

Other indigenous peoples of the Arctic still have much higher mortality rates, and an IMR below 100 was achieved only after 1950 in most countries (29, 30). Between 1910 and 1939, the native people in Canada had an IMR between 120 and 205 (31). Serning reported remaining ethnic IMR differences in Jukkasjärvi and Jokkmokk for the period 1930–1948, but they were rapidly decreasing (22). And, from the 1960s, there are no significant mortality differences between Sami and non-Sami in the area (3). Therefore, the first half of the 20th century is crucial for our understanding of the IMR transition in Sápmi, and hence for our understanding of the Sami demographic, epidemiologic, and health transitions.

Brändström (23) asked if there were reasons to believe that the Sami practiced birth control. Contemporary observers claimed that Sami women gave birth to few children, rarely more than five or six (31), even if they married at early ages (11). By limiting family size, they may have avoided the increased risk associated with higher order births, and by concentrating births in the seasons with lower risk, they may have improved survival. Cultural responses to infectious diseases and the use of a so-called komse, a small wooden boat box where infants were kept almost constantly for 1 or even 2 years (32, 33) helped in the care of the newborn children.

The traditional nomadic life style is important for our understanding of Sami infant mortality (25), but there is no reason to believe that hard working conditions caused the Sami women to stop breast-feeding their infants, as was often the case in other contexts (34). Reindeer herding was an extreme form of living, and the social organization did not offer any assistance. Sami women either rejoined the continuous travel with the reindeer only a couple of days after giving birth (31) or were left alone with the child in a hut (22). This would certainly have increased the risk of the infants dying.

Until the mid-19th century, the Sami IMR was considerably higher than the non-Sami in the area, even though extensive breast-feeding prevented infectious diseases and nutritional deficiencies. We can note cultural differences within Sápmi, where the South Sami joined the low IMR of the district of Jämtland, whereas the northern parishes remained at higher levels. However, there is no evidence that medical interventions played any significant role in the reduction in infant mortality. The Sami rarely had any contact with the district physicians, and midwives were not appointed in the northern parishes until the late 19th century.

Demographic changes certainly occurred in Sápmi during the process of colonization. Kertzer and Fricke (35) take a cultural approach to demographic behavior, arguing that from an anthropological perspective, the concept of agency must be given more prominence. They emphasize a cultural sphere that is interwoven with, both shaping and being shaped by, political and economic institutions as well as by kinship and other social organizational structures.

The Sami population has slowly increased since the 18th century and onwards, and the previous general opinion that the Sami were a dying race has been proven to be mistaken. It is the Sami culture, and not the Sami race, that is under threat today (36). But the path to this point has been long and winding, including great improvements in life expectancy. Infant mortality was a difficult obstacle to overcome, and the final breakthrough did not occur until the 20th century.

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Prevalence of self-reported suicidal thoughts in SLiCA. The survey of living conditions in the Arctic (SLiCA)

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Objectives: The Survey of Living Condition in the Arctic (SLiCA) is an international research project on health and living conditions among Arctic indigenous peoples. The main objective of this article is to examine the prevalence of self-reported suicide thoughts among the study population in Alaska, Greenland, Sweden and Norway.

Study design: Population-based survey.

Methods: Indigenous participants aged 16 years (15 years in Greenland) and older living in traditional settlement regions in Alaska, Sweden and Norway and across the entire Greenland were invited to participate. Data were collected in three periods: in Alaska from January 2002 to February 2003, in Greenland from December 2003 to August 2006, in Sweden from spring 2004 to 2006 and in Norway in 2003 and from June 2006 to June 2008. The principal method in SLiCA was standardised face-to-face interviews using a questionnaire. A questionnaire had among other things, questions about health, education, traditional activities, ethnicity and suicidal thoughts.

Results: Information about suicidal thoughts, gender and age were available in 2,099 participants between the ages of 16 and 84 from Alaska, Greenland, Sweden and Norway. Greenland had the highest rates of suicidal thoughts when adjusting for age and gender (p<0.003). When stratifying on age and gender, significant differences across countries were only found for females in the two youngest age groups. Differences in suicidal thoughts across countries could partly be explained by educational level.

Conclusion: Swedish respondents had less suicidal thoughts than those in any other countries. In the future, analyses of suicidal thoughts should take socioeconomic status into account as well as self-reported health, depression and anxiety.

Keywords: suicidal thoughts; SLiCA; survey; inuit; Inupiat; Sami; indigenous peoples

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In the last century, health problems among indigenous people have changed from mainly infectious diseases towards other health risks, due to urbanisation (1). Communicable diseases as tuberculosis and venereal diseases continue to affect indigenous populations, although incidence rates are decreasing (2, 3). However, cancer, ischemic heart disease, obesity and diabetes have become the modern indigenous health risk and show increasing trends. In addition, alcohol and drug abuse, suicide, accidents and violence are important health problems among indigenous groups. Change in dietary patterns, reduction in physical activity and lastly exposure to new environmental hazards are the most suitable explanation of these new health challenges (2, 4). Also, the prevalence of suicidal behaviour within different indigenous groups indicates great variation (5, 6). The majority of studies show higher prevalence of suicide attempts among indigenous groups than among their majority peers (1, 7). Although several studies have shown considerable disparities in health status among indigenous populations and the general population of the national states, surveys comparing different indigenous groups are missing. Undoubtedly, there are considerable variations across regions and countries.

The Survey of Living Condition in the Arctic (SLiCA) is an international research project on the health and living conditions among indigenous peoples in the Alaska, Canada, Greenland, Norway, Sweden and Russia (8, 9).
The motivation for launching SLiCA was an ambition of reflecting the ways of life of Arctic indigenous peoples more appropriately with regard to resource utilisation. The SLiCA is the first international cooperative study that compares indigenous peoples of the circumpolar north with regard to health and living conditions. The survey aimed to develop a context-specific concept of living conditions more suitable for indigenous peoples who still rely on the harvest of local resources. Accordingly, it was considered more appropriate to explore health and other aspects of the living conditions of peoples with similar ways of life and environmental circumstances, than to compare northern indigenous peoples and southern majority populations (10, 11).

The main objective of this article is to examine the prevalence of self-reported suicide thoughts among the study population in Alaska, Greenland, Sweden and Norway.

The Arctic indigenous peoples

The Sami

The Sami is the indigenous people of the Nordic countries. The Sami live in the northern regions of Fennoscandia in what today comprises the northern area of Norway, Sweden, Finland and Russia’s Kola Peninsula. No exact overview over the total number of Sami exists, and estimates vary in accordance with criteria used such as genetic heritage, mother tongue and sense of belonging to the Sami. Norway has the greatest proportion of the total Sami population.

The Inuit

The traditional homeland of the Alaskan and Greenlandic Inuit comprises the Western and Northern coasts of Alaska and the coastline of Greenland. A substantial Inuit population is settled at the Arctic coast and Arctic Archipelago in northern Canada and at the coast of the Chukotka Peninsula (1, 12). In the SLiCA survey, the Inuit in Alaska was defined by the Inupiat people living in the North Slope, the Kotzebue region and the Nome region. Inupiat people of Alaska have the most in common with Inuit people elsewhere in the Arctic.

Material and methods

Indigenous participants living in traditional settlement regions in Alaska, Sweden and Norway and across the entire Greenland were invited to participate. Data were collected in three periods: in Alaska from January 2002 to February 2003, in Greenland from December 2003 to August 2006, in Sweden from spring 2004 to 2006 and in Norway in 2003 and from June 2006 to June 2008. The principal method in SLiCA has been standardised face-to-face interviews using a questionnaire on health and other aspects of living condition, indigenous language and culture. Cue cards were used to efficiently present respondents with response choices. The duration of each interview was approximately 1.5–2 hours. The SLiCA target population is indigenous individuals aged 16 years (15 years in Greenland) and over residing in a traditional settlement region. Indigenous participants were ascertained by self-reported ethnicity. SLiCA’s conceptual design has been described in detail elsewhere (8, 9, 13).

Age

The study sample was restricted to persons of age 16–84 years (15–84 years in Greenland), the age span common for all countries. In further analyses, age is categorised into three groups, 16–34, 35–59 and 60–84 years.

Questionnaire

The questionnaire was developed in 11 workshops from 1998 to 2001 and was field tested in Alaska and Greenland (9). All fieldworkers in SLiCA have been trained in interviewing techniques and procedures. Also, an interview guide was produced to optimise standardisation of the training.

Suicidal behaviour

The questionnaire contained two questions about suicidal behaviour. The question ‘Have you ever seriously considered to commit suicide?’ was used to measure prevalence of suicide thoughts. Alternative answers were ‘yes/no’. In addition, respondents who answered ‘yes’ were asked if this thought was in the course of the last year.

Education

There are some discrepancies in the questionnaire with regard to primary and secondary education, due to different wording of some categories. This is mainly due to discrepancies between the various national and regional school systems. In Norway and Alaska, the question was What is the highest level of schooling or training you have completed? In Alaska category, one was ‘Advanced traditional training’. Apart from this, response choices in Norway and Alaska ranged from primary school through PhD degree. In Greenland, education attainment was measured using three questions: ‘What level of schooling do you have?’; ‘are you at the moment undertaking higher education/vocational training?’ and ‘have you previously completed higher education/vocational training?’ To the last two questions, specifying the degree undertaken or completed was possible. In the first question, response choices ranged from ‘less than seven years of schooling’ through ‘high school’. Other response choices were ‘other’ and ‘still in school’. Those still in school (n = 40, data not shown) were categorised according to the highest level of schooling or education completed. Participants reporting other’ schooling (n = 67, data not shown) and individuals in Alaska
reporting advanced traditional training \((n = 2, \text{ data not shown})\) were classified in the appropriate formal category. By re-coding and generating a joint education variable, education level was divided into three groups, less than High School/Vocational School, High School/Vocational School and University education.

**Ethics**

The survey is in accordance with the Helsinki Declaration of 1975 and to International Arctic Social Sciences Association (IASSA) Guiding Principles for the Conduct of Research in the Arctic (1998). All participants gave written informed consent prior to the interview. In Norway, the study was accredited by the Norwegian Social Science Data Service and the National Committee for Research Ethics in the Social Sciences and the Humanities. In Alaska, the study was approved by the University of Alaska Institutional Review Board.

**Statistical analyses**

Results are presented as counts and percentages. Differences in sample characteristics across countries were tested by ordinary Chi-square tests. When stratifying for gender and age groups, differences in suicidal thoughts between countries were tested by the Fisher exact test, due to small expected cell counts. The Cochrane–Mantel–Haenszel test was used to perform an age- and gender-adjusted test for differences between countries.

Two ordinal logistic regression models were fitted to model effects on the three level variables on suicidal thoughts. Explanatory variables in model 1 were country, age group and gender. In model 2, education was added. The age group 60–84 years was excluded in the regression analyses due to a small number of people in this age group having had suicidal thoughts.

Statistical analyses were performed using the SAS statistical software for Windows version 9.1 (SAS Institute Inc., Cary, NC, USA).

**Results**

Table 1 shows country-specific characteristics. Information about suicidal thoughts, gender and age were available in 2,099 indigenous participants between the ages of 16 and 84 from Alaska, Greenland, Sweden and Norway. Furthermore, education level was available for 2,064 participants.

The Sami cohort is older than the samples from Greenland and Alaska.

University education was more common among the Norwegian participants. Greenlandic participants reported the lowest educational level. No discrepancy in level of education was observed between Alaska and Greenland in the oldest age stratum (data not shown).

A total number of 298 participants (14.2%) reported to have thought seriously of committing suicide, out of which 125 (6%) reported having had thoughts during the last year.

Table 2 shows the distribution of suicidal thoughts by countries, age and gender. Suicidal thoughts were rare among the oldest part of the sample and more common among the youngest and middle-aged groups. Females reported suicidal thoughts more often than males. There was a significant difference between countries when adjusting for age and gender \((p = 0.003)\). Greenland had the highest rates and Sweden the lowest. When stratifying on age and gender, significant differences across countries were only found for females in the two youngest age groups (Table 2).

Ordinal logistic regression showed that, adjusted for age and gender, suicidal thoughts were significantly more common in Greenland than in Alaska and significantly

---

**Table 1. Sample characteristics \((n = 2099)\)**

<table>
<thead>
<tr>
<th></th>
<th>Greenland (n (%))</th>
<th>Norway (n (%))</th>
<th>Sweden (n (%))</th>
<th>Alaska (n (%))</th>
<th>(P)-value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15–34</td>
<td>332 (34)</td>
<td>71 (21)</td>
<td>48 (24)</td>
<td>224 (39)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>35–59</td>
<td>527 (54)</td>
<td>209 (61)</td>
<td>109 (56)</td>
<td>281 (49)</td>
<td></td>
</tr>
<tr>
<td>60–84</td>
<td>126 (13)</td>
<td>63 (18)</td>
<td>39 (20)</td>
<td>70 (12)</td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.03</td>
</tr>
<tr>
<td>Male</td>
<td>473 (48)</td>
<td>171 (50)</td>
<td>102 (52)</td>
<td>243 (42)</td>
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</tr>
<tr>
<td>Female</td>
<td>512 (52)</td>
<td>172 (50)</td>
<td>94 (48)</td>
<td>332 (58)</td>
<td></td>
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<tr>
<td>Education</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>Less than high school/vocational school</td>
<td>573 (59)</td>
<td>45 (13)</td>
<td>26 (15)</td>
<td>155 (27)</td>
<td></td>
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<tr>
<td>High school/vocational school</td>
<td>312 (32)</td>
<td>109 (32)</td>
<td>103 (59)</td>
<td>387 (67)</td>
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</tr>
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<td>University</td>
<td>89 (9)</td>
<td>187 (55)</td>
<td>46 (26)</td>
<td>32 (6)</td>
<td></td>
</tr>
</tbody>
</table>

*Chi-square tests.
There was no significant difference between Norway and Alaska.

When educational level was added to the regression, Greenland and Alaska no longer showed a significant difference in suicidal thoughts.

**Discussion**

In this survey of Arctic Indigenous people in Alaska, Greenland, Sweden and Norway, we have observed the prevalence of suicidal thoughts among the Inuit and the Sami. The prevalence of suicidal thoughts was studied in relation to countries, gender, age and educational level. The main results demonstrated that there was a significant difference between countries, where suicidal thoughts were more common in Greenland than in Alaska and significantly lower in Sweden.

Education is often used as a proxy for socioeconomic status and represents an important variable in terms of measuring living condition. In numerous studies, socioeconomic status was shown to be associated with health and other living conditions as, for example, housing condition (14).

In present-day Alaska, Norway, Sweden and Greenland, a high school diploma represents 13 years of schooling (kindergarten-12th grade, or 1st–13th grade) and is a requirement for commencing college/university education. In Alaska, the general education development test is an alternative to a high school degree. In Norway and Sweden, vocational training is usually integrated into high school education, whereas local vocational schools provide such training in Greenland and Alaska. Unlike tertiary education in Greenland, Sweden and Norway, education beyond high school in Alaska is fee paying.

Naturally, the level of education among the Inuit and the Sami is associated with age, as the availability of education has increased throughout the 20th century. In Greenland, after the introduction of Home Rule in

### Table 2. Suicidal thoughts by country, gender and age

<table>
<thead>
<tr>
<th>Suicide thoughts</th>
<th>Greenland</th>
<th>Norway</th>
<th>Sweden</th>
<th>Alaska</th>
<th>P-value</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes, last year</td>
<td>83 (8)</td>
<td>6 (2)</td>
<td>3 (2)</td>
<td>33 (6)</td>
<td>0.003*</td>
</tr>
<tr>
<td>Yes, but not last year</td>
<td>87 (9)</td>
<td>32 (9)</td>
<td>7 (4)</td>
<td>47 (8)</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>815 (83)</td>
<td>305 (89)</td>
<td>186 (95)</td>
<td>495 (86)</td>
<td></td>
</tr>
<tr>
<td><strong>Male</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>15–34</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Yes, last year</td>
<td>15 (10)</td>
<td>1 (3)</td>
<td>0</td>
<td>9 (9)</td>
<td>0.57**</td>
</tr>
<tr>
<td>Yes, but not last year</td>
<td>17 (11)</td>
<td>2 (6)</td>
<td>1 (5)</td>
<td>7 (7)</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>124 (79)</td>
<td>29 (91)</td>
<td>21 (95)</td>
<td>81 (84)</td>
<td></td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes, last year</td>
<td>11 (4)</td>
<td>0</td>
<td>1 (2)</td>
<td>3 (3)</td>
<td>0.41**</td>
</tr>
<tr>
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<td>17 (7)</td>
<td>6 (6)</td>
<td>2 (4)</td>
<td>8 (7)</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>225 (89)</td>
<td>92 (94)</td>
<td>54 (95)</td>
<td>99 (90)</td>
<td></td>
</tr>
<tr>
<td>60–84</td>
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</tr>
<tr>
<td>Yes, last year</td>
<td>1 (2)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.84**</td>
</tr>
<tr>
<td>Yes, but not last year</td>
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<td>3 (7)</td>
<td>0</td>
<td>1 (3)</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>60 (94)</td>
<td>38 (93)</td>
<td>23 (100)</td>
<td>35 (97)</td>
<td></td>
</tr>
<tr>
<td><strong>Female</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15–34</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes, last year</td>
<td>34 (19)</td>
<td>4 (10)</td>
<td>1 (4)</td>
<td>14 (11)</td>
<td>0.05**</td>
</tr>
<tr>
<td>Yes, but not last year</td>
<td>26 (15)</td>
<td>8 (21)</td>
<td>2 (8)</td>
<td>12 (9)</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>116 (66)</td>
<td>27 (69)</td>
<td>23 (88)</td>
<td>101 (80)</td>
<td></td>
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<tr>
<td>35–59</td>
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<td>Yes, last year</td>
<td>22 (8)</td>
<td>1 (1)</td>
<td>0</td>
<td>7 (4)</td>
<td>0.01**</td>
</tr>
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<td>23 (8)</td>
<td>11 (10)</td>
<td>1 (2)</td>
<td>16 (9)</td>
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<tr>
<td>No</td>
<td>229 (84)</td>
<td>99 (89)</td>
<td>51 (98)</td>
<td>148 (87)</td>
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<td>60–84</td>
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<td></td>
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<tr>
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<td>0</td>
<td>0</td>
<td>1 (6)</td>
<td>0</td>
<td>0.08**</td>
</tr>
<tr>
<td>Yes, but not last year</td>
<td>1 (2)</td>
<td>2 (9)</td>
<td>1 (6)</td>
<td>3 (9)</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>61 (98)</td>
<td>20 (91)</td>
<td>14 (88)</td>
<td>31 (91)</td>
<td></td>
</tr>
</tbody>
</table>

*Cochran-Mantel-Haenszel test for differences across countries adjusted for age and gender.  
**Fisher exact test.
1979, 7 years of compulsory schooling was replaced by 9 years of obligatory primary and middle school. From 1977, high school education was made available (15). In 1983, the Inuit Institute College was established and later assigned university status in 1989: Ilisimatusarfik, University of Greenland, Alaska, USA (16).

Until the late 1970s, school facilities on Alaska’s North Slope were available only up to ninth grade, and high school students had to attend boarding schools far from home. A law suit was brought against the state of Alaska in 1976 committing it to establish high schools in rural villages, with the further aim of including Inupiaq language and culture in the curriculum. New school programmes were consequently introduced in 95 communities throughout rural Alaska (17). A handful of colleges and the University of Alaska system provide tertiary education today. The Bureau of Indian Education serves American Indian and Alaska Native post-secondary students through higher education scholarships (18). As in Greenland, primary and middle school constitutes today 10 years of compulsory schooling both in Norway and Sweden. The University of Tromsø was opened in 1972. The Sami University College was established in Kautokeino in 1989 (19). Students from different part of Sápmi can study at The Sami University College, where the education is primarily given in Sami language. Today, the level of education is generally high in Norway and Sweden. In Norway, it is higher for women than for men (20). Furthermore, the Sami settlement of Karasjok has one of the nation’s highest levels of education for women aged 25–40 years (21). Education is known to protect against disease. A high education level is closely related to better socio-economic status. However, education level can also be a proxy of urbanisation. Indigenous societies are transformed from rural characteristics in terms of economy, culture and lifestyle, to one which can be characterised as urban. Urbanisation is a global trend and there is a marked divide between regions. Places where educational opportunities are available are growing, whereas the smaller places experience a decline. This leads to various sociocultural changes. In Norway and Sweden, this urbanisation process started after the Second World War and has influenced societies and people for several decades. Among other things, this can be one of the explanations to the education level in Scandinavia. In other regions in the Arctic, the urbanisation process has started some decade later, but the sociocultural changes are today quite similar in the whole region. Not all the changes have been for the best for the indigenous people. In the course of the changes, various new social, political and environmental challenges have arrived (1, 22).

### Table 3. Ordinal logistic regression. Age group 60–84 excluded due to very small numbers of suicide thoughts

<table>
<thead>
<tr>
<th></th>
<th>Model 1 (n = 1801)</th>
<th>Model 2 (n = 1783)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Country</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greenland</td>
<td>1.48 (1.10–2.00)</td>
<td>1.27 (0.92–1.76)</td>
</tr>
<tr>
<td>Norway</td>
<td>0.87 (0.56–1.36)</td>
<td>1.03 (0.63–1.70)</td>
</tr>
<tr>
<td>Sweden</td>
<td>0.34 (0.16–0.73)</td>
<td>0.39 (0.18–0.85)</td>
</tr>
<tr>
<td>Alaska</td>
<td>1.0 (ref)</td>
<td>1.0 (ref)</td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>1.71 (1.31–2.24)</td>
<td>1.74 (1.32–2.28)</td>
</tr>
<tr>
<td>Male</td>
<td>1.0 (ref)</td>
<td>1.0 (ref)</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15–34</td>
<td>2.28 (1.76–2.96)</td>
<td>2.18 (1.68–2.84)</td>
</tr>
<tr>
<td>35–59</td>
<td>1.0 (ref)</td>
<td>1.0 (ref)</td>
</tr>
<tr>
<td><strong>Education</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than high school/vocational school</td>
<td>1.0 (ref)</td>
<td></td>
</tr>
<tr>
<td>High school/vocational school</td>
<td>0.65 (0.48–0.88)</td>
<td></td>
</tr>
<tr>
<td>University</td>
<td>0.54 (0.33–0.87)</td>
<td></td>
</tr>
</tbody>
</table>

*aExplanatory variables in model 1 were country, age group and gender.

*bExplanatory variables in model 2 were country, age group, gender and education.
Alaska (23, 26–28). In the SLiCA survey, the percentage of suicidal thoughts in Greenland, Alaska, Norway and Sweden were 17%, 14%, 11% and 6%, respectively. The prevalence of suicide thoughts is highest among the Greenland and Alaskan participants and very low among Swedish participants. In addition, suicidal thoughts were most frequent in the youngest age group in all countries. When education level was added to the model, the difference between Greenland and Alaska was no longer significant. The variation in prevalence of suicidal thoughts between the different indigenous groups in SLiCA cannot be easily explained. However, transition from traditional to modern lifestyle among the indigenous populations has increased the prevalence of several chronic diseases as cancer and cardiovascular disease (24). Poor health in general is known to influence mental health. Grossmann and colleagues found that self-perception of poor general health was associated with history of suicide attempts among Navajo adolescents (25). Associations have been found between somatic symptoms and depression, anxiety and suicide attempts in other adolescent populations (29, 30). One major challenge in our study is the historical and country-specific differences between the ethnic groups, the Sami and the Inuit. Indigenous populations participating in SLiCA are diverse. Setup and access to health care systems vary greatly according to geography and country. Development of community-level health systems and public-health planning that reflect geographic location and indigenous ethnic groups varies between countries. In additions, suicidal thoughts and attempts are context dependent. In a community with a high rate of suicidal attempts, this can affect especially the young people, as an accepted pattern of behaviour.

In our analyses, we have not adjusted for these factors, but several associations shall be investigated in future studies. And, lastly it is important to emphasise that although suicidal thoughts and suicidal attempts are different phenomena, suicidal thoughts are associated with suicidal attempts and therefore important clinical indicators.

When stratified in age groups and gender, the differences on suicidal thoughts between countries were significant only for the female participants. Moreover, females reported suicidal thoughts more often than males in all countries, except for Sweden. Our results are in accordance with an earlier study on indigenous Sami adolescents in Norway where females reported a higher degree of suicidal thoughts (19%) (6).

Among Arctic Indigenous people, little is known about the causes of mental health problems in general and the impact of rapid sociocultural changes in particular. The SLiCA survey’s contribution to this research is important to expand the understanding of the topic. Especially, epidemiological knowledge about suicidal behaviour among indigenous populations is important for the implementation of appropriate prevention strategies in the health care system in local communities.

In the future analyses of suicidal thoughts, education and other measures of socioeconomic status should be taken into account as well as self-reported health, depression and anxiety.

Acknowledgements

We would like to thank all project workers participating in the data collection and processing in Greenland, Alaska, Sweden and Norway. Above all, we thank the Kalaalit of Greenland, the Inupiat and Yupik of Alaska and the Sami of Sweden and Norway who participated in the study. Especially, thanks to the SLiCA international working team; Jack Kruse, Birger Poppel and Hugh Beach. Also, thanks to Anne Silviken for valuable comments on the manuscript.

Conflict of interest and funding

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References

Climate change and environmental impacts on maternal and newborn health with focus on Arctic populations

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Background: In 2007, the Intergovernmental Panel on Climate Change (IPCC) presented a report on global warming and the impact of human activities on global warming. Later the Lancet commission identified six ways human health could be affected. Among these were not environmental factors which are also believed to be important for human health. In this paper we therefore focus on environmental factors, climate change and the predicted effects on maternal and newborn health. Arctic issues are discussed specifically considering their exposure and sensitivity to long range transported contaminants.

Methods: Considering that the different parts of pregnancy are particularly sensitive time periods for the effects of environmental exposure, this review focuses on the impacts on maternal and newborn health. Environmental stressors known to affect human health and how these will change with the predicted climate change are addressed. Air pollution and food security are crucial issues for the pregnant population in a changing climate, especially indoor climate and food security in Arctic areas.

Results: The total number of environmental factors is today responsible for a large number of the global deaths, especially in young children. Climate change will most likely lead to an increase in this number. Exposure to the different environmental stressors especially air pollution will in most parts of the world increase with climate change, even though some areas might face lower exposure. Populations at risk today are believed to be most heavily affected. As for the persistent organic pollutants a warming climate leads to a remobilisation and a possible increase in food chain exposure in the Arctic and thus increased risk for Arctic populations. This is especially the case for mercury. The perspective for the next generations will be closely connected to the expected temperature changes; changes in housing conditions; changes in exposure patterns; predicted increased exposure to Mercury because of increased emissions and increased biological availability.

Conclusions: A number of environmental stressors are predicted to increase with climate change and increasingly affecting human health. Efforts should be put on reducing risk for the next generation, thus global politics and research efforts should focus on maternal and newborn health.

Keywords: climate change; environment; maternal and child health; Arctic

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last 250 years. IPCC also stated that it is extremely unlikely that the changes in global climate could have occurred without greenhouse gases from human activities. Although there are still many uncertainties about climate change, its extent and the effects of global warming, there is currently a scientific consensus that climate change is occurring (1).

As we are struggling to understand the occurring climate changes and predict future scenarios, there is considerable less knowledge about the impacts climate change will have on human health. Costello et al. asked the following question in 2009: “Have we yet understood the profound significance of the connection between climate change and human health?” (2). Since then, there has been a considerable increase in the number of publications on related topics. The Lancet commission has further identified the following six ways in which climate change can affect human health: Changing patterns of disease and morbidity, food, water and sanitation, shelter and human settlements, extreme

Fig. 1. The Arctic is warming quickly (1, 35).

Fig. 2. The ocean streams are important and vulnerable (11, 35).
Climate change is particularly inter-linked with air pollution as it is both a cause (greenhouse gases) and an effect of, because increased temperatures in urban areas leads to increased concentration of air pollutants. Many strategies to reduce greenhouse gas emissions also decrease emissions of health-damaging air pollutants and precursor species. As a result of increased industrial growth, the concentrations of air pollutants are already increasing, particularly in urban areas of developing countries, and the big cities of the north (1). Big areas of the developing world, as well as the Arctic areas, are likely to experience the heaviest impact of climate change, with women bearing the greatest toll (2).

Considering that a number of studies have identified the pregnancy as a particular sensitive time period for the effects of environmental exposure, this literature review focuses on the impacts of environmental factors on the maternal and newborn health in a changing climate.

**Climate change influences pollution**

There seems to be growing evidence that climate change will have negative impacts on the distribution and toxicity of environmental contaminants (4–10). However, there are only a limited number of studies focused on contaminant interactions in northern areas, where there is an urgent need for more knowledge on how climate change affects chemical distribution and toxicity (11). This is especially important because the vulnerable populations are more sensitive due to other stressors such as malnourishment and disease. Temperature and precipitation, as altered by climate change, are expected to have the largest influence on the partitioning of chemical toxicants.

Anthropogenic emissions are a leading cause of climate change, and climate change is also impacting the concentration and distribution of pollutants in the atmosphere. Ozone (O₃) and particulate matter (PM) are among these chemical species that cause concern (12–14).

**Particles and ozone**

Air quality is expected to degrade as a result of climate change, and the severity and frequency of ozone episodes are expected to increase, even though there is considerable uncertainty associated with the direction and magnitude of change for tropospheric ozone (15–18). An increased burden of disease linked to climate change is expected especially for allergy and asthma due to prolongation of the pollen seasons. An interaction between air pollution and pollen loads is expected, e.g. thunderstorms, extreme precipitation events, increased ground level ozone concentrations, increased ambient air pollution from natural and anthropogenic sources and probably an increasing number of fires (19).
**Persistent toxic substances**

As climate change alters primary and secondary releases of persistent organic pollutants (POPs), levels and patterns of exposure to wildlife and humans will change. Climate change is already altering food web structures in some areas, including influence on the exposure of wildlife and humans to POPs (11). The toxicity and toxicokinetics of POPs in the nature might also be altered as a direct result of changes in temperature (20).

The interactions between climate change and contaminants are complex. Increased temperature could result in increased toxicity of many persistent toxic substances (PTS) and increased mobility of chemicals in the environment. At the same time, increasing temperature could also enhance the degradation rate of pollutants in nature, leading to decreasing concentrations. Climate change is associated with changes in the regional precipitation pattern. The United Nations Environment Program (UNEP) review on organic contaminants, air pollution and climate change (19), and the overview by Noyes et al. (20) indicates that in temperate regions, reduced precipitation will increase the volatilisation of organic pollutants and also result in increased air pollution in urban areas. Climate change could also affect food safety as increasing temperatures may result in alterations in food web structures, lipid profiles and carbon flux that in turn will affect the concentrations of organic pollutants in water, soil and biota (20). Warmer climate may lead to increased use of pesticides as the number of infection-based diseases are expected to increase (21).

Within the Arctic, changes in food web structures and bioaccumulation properties of PTS are also expected as results of temperature changes (22). Recent simulation studies indicate that the bioaccumulation of some POPs will decrease in the marine environment with increasing temperature, assuming no change in food web structure and constant contaminant exposure (23). Other studies from the Arctic indicate slightly increased concentrations of PTS in the marine environment with increasing temperatures (24). It is not yet fully understood how bioaccumulation in the environment will be affected by climatic change. What we do know is that climate change will cause changes that will ultimately affect people living in the Arctic and feeding from the Arctic environment.

**Indoor air pollution**

More than half of the global population still cooks with wood, coal or agricultural residues on simple stoves or open fires (25). This results in exposure to a number of pollutants associated with smoke. Largely women and young children are exposed to indoor air pollution in developing as well as Arctic countries as they tend to spend more time doing indoor activities (26). People are exposed to polycyclic aromatic hydrocarbons (PAHs) when indoor, even when residing in proper houses, clearly implying that with poorer housing conditions, the indoor exposure to PAHs or PM will increase (27). In the Arctic, increasing temperatures are believed to increase the exposure to radon from the ground as the permafrost is retreating (19).

**Air pollution and effects on maternal and newborn health**

Evidence that poor air quality can adversely affect birth outcomes is increasing. A small number of review articles have summarised existing studies and concluded that there is likely an adverse effect of air pollution on pregnancy outcome (28). The burden of evidence seems strongest for PM of the atmospheric chemical species. Exposure to ambient PM has been associated with adverse health effects, but the exact constituents of PM that cause disease and the mechanisms involved are unknown. Several reviews conclude that exposure to PM is strongly and consistently associated with post-neonatal respiratory mortality and less consistent with sudden infant death syndrome (28, 29). Gliniana et al. have also concluded that the available evidence is compatible with either a small adverse effect of particulate air pollution on foetal growth and duration of pregnancy or with no effect (28).

Intra-uterine growth retardation and pre-term birth are associated with PM (30, 31). There is only one available study that describes an association between PM exposure during pregnancy and birth defects, reporting a possible increased risk of isolated atrial septal defects (32). There is too limited evidence to conclude on a possible effect of PM on stillbirth risk (28). Whether the reported association between PM and intra-uterine growth retardation really results from an effect of PM or from air pollutants trapped in the PM or correlated with PM values such as PAHs remains to be elucidated (28).

Heinrich et al. (33) concluded that although the mechanisms of air pollution effects are not completely understood, children, infants and pregnant women need specific protection against exposure to fine particles. Especially, the first months after birth might be of particular sensitivity due to immature and developing organs. Despite the growing knowledge on the effects of maternal exposure to PM and the effects on the birth outcome, there are still considerable knowledge gaps regarding more sensitive time periods during pregnancy, making preventive actions harder to accomplish (28).

Ozone is described as an extremely reactive chemical that has been shown to have harmful effects on human health, crop production and natural areas (8). The negative health effects are somewhat similar to the effects of PM, or at least they are to a large extent associated.

Nitrogen dioxide (NO₂) is the air pollutant most frequently used as a surrogate for traffic-related pollution in prospective studies, both in adults and in children (34).
This is due to the fact that outdoor NO₂ levels correlate well with pollutants generated by traffic, they can be easily measured using passive samplers and they are routinely measured by air quality networks that allow for correction for seasonality. A recent study suggests that pre-natal exposure to airborne PAHs adversely affects children’s cognitive development by 5 years of age, with potential implications for school performance (35).

PTS and health effects

Persistent toxic substances are inorganic or organic compounds. Some of them (e.g. heavy metals) occur naturally, but the majority originates from past and current human activities. Most of them are persistent in nature, fat soluble and toxic to living organism also in very low concentrations (11). As a result of their chemical properties, many PTS bioaccumulate in organisms and magnify in food chain, resulting in high concentrations in species on top of the food chain. Even though many POPs were phased out of production many years ago, they remain as hazardous waste in old industrial equipment for ages and can easily be remobilised in nature. A large proportion of electronic waste from industrial countries ends up in recycling stations in Asia and Africa due to lower costs and less strict waste handling legislation. High levels of polychlorinated biphenyls (PCBs), brominated flame retardants (PBDEs), toxic metals, dioxins/furans (PCDDs/PCDFs) and PAHs have been found in such dumping sites (22). Recently, a study from India reported significantly higher concentrations of non-dioxin like PCBs and total PCBs in breast milk from mothers living close to a waste dumping site than in breast milk from a reference area (26).

The effects of long-term environmental exposure to pollutants are often complicated to investigate as the mechanism of actions in humans are not well characterized. Humans are also exposed not only to one contaminant at a time but to a complex mixture of substances. The time between exposure and outcome is often long and the potential endpoints may have large normal variability (e.g. birth weight) or being a complex disease (e.g. cancer). The effects can also be transgenerational. Comprehensive data on the distribution and health effects of PTSs in the northern hemisphere are slowly emerging, but data for the southern hemisphere are scarce. A number of countries in the southern hemisphere are defined as developing countries, where socioeconomic and health characteristics of the population differ from those in the industrialised countries (3). Hunger, malnutrition, lack of proper housing and sanitation and high unemployment rates result in poor health status and high incidence of communicable diseases. Most seriously affected are women and children. Population migration and rapid urbanisation with its wide range of anthropogenic activities also contribute to the environmental degradation and pollution, resulting in extreme susceptibility and vulnerability of the population to negative impact of PTS.

Climate change, PTS and maternal and child health outcomes in Arctic populations

There is a concern that climate change will affect the health situation of people in Arctic regions. POPs are transported to the polar regions from urbanised/industrialised areas via atmospheric and ocean transport (11, 19, 21). Several places also have substantial local exposure to contaminants through storage of PCB oils from former military complexes and industrial waste (11, 36). The environmental stores and possible effects on biological exposure have been thoroughly discussed in different reports from The Arctic Monitoring and Assessment Programme (11) since 1993. Recently, some decreasing human levels of the classical compounds, e.g. PCBs and the DDT group, are presented through new trend studies of the Russian Arctic (37). The declining levels might be associated not only with global agreements on reduced emissions (19), but also with local public health information campaigns (36). Even so, the issue of increased emission of Mercury associated with temperature change remains (38). As we can calculate that approximately 50% of the global Mercury emission is anthropogenic and the remaining part is natural evaporation from oceans, big rivers and ice cores, there will probably be an increase in exposure during the next 30–50 years, associated with increased impact from the bacteria responsible for the methylisation of Mercury into the biologically active Methyl Mercury (MeHg) (38).

Health of Arctic indigenous populations and the possibilities for good health studies

In general, the health status of indigenous people of the Arctic countries is characterised by lower life expectancy, higher infant mortality, higher rates of infectious diseases (particularly among children) and much higher incidences of injuries and suicide, when compared with the non-indigenous populations of these countries (11). It is likely that the higher prevalence of tobacco use, more sedentary lifestyles and consumption of more calorie-rich and nutrient-poor store-bought foods have contributed to an increasing burden of chronic diseases. With or without a climate change, health intervention strategies and population health in the Arctic will only improve with better information and better cooperation between all players. A full understanding of ethnic-specific health status can only arise if common health status indicators are selected and assessed both at short and long term. This will require that all relevant authorities and organisations in each country work closely together.

Contaminants play a role in the current health status of indigenous populations in many areas of the Arctic but
must be assessed together with other important factors, e.g. education, economic well-being, cultural strength, community engagement, lifestyle choices, genetic susceptibility and availability of public health services.

Conducting studies to give advice to the public health authorities in the Arctic is difficult due to a variety of limiting factors: exposure to complex contaminant mixtures, small population size, contaminant-nutrient interactions, genetic factors, confounding factors and health priorities. The climate change adds even more difficulties to the assessment of contaminants and health outcomes. Indigenous populations in the Arctic are exposed to mixtures of contaminants primarily through the food chain. It is clear from studies of chemical mixtures that data derived from single chemical experiments cannot be used to predict the risk resulting from exposure to complex mixtures of POPs. Interactions between components of the mixture not only modify the disposition of individual components but also their dose-response relationship for various developmental endpoints. These interactions, coupled with differences in nutrient levels, could explain some of the differences between different ongoing cohort studies (11).

Environmental POPs and health in the Arctic

Selected results from the monitoring programme in AMAP are visualised in Figs. 5 and 6 (11). The figures clearly demonstrate high body burdens of PTS in indigenous Greenlandic, Canadian and Russian populations from the Arctic. Many POPs, including PCBs, PCDDs, PCDFs and pesticides, can mimic hormone activities. As potential endocrine disruptors, they are suspected to be capable of increasing the risk of cancer, birth defects and reproductive, neurodevelopmental disorders and immune system effects. To date, no clear evidence for adverse endocrine-related human health effects of POPs has been obtained at the individual or population level. However, data from studies on wildlife species, laboratory animals and biomarker effects in vitro have strengthened the need for further research to address the potential impacts of endocrine disruptors on human populations (11). There have been associations found in individual cohort studies between fish consumption, POPs exposure and head circumference, birth weight, duration of pregnancy and infant growth, but the relationships differ between studies (11). It is clear that a number of confounding factors such as the diet, individual susceptibility to contaminants and co-variation of other contaminants may alter the results in human PTS studies. It is therefore recommended that as many as possible of these factors are taken into account. Results from the PCB studies conducted in the Faroe Islands and Nunavik so far suggest that pre-natal exposure to PCBs is related to a relatively specific profile of cognitive impairments in children. Among the cognitive functions assessed, effects have been most clearly demonstrated on executive functions and speed of information processing. Those effects can be responsible for the small decreases in IQ observed in most studies. Verbal abilities and visual recognition memory are also likely to be impaired. Several recent studies in Arctic Canada confirm and support the relationship between contaminant exposure and depressed immunity (39). Both PCBs and DDE are associated with a higher incidence rate of acute otitis media and respiratory tract infections in Inuit children during the first 6 months of life. Concentrations of lymphocytes and immunoglo-
bulin A have been found to be depressed in comparative studies of breast-fed babies and bottle-fed babies. The effectiveness of vaccination programmes among Inuit children and children from the Faroe Islands appears to be compromised by perinatal exposure to PCBs (as a marker of POPs) (40). New research with piglets supports these findings and indicates that transplacental POPs’ exposure leads to a reduction in antibody response. Findings from a Russian Arctic cohort add evidence that higher levels of maternal blood PCBs might be associated with more frequent occurrences of low birth weight, premature births, stillbirths and menstrual irregularities (36). The cohort is being assessed for the 6-years child follow-up these days.

New research results with pigs, which have a similar reproductive system to humans, indicate that exposure of sperm to environmentally pertinent organochlorine mixtures in vitro adversely affects oocyte development, sperm fertility and embryonic development. However, a comparison of existing population studies do not reveal any definitive or consistent relationships (11).

The multi-national INUENDO study has indicated some links between POP exposure and biomarkers of male reproductive function (41). Associations were found between high PCB153 serum levels and low sperm counts, decreased sperm motility and damage to sperm chromatin integrity in some of the sub-populations studied. In spite of these effects, fertility was not related to POPs except in Inuit. There are also open questions related to the role of genetic background, lifestyle and/or diet nutrition factors such as trace elements/antioxidants (e.g. Se) that may interfere with the possible adverse health effects of POPs (41).

Exposure to POPs may contribute to the development of metabolic syndrome. The endocrine-disrupting properties of several contaminants, especially dioxin-like compounds, can affect glucose and lipid metabolism that in turn affect the onset of metabolic syndrome. Genetic factors and lifestyle are also important determinants of metabolic syndrome. The dramatic increase in the rate of diabetes among Inuit and Alaskan Natives may be affected by multiple factors, but the role played by contaminants in obesity, metabolism and diabetes warrants new, comprehensive studies (42).

**Toxic elements and human health in the Arctic**

Fig. 7 visualises the Mercury burden of Arctic people, especially the Greenlandic indigenous populations. The growing foetus and newborn children are especially sensitive to the toxic effects of environmental mercury (Hg) and lead (Pb), providing a special concern for the effects of emissions due to climate change. Animal studies indicate that exposure to environmentally relevant mixtures of POPs and metals has significant effects on reproduction. Exposures led to decreases in maternal weight gain, weight gain in offspring and increased mortality rates in pups prior to weaning (11). Interactions between MeHg and POPs in mixtures warrant further study as lower levels of MeHg administered alone have been found to lead to more polar bear pup mortality than that found in mixture studies containing higher levels of MeHg (11).

Potential neurobehavioural effects associated with MeHg exposure have been found in the Faroe Islands...
in the domains of verbal function, visuomotor integration and attention (43). However, the most consistent marker of pre-natal MeHg exposure is delayed auditory processing assessed from brainstem auditory event potentials. Because of the inconsistencies between studies, there is a need for additional well-conducted prospective studies to elucidate the specific growth and neurobehavioural effects of MeHg and to assess the impacts of differences in maternal diet during pregnancy on susceptibility to MeHg exposure. Recent studies in the Faroe Islands, Greenland and Nunavik all indicate that Hg can affect circulatory parameters such as pulse pressure, heart rate and heart rate variability, blood pressure, hypertension and atherosclerosis, imposing higher risk, e.g. pre-eclampsia during pregnancy (11). Pre-natal exposures to MeHg may also affect the development of cardiovascular homeostasis. If these preliminary findings are confirmed, the estimated attributable burden of diseases due to contaminant exposure might increase. Even small relative risks have a large impact on diseases having high incidence and mortality and could affect policy development on safe levels of exposure. Confirmation of these findings in other studies is needed as the current findings have potentially significant implications for Hg intervention policies. In addition, more research is needed to determine the relationship between changes in risk of cardiovascular disease and changes in diet among Arctic indigenous populations (1).

Lead is well known to adversely affect neurodevelopment and behaviour in children. Until recently, studies of behavioural effects of Pb in children have only confirmed effects from post-natal exposure, not from pre-natal exposure. New studies with children from Nunavik have shown that cord blood Pb concentrations were related to observational measures of inattention, even at cord blood Pb concentrations below 10 μg/L (1). The new data indicate that behavioural effects of low prenatal Pb exposure are likely to be observed when testing protocols that include sensitive measures of behaviour. Some new associations have been reported in Arctic Russia between spontaneous abortions and Hg levels in blood (11). No negative associations were found between maternal exposure to nickel and the risk of delivering a newborn with malformations of the genital organs.

**Fig. 7.** The Arctic Monitoring and Assessment Programme (AMAP). Circumpolar levels of Mercury (μg/L maternal blood) (11).

**Nutrients, contaminants and health in the Arctic**

Nutrients and antioxidants found in seafood are thought to be capable of attenuating the effects of some environmental pollutants, especially Hg, but the hypothesis has not been adequately tested in humans. Very high intakes of Se, a well-studied antioxidant, may actually have had a negative impact on the visual system in Nunavik children, instead of being beneficial or protective against Hg neurotoxicity (44). Further research on the relationships between nutrients, especially Se, and contaminants (especially Hg in the context of climate change) is needed. Vitamin A and n-3 fatty acids are known to be capable of modulating immune function. Several organochlorine compounds have been shown to alter vitamin A homeostasis in a number of species (11). New data for preschool Inuit children from Nunavik indicate that vitamin A deficiency is a risk factor for acute respiratory infections and otitis media among Inuit children from Nunavik (45). Imbalances or deficiencies of certain PUFAs of the n-3 and n-6 series are also thought to contribute to shorter duration of pregnancy and a wide
range of childhood difficulties, including ADHD or related symptoms, disruptive behaviours and learning difficulties. Nutritional factors including antioxidants and PUFAs can alter responses to contaminant exposures and could account for differences in the results found in the two compatible Seychelles Child Development and the Faroe Islands cohort studies (46).

Genetics and health in the Arctic
Some contaminants (PCBs and MeHg) and some nutrients (vitamin A) are able to directly affect gene expression (47). These findings have consequences for health outcomes and may indicate modes of action of some of these entities and how they interact. This research is really at the starting point but might get increasing importance in a changing climate. The possibility that organochlorines adversely affect the genome by decreasing global genomic methylation is intriguing and should be examined in other circumpolar populations (11).

The vulnerable Arctic people and implications for policy making
Changing the energy system to stabilise the climate is likely to have a wide variety of effects that are not directly related to greenhouse gas emissions, including human health, macroeconomy, ecosystems, agricultural yields and employment patterns (1–3, 38).

Food safety is a crucial issue for the pregnant population in a changing climate. Available food without environmental contamination can be provided through a good monitoring of hazardous substances in food (36) (Fig. 8). Very good results have been reached through dietary advice for young people and pregnant women in the Faroe Island (3, 36). The perspective for the next 1–2 generations will possibly be a change in exposure patterns; decrease in organic substance exposure through global collaboration and cleanup of local sources (11, 19, 36) but increased exposure to Mercury because of increased emissions and increased methylation (38).

The different stages of the pregnancy provide special challenges. The embryological period is especially sensitive to environmental impact, with Thalidomide as a

Fig. 8. Grandmothers dilemma, also known as the Arctic dilemma: feeding the child with the very best dietary items, without knowing the contaminant content (11).

Fig. 9. The placenta is a very vulnerable organ for environmental impact, especially from smoking, infectious agents, and contaminants. This picture is taken after a premature delivery of a very dysmature baby from a mother smoking 30 cigarettes daily during pregnancy (Odland, private picture).
tragic example (48). After the placentation, the placenta barrier still allows crossing of different metals and POPs (49). The change in zoonosis patterns of the polar regions due to climate change will increase the risk of exposure to new bacteria and viruses for the unborn child (50) (Fig. 9). The brain development is also ongoing throughout the pregnancy, leading to harmful effects from, e.g. Mercury and Lead on the brain development, even after birth and the first part of childhood (44). As a consequence of this, a systematic implementation of mother–child cohorts to discover complications or delayed development of children is highly warranted and ongoing (11, 49).

As the latest reports on trends in biological levels of POPs are promising (37), the scenario for the next generations in the Arctic is worrying (38). The situation for the unborn child during the different stages of pregnancy is especially problematic because of the change in maternal exposure related to changes in external temperature (38). Some worsening conditions for the embryo and the foetus might be prevented through detailed trend studies connected to good dietary advice for the pregnant women (36, 38). Even so, good and safe food is also associated with good socioeconomic conditions and specific challenges to secure the diet for the pregnant population (11). The gender perspective must have a high focus and priority for the coming research on climate change and human health. The security for the unborn child must have top priority in the future and we strongly recommend that the next IPCC report focuses more closely on this topic.

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The authors declare that there were no financial competitive interests and no scientific conflicts of interest.

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Climate change effects on human health in a gender perspective: some trends in Arctic research

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Background: Climate change and environmental pollution have become pressing concerns for the peoples in the Arctic region. Some researchers link climate change, transformations of living conditions and human health. A number of studies have also provided data on differentiating effects of climate change on women's and men's well-being and health.

Objective: To show how the issues of climate and environment change, human health and gender are addressed in current research in the Arctic. The main purpose of this article is not to give a full review but to draw attention to the gaps in knowledge and challenges in the Arctic research trends on climate change, human health and gender.

Methods: A broad literature search was undertaken using a variety of sources from natural, medical, social science and humanities. The focus was on the keywords.

Results: Despite the evidence provided by many researchers on differentiating effects of climate change on well-being and health of women and men, gender perspective remains of marginal interest in climate change, environmental and health studies. At the same time, social sciences and humanities, and gender studies in particular, show little interest towards climate change impacts on human health in the Arctic. As a result, we still observe the division of labour between disciplines, the disciplinary-bound pictures of human development in the Arctic and terminology confusion.

Conclusion: Efforts to bring in a gender perspective in the Arctic research will be successful only when different disciplines would work together. Multidisciplinary research is a way to challenge academic/disciplinary homogeneity and their boundaries, to take advantage of the diversity of approaches and methods in production of new integrated knowledge. Cooperation and dialogue across disciplines will help to develop adequate indicators for monitoring human health and elaborating efficient policies and strategies to the benefit of both women and men in the Arctic.

Keywords: climate change effects; human health; gender; research in the Arctic

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Recent changes in the lives of the Arctic communities have had different impacts on the lives of women and men; these include the rapid social changes caused by welfare state policies, economic policies and urbanisation. More recently, gender issues in the northern populations have been shaped by factors such as climate change and environmental pollution, which have become pressing concerns for the residents of the Arctic region. Several studies have shown that the societies living in the Arctic, along with ‘traditional’ gender inequality problems, are challenged with the new gender issues that are the result of contemporary transformations in the life styles, living conditions and well-being in the Arctic (1, 2).

Despite the formal recognition of the importance of gender ‘lenses’ for understanding the Arctic human development (2), some researchers argue that gender perspectives in the Arctic research on climate change impacts on peoples’ health are very seldom represented (3–7). This article shows how the issues of climate and environment change, human health and gender are addressed in current research in the Arctic. The main purpose of this article is not to give a full review but to draw attention to the gaps in knowledge and challenges in...
the Arctic research trends on climate change, human health and gender.

Natural and medical sciences on climate change, human health and gender in the Arctic

In recent upsurge of interest for an adequate scientific knowledge about human development in the Arctic, an academic division of labour, the legacy of Cartesian dualism, has left the material body to the natural and medical sciences, with social sciences and humanities for the most part occupied with intersections of individual and collective, autonomy and agency, culture and the social (8). Relevant literature addressing climate impacts on human health is dominated by natural and medical sciences.

The studies of climate change impacts on human health, as a consequence of the division of labour, have often been split into a number of areas. There are those whose concern is to point out the possible direct and indirect consequences of climate and environment change for the health of population in the North, e.g. the impacts of various forms of contamination, thermal stress, ultraviolet radiation in the Arctic; the effects of environmental changes on wildlife and their impacts on the food chain, nutrition and dietary patterns; climate change effects on local environment and their subsequent impact on the traditional lifestyles and human health in the Arctic (9-17). This has become a very powerful trend, which tries to establish links between climate and environment change and human health in the Arctic. Others focus on health vulnerabilities of women and men to the effects of climate change. The physical condition of both women and men, especially of women, is connected to the health of their children and, consequently, to the health of their communities (7, 18). Some studies have proven links between climate change, changing living-conditions and negative health outcomes among Arctic population, especially indigenous peoples, also indicating differences between men and women (19-25). Climate change-driven transformations of living conditions and the disruption of traditional lifestyles contribute to mental and social stress associated with the loss of community and culture. Indirect effects of climate change include changes in the environment and potential changes in bacterial and viral diseases as well as access to quality water and food sources (15, 17). Some studies also show associations between mental and social stress, violence or sexual abuse and current health problems, which are more common in women and children (7, 9).

Evidence-based research provides data showing that (a) the effects of climate change are not gender neutral and (b) direct and indirect impacts of climate change and health risks vary for women and men (26). Globally, women and men face different vulnerabilities due to their different gender roles (26-28). Women form a disproportionately large share of the poor all over the world and especially in developing countries. In southern countries, women are more dependent than men (e.g. in agriculture) on primary resources that are threatened by climate change because of their responsibility to secure water, food and energy for cooking and heating (27, 28). As a result, women more often come in contact with poor-quality water and are more vulnerable to water-related diseases; women also bear the main burden of caring for those who are ill (26). Women are vulnerable to extreme weather effects in particular ways before, during and after the extreme event: women’s traditional roles (looking after children and elderly) and cultural restrictions may hamper their self-rescue efforts (28). Women’s mortality, especially of elderly women, related to heat waves is higher than the mortality of men (27). Being male or female has an impact on individual health since the natural course of a disease may be different for women and men; individuals may respond differently to illness and society may react differently to sick women and men (26). Women may have less access to vital information on mitigation or adaptation strategies because of time constraints due to the caring and other domestic responsibilities. Still Preet et al find it as a general tendency that gender perspective is hardly represented in the research and policies on climate change and health (5).

Anyway, the point here is not to claim that gender perspectives remain of marginal interest within the climate change studies or in the Arctic research on climate change and human health. Rather, the point is to state that we still continue to observe a disciplinary division of labour. When present in studies, gender is often used as one of the variables in making the statistical data rich. Very often gender paragraph is simply added to the overall picture (see e.g. 22, 23). Of course, gender is but one, albeit important, perspective alongside with other perspectives that are important in climate change studies. Still gender is hardly ever a keyword introducing the articles’ contents in the scientific journals, such as the International Journal of Circumpolar Health, even when there are paragraphs or sections on gender there. And the problem here is that medical and natural science papers often operate with the category of ‘gender’ implying ‘women’ and ‘men’ as sexes, in a purely demographic sense (see e.g. 29-31). Within social sciences, and gender studies in particular, the category of gender has connotations of power misbalances between and within men and women and consequent differences in their social roles and positions. Gender approach towards climate change impacts on human health would imply exploring, e.g. how gender power relations affect and are involved into bigger contexts of climate and environment changes impacts on human health; what dispositions are available to men and women; which adaptation, resilience strategies are at the disposal.
of women and men; how health risks, health rights and health security are perceived by women and men and, in turn, how their awareness affects their situation and agency. In no way the message here is that qualitative studies that operate with gender/sex as a variable have little value and significance or that the discussions on power should be a part of each paper mentioning women and men. Different research projects have their own goals, research perspectives and tools. The criticism here is mainly addressed to the traditionalism of the approaches in knowledge production and the terminology confusion that arises from discipline segregation. Human development is complex (2, 32) and in order to grasp this complexity, the diversity of populations and their lifestyles, health risks and adaptation strategies we need to develop more sophisticated tools via multi/transdisciplinary research. Yet the blame cannot be entirely laid on climate change and health sciences, as I would further show, social sciences and humanities likewise show little interest in studying intersections of climate change impacts, human health and gender.

Arctic research, climate change and health in gender studies

Within social sciences and humanities it is acknowledged that climate change has an impact on well-being of people in local communities (1, 2, 32, 33). Indigenous people, elderly, women and children are considered particularly vulnerable groups in Arctic communities (4, 34). By focusing on cultural and social aspects of knowledge production in/on the Arctic, a number of researchers point to the fact that the Arctic has an image of a male world (6, 35, 36) or, what is more, of masculinity and whiteness (37, 38). Researchers explain this (re)presentation of the Arctic by two major reasons. First, Arctic exploration was predominantly male-driven: expeditions; search of natural resources; search for the Northwest passages; fur-trading, whaling, hunting, mining and military activities were all male-centred activities. Women quite recently entered this area as paid workers (2). Second, most literature written on peoples of the Arctic was written by men (mostly white) and mostly about men, transmitting male values (35). The scientific language employed in the Arctic research is marked by masculinism, nationalism and colonialism (37). Women’s contribution to local communities’ survival, the decision-making, hunting/fishing economy and spirituality of relations has been underestimated (39-41). In Russian Pomor traditional culture, in Canada and Greenland, we find evidence that women played a key role in household, family and local community life; women were the ones who distributed food, organised everyday routines, hold families together and raised strong leaders for their communities (1, 2). As some scholars have mentioned, among the indigenous populatons, the Arctic was home for at least as many women as men. Dowsley et al. provide examples when Inuit women have dominant economic and governmental positions in their communities, territories and global political forums, and yet social sciences focus on observations by male Inuit hunters (6).

Some scholars suggest that climate change affects women harder in the south, while in the north it is men who experience the effects of climate and environment change more dramatically (42). The disruption of traditional roles for men has been identified in a number of studies as a reason for profound problems in male identity and loss of men’s self-esteem which, in turn, leads to a lot of psycho-social disorders among men, including higher suicide rates and alcoholism (1, 34, 43). Also, men’s loss of identity and self-worth, societal tension and issues of power and control have been identified in some studies as contributing factors to increased violence against women and children, increased human trafficking and prostitution (1, 2, 43).

Another effect of climate and environment change on well-being of people in Arctic communities observed is a pattern of out-migration by young adult females in a number of northern regions, including Alaska, Greenland, the Faroe Islands, Iceland, Norway, Newfoundland and Russia (33, 34, 39, 44). Researchers point to education, marrying outsider men, access to services, including health care services, employment opportunities and search for security as the major reasons affecting women’s decision to move from small rural places and communities (2). Following consequences of female out-migration were highlighted in the studies: the lack of reproduction in the communities contributes to their stagnation. Development of ‘homosocial bachelor cultures’ as a result of men’s need for sustaining certain aspects of masculine identity is another feature (45). Ageing of population and increased poverty are also possible consequences (33). In many parts of the Arctic, economic cutbacks by national governments have often negative impact on small, rural and remote places, reducing the standard of living and the quality of life in these areas through limited employment opportunities, low wages and poor infrastructure and social services. According to Hoogensen, this leads to increased feeling of insecurity among women for their own future and the future of their children in the current place of residence and becomes one of the factors forcing women to migrate (45).

Thus, what social sciences and humanities mainly contribute with is proving to the fact that the picture of human development in the Arctic generally and the studies on climate and environment impacts on human health is to be understood in the light of gender approach. A gender approach in this respect contributes to knowledge building essential for human development.
of the Arctic (2). What is more inspired by the traditions of post-structuralism and post-colonialism, social sciences and humanities turned their attention to the complexity of phenomena as well as concepts, representations and interpretations used to describe them. To grasp the complexity of human development in the Arctic, analysis of intersections of gender, ethnicity and of various processes that create differences between people in the Arctic brings very important perspectives into both research and policy agenda.

**Multidisciplinary approach to climate change, human health and gender in the Arctic**

Though the research addressing intersections of human health, climate change and gender is indeed scarce, there are some multi/transdisciplinary studies where these intersections are explored. One can mention, for example, the research carried out by Joanna Kafarowski on gendered dimensions of environmental health and contaminants in Nunavik in Canada (3, 46, 47). Kafarowski studies the differences between women’s and men’s perceptions of contaminants’ threat to human health and shows that men and women not only have different perceptions of health risks but also develop different adaptation strategies. She concludes that both gender and ethnicity affect people’s visions and are important for developing efficient environmental health policies and strategies in response to the contaminants in small native communities. Another example is Sandra Owens’ research on Inuit indigenous women in Nain, Canada, and the ways indigenous people experience climate change through their daily activities. In her study, she particularly focuses on how indigenous women experience changes in the dietary patterns as a constantly decreasing access to traditional foods as healthy and nutritious ones (48). Women’s access to decision-making processes is seen as crucial when encompassing reproductive health, sexual health and environmental justice (46, 49). Some researchers suggest, even though women develop original solutions to complex environmental issues in the Arctic, they, nevertheless, mostly advance the agenda at the grassroots level, within social and environmental activism (2, 6). Beyond the grassroots level, women are less visible in environmental politics. Men tend to assume positions of responsibility and power in the public sphere and, therefore, it is likely that environmental decision making itself is deeply gendered. The contributions of women are valued less than the contributions of men in western, non-indigenous societies and women are less likely to attain decision-making positions (39, 43, 44, 49).

What is of particular value with these studies is that they do their research at intersections of gender, ethnicity and the variety of processes that create differences in peoples’ health rights and climate justice in the Arctic. The only limitation is that the studies linking climate and health with gender and ethnicity, to our knowledge, mostly have been carried out in Alaska and Arctic Canada. Climate change is one of many sources of stress for communities in the Arctic. It affects people and their environment with potential consequences for communities’ and individuals’ psychosocial well-being and health (15–17). At the same time, ‘any discussion of power relations and gender roles must also recognize the social and cultural diversity across the circumpolar North and the fact that many different perspectives can be applied when analyzing these roles’ (2:187). Vulnerability of communities and individuals will vary depending on differences in climate alterations, distances, infrastructure, resources, etc. Climate change impacts on human health also vary between and within communities in the Arctic, and the examinations of gender relations illustrate the complexity of communities in the differences of perspectives that abound within and between them.

**Conclusion**

Various academic disciplines within Arctic research provide data showing that (a) climate change effects are not gender neutral and (b) direct and indirect effects of climate change and health risks vary for women and men. Gender perspectives on climate change and health is formally recognised as an important field of research. The analysis, undertaken in this article, illustrates that gender issues remain of marginal interest for environmental, climate change and public health studies in the Arctic. Yet the blame cannot be completely laid on climate change and health sciences as social sciences and humanities have likewise often ignored gendered dimensions of climate change impacts on human health. Or, rather, gender studies show little interest to climate change and the Arctic population health issues. As a result of the division of labour between disciplines, little dialogue is established cross-disciplinary, which results in narrow use of concepts and the disciplinary-bound pictures of human development in the Arctic.

The Arctic population health is an important dimension and an indicator of monitoring human development. There are different starting points for investigation of peoples’ lives and climate change effects on their health. Awareness of differentiated climate and environment effects on health of women and men has to be incorporated in knowledge production in order to understand the processes taking place in the Arctic human development and to plan the future strategies. Attempts to implement a gender perspective will be successful only when different disciplines work together in multi/transdisciplinary research. Transdisciplinarity is a way to challenge academic/disciplinary homogeneity and their boundaries, to take advantage of the diversity of approaches and methods in the production of new integrated knowledge.
It is also a way to escape reproduction of trivial approaches towards complex phenomena and to develop new indicators for monitoring human health and elaborating effective and adequate policies and strategies to the benefit of both women and men in the Arctic.

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Climate change and water security with a focus on the Arctic

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Water is of fundamental importance for human life; access to water of good quality is of vital concern for mankind. Currently however, the situation is under severe pressure due to several stressors that have a clear impact on access to water. In the Arctic, climate change is having an impact on water availability by melting glaciers, decreasing seasonal rates of precipitation, increasing evapotranspiration, and drying lakes and rivers existing in permafrost grounds. Water quality is also being impacted as manmade pollutants stored in the environment are released, lowland areas are flooded with salty ocean water during storms, turbidity from permafrost-driven thaw and erosion is increased, and the growth or emergence of natural pollutants are increased. By 2030 it is estimated that the world will need to produce 50% more food and energy which means a continuous increase in demand for water. Decisionmakers will have to very clearly include life quality aspects of future generations in the work as impact of ongoing changes will be noticeable, in many cases, in the future. This article will focus on effects of climate-change on water security with an Arctic perspective giving some examples from different countries how arising problems are being addressed.

Keywords: Health and environmental change; Arctic

Water security may be defined as ‘sustainable access, on a watershed basis, to adequate quantities of water of acceptable quality, to ensure human and ecosystem health’ (1).

Water is of fundamental importance for human life; access to water of good quality is of vital concern for mankind. Currently however, the situation is under severe pressure due to several stressors that have a clear impact on access to water. These stressors include a continuous increase in the world population, an increase of urbanisation, consequences of agricultural changes when the demands for dietary changes occur during development, increasing pollution of water resources and the overuse of groundwater and various impacts of climate change (2, 3). In the Arctic, climate change is having an impact on water availability by melting glaciers, decreasing seasonal rates of precipitation, increasing evapotranspiration and drying lakes and rivers existing in permafrost grounds. Water quality is also being impacted as manmade pollutants stored in the environment are released, lowland areas are flooded with salty ocean water during storms, turbidity from permafrost-driven thaw and erosion is increased and the growth or emergence of natural pollutants is increased.

Global aspects on water security

The global population growth is estimated to increase from 6.8 million today to 8 billion by 2025, which will put pressure on water demand from many perspectives as water is used in the production of both food and energy (4). More people demand more food and also, with a shift in diet to more so-called westernised food, there will be an increased pressure for water; agriculture accounts for 70% of all water use today (5).

By 2030, it is estimated that the world will need to produce 50% more food and energy that means a continuous increase in demand for water. The pollution of the seas is an established fact, and ocean transport of contaminants is growing as a health concern for populations in the area (6–8).

Decision makers will have to very clearly include life quality aspects of future generations in the work as the
impact of ongoing changes will be noticeable, in many cases, in the future.

Recently, an estimation of an increase of 30% of fresh water is needed to mitigate the causes of and adapting to climate change (5).

Thus, according to these estimations, the demand for water will without doubt be increased in the near future.

This article will focus on effects of climate change on water security with an Arctic perspective, giving some examples from different countries how arising problems are being addressed.

Water stress and water footprint

Water stress occurs when the demand for water exceeds the available amount during a certain period or when poor quality restricts its use.

In 2010, a report from the World Bank found that the effects of water shortages are felt strongly by 700 million people in 43 countries (9). Another report from 2010 states that 80% of the world’s population is exposed to high levels of threat to water security (3). The stress is not limited to the human sphere as a majority of the flora is also threatened; a majority of biodiversity dependent on river discharge is at risk for extinction as well as flora and fauna are dependent upon Arctic lakes (3).

The impact on human health is thus complex with many parts of nature being affected and interacting in an interwoven biological/physiological communication.

It is a scenario that causes anxiety and worries. Although the situation is a cause for considerable concern, technologies and expertise are being developed that can help address these problems. But to implement effective adaptation measures, it is important to raise awareness among decision makers as well as the general public as changes in water consumption at an individual level will be crucial to tackling water scarcity. It is a challenge of pedagogical nature to show the need for individual actions and for personalised willingness to take on responsibility for mitigating changes of climate.

Water has traditionally been regarded as a free resource, but this can be changed. The term water footprint is a measure how much water has been used during the production process of any goods or food. Recognition of the water footprint in all aspects of society is needed to change public awareness about water value, and ultimately water consumption behaviour.

Climate change in the Arctic

Air temperature has increased in the Arctic, warming 0.6°C since the early 20th century, with seasonal as well as geographical variations.

Precipitation is a parameter that is difficult to measure in the Arctic and complex to predict. Arctic climate impact assessment (ACIA) suggests that a 1% increase in precipitation per decade has occurred over the last century (2). Seasonal distribution of precipitation is important to consider as winter precipitation has increased since the 1970s and because Arctic winter precipitation is projected to increase with continuing climate change. Despite increased annual precipitation, a net summer drying effect is occurring due to decreased seasonal precipitation, increased temperatures, thawing permafrost and increased evapotranspiration.

There has also been an increase in wind since the 1960s and in cyclone activity.

Ecosystem change is occurring due to a longer growing season – this is favourable for northward expansion of agriculture and in natural plant and animal distribution.

Shrubs are expanding into the tundra and the Arctic tree line is moving north. This will cause an increased loss of water due to evapotranspiration contributing to drier summer conditions in the future.

Climate change effects on water security in the Arctic

Degradation of the permafrost can result in drainage of ponds. In Siberia and Alaska, lakes in permafrost regions have undergone rapid change, some increasing in size and number, whereas others have decreased and in some instances disappeared. Siberian rivers have, as rivers in Alaska, increased in winter discharge, even in non-dammed tributaries. Vast territories of the tundra in the Russian Arctic may be replaced by taiga. Forecasts say that the total area of permafrost may shrink by 10–12% in 20–25 years with permafrost borders moving 150–200 km northeast in Russia (10).

In the Arctic, permafrost extends to up to 500 m below the ground surface, and it is generally just the top metre that thaws in the summer (8). Lakes, rivers and wetlands on the arctic landscape are normally not connected with groundwater in the same way they are in temperate regions. So, when the surface is frozen in the winter, only lakes deeper than 2 m and rivers with significant flow retain liquid water. Surface water is often abundant in summer, when it serves as a breeding ground for fish, birds and mammals. In winter, many mammals and birds are forced to migrate out of the Arctic.

Many humans in the Arctic rely on surface water for community use, so when conditions change and access to water is diminished, the prerequisites for human survival are affected. Only 40% of Yakutia’s population is supplied with running water from centralised sources and 140 operational water pipes fail to meet sanitary standards (10). The population in the Arctic part of Russia is also estimated to increase at huge investments in infrastructure and regional planning will occur during the next coming decades.
A study from Alaska shows that when access to water is limited, it causes consequences for the health care. Studies have shown a 2-4 times higher hospitalisation rates among children <3 years of age for pneumonia, influenza and childhood respiratory syncytial virus infections and higher rates of skin infections in persons of all ages in villages where the majority of homes had lower water availability because of no in-house piped water source, compared to homes that had higher water availability because of in-home piped water service (11). In Alaska, climate change is resulting in damage and disruption of community water infrastructure in many Arctic communities (12). Reduced availability to safe water results, according to the study performed in Alaska, in increased rates of hospitalisation for respiratory and skin infections. This could increase the use of antibiotics, and an overuse of antibiotics might result in an increase in resistant bacteria. Studies are in progress to investigate the situation.

Today in parts of northern Russia as well as other areas of the Arctic, surface water meets domestic needs as drinking, cooking and cleaning as well as subsistence and industrial demands. Indigenous communities depend on sea ice and waterways for transportation across landscape and access to traditional country foods. The industries also use large quantities of surface water during winter to build ice roads and maintain infrastructure. For all of these reasons, it is critical to understand the impacts of climate change on water security in the Arctic with its specific demands.

Arctic warming means thawing of permafrost that is impacting both the community source water (groundwater, rivers and lakes) and water infrastructure, the piped water and water storage and purification systems often build on permafrost. Hence, disturbances of infrastructures as housing, railroads, roads are already occurring. Floods have affected Yakutia more than other regions in Russia. In 2001, a flooding occurred in the city of Lensk. A spring flood made the water level rise by 2.0–2.5 m resulting in city infrastructure being destroyed and a 30-fold increase of hepatitis A. The total damages amounted to over 7 billion roubles (10).

The so-called geocryological hazard index used to assess the risk of damage to structures built on permafrost is especially high in Chukotka, on the coast of the Kara Sea, in Novaya Zemlya and the north of the European part of Russia. Permafrost degradation along the coast of the Kara Sea may lead to intensified coastal erosion that moves the coastline back by 2–4 m per year posing considerable risks for coastal population centres in Yamal and Taymyr.

Even in areas where there is good infrastructure, unexpected problems arise. During 2010 and 2011, outbreaks of Cryptosporidium parvum infections occurred in two municipalities in northern Sweden causing disease in thousands of individuals and disrupting everyday life as water had to be boiled before being used. In Östersund, the first municipality struck, >12,000 persons got sick with gastrointestinal symptoms, 61 were hospitalised. More than 50,000 persons were affected by the advice from the authorities that all water used for drinking or cooking should be boiled. This regulation lasted 84 days.

The second outbreak affected the population in Skellefteå, in northern Västerbotten where >6,000 got sick. The water used for drinking had been boiled since the middle of April and the final cleaning of the water occurred in September 2011. The advice about boiling caused a rapid response; 2 days after this statement to the public, the number of new persons with symptoms declined.

One cause that is under investigation is that the intake of surface water for drinking water is close to the sewage outlet and as more precipitation has occurred during the last decades, a connection is established. As in other parts of the Arctic, the infrastructure of yesterday, supposed to last until tomorrow, is not sufficient for the situation of today.

Surveillance
Improved surveillance systems are needed for community source water, including waterborne and water-washed diseases to detect impacts of climate change in the Arctic, and international networks need to be further developed. Microbial surveillance of drinking water including water sources for indigenous peoples in the Arctic should be prioritised. Climate change health assessment methods have been developed in Alaska (13).

In Greenland, water quality is secured by legislation, day-to-day running of the water supply and supervision of the water resource. The Government is implementing the EU Drinking Water Directive that also is an EU demand, if Greenland wants to continue to export foodstuffs to EU (14). The directive demands water quality information from public utilities at a level not used in Greenland before. So, there is a need for information material, both in the form of data sheets with analysis results and as explanations and descriptions of the analysis results. A portal, owned by Greenland Resources, is the authorities’ medium for information to the public. Besides, there is a general request for a gathering and structuring of all the knowledge that is accumulated in the last 5 years about water quality, water resources, water handling and authority matters.
including legislation and the last 20 years’ water chemical analysis results.

Policymaking
The impact of policy in one nation can have impact on the water security of other nations. There is a need for governance at all scales—global, regional, national, local as well as the catchment level and a need for linkages between these scales.

The Arctic Council has, through the Sustainable Development Working Group, established the Arctic Human Health Expert Group (AHHEG). This group of experts have the task to develop working plans for improvement of health for the people living in the Arctic.

Agreements for water allocation and sharing across borders may be stated in international treaties. Water security is important for national security as demonstrated by the international conflicts around access to water occurring in East Africa.

What is required to meet the increased demand is the implementation of effective governance, financing and regulation to allow technical solutions to be effective for global water security.

Thus, today it is of uttermost importance to raise awareness of key issues and potential responses and have a broader public debate on sustainable resource use and management.

Existing values, cultural norms and organisational structures that empower the individual determine patterns of individual behaviour and organisational response—to influence this is a great pedagogic challenge, but the success of implementation from governments and public authorities relies on the response from the individual.

Maintaining and ensuring the security of water and ability to supply demands from the water resources available are essential to humankind everywhere now and in the future and are equally important for vulnerable populations in the North.

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The authors have not received any funding or benefits from industry or elsewhere to conduct this study.

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Climate change and consequences in the Arctic: perception of climate change by the Nenets people of Vaigach Island

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**Background:** Arctic climate change is already having a significant impact on the environment, economic activity, and public health. For the northern peoples, traditions and cultural identity are closely related to the natural environment so any change will have consequences for society in several ways.

**Methods:** A questionnaire was given to the population on the Vaigach island, the Nenets who rely to a large degree on hunting, fishing and reindeer herding for survival. Semi-structured interviews were also conducted about perception of climate change.

**Results:** Climate change is observed and has already had an impact on daily life according to more than 50% of the respondents. The winter season is now colder and longer and the summer season colder and shorter. A decrease in standard of living was noticeable but few were planning to leave.

**Conclusion:** Climate change has been noticed in the region and it has a negative impact on the standard of living for the Nenets. However, as of yet they do not want to leave as cultural identity is important for their overall well-being.

**Keywords:** globalization; population; community; health determinants

*The social consequences of climate change are one of the most pressing global problems. Climate change was included for the first time this year in the agenda of the BRICS (Brazil, Russia, India, China, and South Africa) summit. BRICS leaders considered it as a global threat and agreed to strengthen practical cooperation in the economies of the five countries to adapt to climate change (1). The concept of long-term socio-economic development of the Russian Federation in 2020 specifies the objectives of development of economic sectors and territories, taking into account climate change, for example, in changes of infrastructure in the Arctic region to handle the projected climate change (2).

As the results of sociological ‘measuring’ of public opinion show, the problem of climate change concerns an increasing number of people around the world (3). The poll of Russians held in March 2007 by VTSIOM (All-Russian Sociological Questioning Center) showed that more than 90% of respondents are aware of global warming. The vast majority of them (59%) believe that the impact of global warming will ‘probably be negative,’ 18% expressed the opposite point of view, and 23% found it as ‘difficult to forecast’ (4). For Russia, the economic costs of climate changes are most consistently and fully explored in the works of Porfiriev. In his opinion, the changes in climate can have negative impacts such as creating special ‘climate zones,’ thus risking expected economic growth. Among the risks Porfiriev mentions are permafrost degradation and melting of ice in the seas surrounding Russia in the Arctic Ocean which increases the risks of flooding, storms, hurricanes, etc., and the emergence of ‘climate zones’ for economic development and individual industries. At the same time, melting of ice in the Arctic Ocean can lead to the revitalization of maritime transport: even a partial unblocking of the Northern Sea Route rapidly increases the duration of the period when navigation is possible.
and the capacity of the major trans-continental (Eurasian) transport corridor with all the positive implications for transportation in the country (5, 6).

Climatic change in the Arctic causes diverse health risks for indigenous and endemic populations. Some risks are caused by the northward propagation of ‘southern’ infections, whereas others are related to deformations of the permafrost zone that brings about breakdowns in infrastructure, sanitary functions, etc. Ice thinning and difficult conditions for the sea-hunting industry (sealing) may lead to increased incidence of injuries among the small populations of indigenous peoples of the North. Today, the mortality rate among these groups significantly exceeds the average mortality rate in the RF (7).

Methods, model area and population
Vaigach Island (3,383 sq km) was chosen as a model area for the study of climate change and its impacts in the Arctic. Vaigach is one of the key points of the North Sea Route because ships can reach the seas of Siberia from the West only by two straits: Karskiye Vorota (to the North of Vaigach) and Yugorsky Shar (to the South of Vaigach). This island is visited by helicopter twice a month. It is located between the archipelago of Novaya Zemlya and the mainland in the subarctic natural area on the border of the Arctic-European and Arctic-Asian island provinces of the Arctic Ocean. The climatic conditions of Vaigach are more severe than in the South Island of Novaya Zemlya that is located to the north of it, as the southwestern part of Novaya Zemlya is affected by the warm Western Novaya Zemlya current and the East Novaya Zemlya current during the cold season. This brings ice from the Kara Sea, clogging the Karskiye Vorota, and Yugorsky Shar straits. The grass cover of Vaigach is peculiar to northern arctic tundra, there are many small lakes and marshes, and rivers – the rapids are deeply cut into the surface (8).

In August 2010, an expedition was organized to Vaigach island run by Barentsevomorskoe branch of the World Wildlife Fund (WWF), led by Oleg K. Sutkaitis. Along with the biological research into changes to the bird and sea-mammal populations, there was an attempt to study the perception of climate change by the indigenous people, namely the Nenets of Varnek, who have the only settlement on this island. The authors designed a questionnaire used during the survey and which residents of the settlement Varnek answered. Some questions were explored in detail through interviews with the local people. The results were compared with historic data, archive materials, and more broad topics, connected with recent developments in the Arctic.

Varnek today is the only settlement on Vaigach Island. The adult Nenets population originates from the adjacent mainland tundra and from Novaya Zemlya. Varnek was listed as having 101 people in August 2011 (see Table 1).

In Varnek, there are 16 buildings, and 24 families live there. Coal for heating is delivered right into the backyard of houses. In front of the buildings, there are garages for ‘Buran’ (winter motor sledges) and dog huts (insulated buildings for hunting and sled dogs). The village has a shop, club, medical-obstetric stations, and a bakery. The village is lit by electricity from 7.00 am to 2.00 am by a diesel generator.

The traditional economic complex of the Nenets of Vaigach Island
The presence of tundra, the large numbers of marine animals (seals, walruses), and birds (geese) have shaped the features of the traditional economic system of the Nenets living on Vaigach.
Reindeer husbandry plays a lesser role on Vaigach Island compared with the continental tundra Nenets.

There are only three men working with reindeer on Vaigach Island: the foreman and two herders. There are about 1,000 reindeer in a herd (in the 1970s the herd was up to 1,700 reindeer). Free pasture is practiced throughout the island (wolves are rare on the island). The herders use both reindeer and dogs as a traditional means of transport.

Hunting and fishing play a very significant role in the economic activity of the Nenets people on Vaigach Island.

All the men of the village are hunters (the boys start hunting at the age of seven). Every family has a gun. They hunt for geese, eider, and swans. The most popular hunting season is the spring hunt for the arriving birds and then the summer-autumn hunt — for molting birds. A family prepares annually about 100–120 ‘cans’ of bird meat (for their own use). The family collects about 100–120 eider eggs annually (in this case one egg is usually left in the nest) in the spring season. The Nenets store foods at home in iceboxes.

The winter hunt is for marine animals: usually seals (to feed the dogs). In Varnek, there are only nine dog teams. To feed 8–12 dogs over the winter, it is necessary to catch about 30–40 seals.

Many men are engaged in coastal fishing (but there are only a few ‘professional fishermen’ in the village) and catch omul (Arctic cisco), trout, cod, and smelt. In the village, there are about a dozen nets and one traditional ryzha (fishing trap) used for many centuries.

There is one Nenets master making boats (in the old so-called Pomor fashion) from wood and metal from crashed military aircraft.

In summer, the Nenets of Varnek collect Russian root, Snowdon roses, or rosewort (Rhodiola rosea) known in Russian as zolotoy koren (‘gold root’), mushrooms, and cloudberries. A family can collect up to 50 litres of cloudberries that are stored in wooden barrels.

In general, at the present time, the village of Varnek constitutes a special kind of Nenets Port economy with elements of the influence of the culture of the Russian Pomors (the original settlers on the White Sea Coast) and the preservation of traditional attitudes toward reindeer.

The activities on the North Sea Route have a great impact on the economic activities and the household life of the Varnek Nenets population as an important segment of this is the Yugosky Shar strait. For the period of 10 days that our expedition stayed in Varnek, the settlement was visited by a barge with two tugs, the ship of the Moscow State University scientific expedition, a trimaran from the Norwegian Circumpolar Expedition, a tanker, and two vessels. Excluding the trimaran from Norway, all the visitors brought alcohol. Fish catch (omul, char), and reindeer and polar fox skins (and illegally harvested skins of polar bears), and cloudberries are collected in exchange for alcohol.

Such an exchange has negative social consequences for the village, transforming the economic direction and nature of the environmental population. Natural resources are exploited not only for local consumption but also in such quantities that they are capable of damaging the life of the Nenets community on the island. Under market conditions, the traditional nature management is transformed according to the demands of the visitors and the Nenets sometimes even break the hunting rules and become poachers.

**Study of public opinion of Varnek residents**

The inhabitants of the village of Varnek comprise 101 persons, including 59 adults, 42 children, and 18 students (studying at a boarding school in the mainland village of Karatayka). During the survey in the village, there were some people who did not participate: about 20 adults were absent and 6 other adults refused to take part in the survey. The survey involved all the socially active population of the village. The sample consisted of 30 people (10 men and 20 women).

**Results**

The respondents believed that the most important activities for their own survival were traditional nature use fishing (14 persons), hunting (12 persons), and reindeer breeding (11 persons). In addition, the villagers described trade and exchange (six persons), picking berries and mushrooms (four persons) as essential for their survival.

**Climate changes by the observations of the local residents of Varnek settlement during 5 years (2005–2010)**

According to respondents’ answers, climate changes had been on Vaigach Island.

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**Table 1. Age-sex structure of population of Varnek (compiled from the household books)**

<table>
<thead>
<tr>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Men</td>
<td>0</td>
<td>3</td>
<td>7</td>
<td>8</td>
<td>5</td>
<td>9</td>
<td>5</td>
<td>11</td>
<td>48</td>
</tr>
<tr>
<td>Women</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>6</td>
<td>3</td>
<td>11</td>
<td>12</td>
<td>15</td>
<td>53</td>
</tr>
<tr>
<td>Total</td>
<td>2</td>
<td>4</td>
<td>10</td>
<td>14</td>
<td>8</td>
<td>20</td>
<td>17</td>
<td>26</td>
<td>101</td>
</tr>
</tbody>
</table>
Most respondents said that over the past 5 years, the climate had become colder, but two men involved in fishing, however, had noticed ‘warming.’ (see Fig. 1)

Seasonal climate changes according to the respondents’ evaluation were as follows: winter was colder and longer, and summer colder and shorter. With respect to changes in the spring period, the respondents had different, even sometimes contradictory opinions. Obviously, the growing season had become longer because more southern species of plants were now able to survive on Vaigach. However, the human impressions of the seasons were different because the spring time started earlier, but the spring itself seems colder (comments by L.R.Lukin, Institute of Ecological Problems of the North, UB RAS).

The island’s inhabitants estimated climate change by observing the melting snow, the arrival, and disappearance of birds (including geese), and the change in vegetation.

Respondents noted the emergence of new species on the island of animals, plants, insects that they could not identify (‘I can not call them anything,’ ‘do not know the name’). Among the known species were crows, whereas ‘before there were none,’ and an increase in wasps. Residents have noted changes in vegetation, it ‘has more flowers,’ ‘the bushes spread,’ and pointed out that the ‘lakes dried.’

Climate change has affected the lives of the islanders, in the opinion of half of respondents (16 persons), others do not notice this effect (9 persons), or found it ‘difficult to give an answer’ (5 persons).

Migratory behavior: opinion of the Nenets people of Vaigach

Despite the fact that the survey results indicate a decrease in the standard of living on the island, the majority of respondents do not intend to leave (Fig. 2). Nevertheless, a more pronounced desire to leave can be seen among women.

The sacred characteristics of the Island of Vaigach

Historically, Vaigach is a holy land of the Nenets people: in the Nenets language, the island’s name is: Hehe Ya or Hebidya Ya. It contains many sites, sacred places of tribal and personal shamanic significance (9). Since ancient times, the Nenets from the continental tundra have gone on pilgrimages to Vaigach. They gathered their reindeer that then crossed the Yugorsky Shar Strait by walking across the ice or by swimming. The sledges with a passenger were tied to the reindeer that swam across the strait pulling them. They did this to make a vow or make sacrifices.

The sacred status of Vaigach has limited economic significance for the Nenets on the island. However, the appearance of the Hebidya Ya, the Russian fishermen, who hunted sea mammals and molting birds initially caused conflict with the Nenets. R. Jones, a member of S. Borrough’s expedition in 1556 wrote about Vaigach: ‘wild Samoyeds live there, not allowing Russians to land’ (10).

Vaigach Island is now a sanctuary and operates as a place of worship for Nenets living in the Far North. In the Nenets’ beliefs, weather events are managed by the
spirits. Fog, wind, rainfall are a form of manifestation of the spirits’ relationship to actions: people’s behavior. Below is a fragment of one of the legends of Vaigach, as submitted by residents of the island:

I learned that there is an inscription on the Semiliky Idol (Spirit with Seven Faces) – translated into Russian: ‘In 1988, six grandchildren will be born of Vesakho Idol.’ There should be six boys in one family line... According to the belief of the villagers of Varnek and my own observations, one of those six grandchildren controls the weather. (…)… Archaeologists took the idol to one of the museums in Moscow... During this time, while Vesakho was absent, on Vaigach there were strong blizzards, hurricanes, sweeping everything in their path, but when he was brought back, the weather calmed down.’(11)

Discussion
The nature of climate changes is still not completely understood and no single scenario of the situation exists. However, the observed Arctic climate change is already having a significant impact on the environment and on economic activity. For the northern indigenous peoples, whose traditions and cultural identity are closely related to the natural environment, any change is of great importance. In addition to the natural transformations, the projected increased economic activity in the Arctic will be another factor, ‘channeling’ the pressure of civilization onto their distinctive way of life. Confronting them is the need to cope not only with changes in the environment but also the need to adapt to life in the context of expanding industrial activity and the overall anthropogenic impact on the Arctic nature.

It should be noted that a person’s experience of air temperature depends not only on the temperature itself but also on the combination of temperature, humidity, and wind speed. For example, a temperature of 0°C experienced at a wind speed of 5 m per second corresponds to −5°C and no wind. So, the subjective impression of the climate changes has to be taken into consideration, as an important characteristic of environmental comfort for human beings on the given territory.

The specifics of the worship of the Nenets people should be taken into consideration, (as an analysis of the answers on the questionnaires shows), although they are in contrast to the ordinary Western way of thinking and analysis of situations. Climate and weather events in some cases depend on human behavior, according to the evaluation of climate changes also in the frame of traditional beliefs. This ‘binary approach’ could be the topic of further study and discussion.

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Thawing of permafrost may disturb historic cattle burial grounds in East Siberia

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Climate warming in the Arctic may increase the risk of propagation of zoonoses due to the expansion of vector habitats, improved chances of vector survival during winter, and permafrost degradation. Monitoring of soil temperatures at Siberian cryology control stations since 1970 has showed correlations between air temperatures and the depth of permafrost layer that thawed during summer season. Between the 1900s and 1980s, the temperature of the surface layer of permafrost increased by 2.4°C; and a further increase of 3°C is expected. Frequent outbreaks of anthrax caused the death of 1.5 million deer in the Russian North between 1897 and 1925. Anthrax among people or cattle has been reported in 29,000 settlements of the Russian North, including more than 200 Yakutia settlements located near the burial grounds of cattle that have died from anthrax. Statistically significant positive trends in annual average temperatures were established in 8 out of 17 administrative districts of Yakutia for which sufficient meteorological data were available. At present, it is not known whether further warming of the permafrost will lead to the release of viable anthrax organisms. Nevertheless, we suggest that it would be prudent to undertake careful monitoring of permafrost conditions in all areas where an anthrax outbreak has occurred in the past.

Keywords: climate change; Arctic; anthrax; zoonoses; Russia

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Climate change in the Arctic may increase the risk of propagation of zoonoses due to the expansion of vector habitats and development of more favorable climatic conditions for their survival during the winter season, increases in average air temperatures, and permafrost degradation. Between the 1900s and 1980s, the temperature of the surface layer of permafrost increased by 2.4°C (1), and a further increase of 3°C is expected (2). The second half of the 20th century was marked by accelerated increases in the temperature of the upper layer of permafrost and the depth of the seasonal melting layer. The Circumpolar Active Layer Monitoring network (http://www.udel.edu/Geography/calm) includes 20 Russian stations, all of which have reported increases in the annual average temperatures of the upper permafrost layer since the 1970s. The magnitude of the increase varies from 1.2–2.8°C in the Russian European North, to 1.0°C in the north of West Siberia, to 1.4–1.8°C in Central and South Yakutia, and to 1.3°C in other regions of East Siberia (3, 4). Various climate models predict the change in summer temperatures to be between 2.7 and 3.8°C in Yakutia cities by 2020. As the permafrost temperatures in Yakutia increase, permafrost degradation becomes evident. For example, the depth of permafrost varies between 250 and 350 m in the center of this region (Yakutsk city). Under natural conditions, the depth of seasonal melting is 1.5–1.7 m for clay loams, 1.6–2.0 m for sand clays, and 2.0–2.5 m for sands. The temperature of the surface layer of the permafrost is predicted to increase by 1.5–2°C in West Siberia and Yakutia, and by 1.0–2.0°C in Chukotka and the north regions of the Far East (5). The measurements of air temperature and permafrost temperature at the depth of 1.6 m at 52 stationary monitoring stations in Siberia showed linear correlation between these variables (6). Frequently observed rock sagging under building and engineering structures in Yakutia is explained by the decomposition of thermokarst, frost heave, waterlogging, and flooding (7).

As a consequence of permafrost melting, the vectors of deadly infections of the 18th and 19th centuries may come back, especially near the cemeteries where the victims of these infections were buried (8). Frequently repeated outbreaks of anthrax caused the death of 1.5 million deer in Russian North between 1897 and 1925 (9). Cases of anthrax among people or cattle have been
reported in 28,986 settlements of the Russian Federation. There are also 13,885 cattle burial grounds, of which 4,961 sites do not meet Federal veterinary and sanitary standards (10). Other literature sources reported that more than half of these burial grounds did not meet sanitary standards and indicated lack of interaction between the State sanitary inspections and veterinary services. Some burial grounds have lost their official records of buried cattle or epizootic maps (11). Many settlements do not exist any more and have been erased from local sanitary databases. Other settlements have become almost deserted by people, who could potentially guide sanitary authorities in mapping the boundaries of the burial grounds (12). Many of the anthrax cattle burial grounds are located in Siberia, where 6,688 settlements received the status of ‘stationary adverse’ territories because of the risk of this disease. Taking into account the vast territory of Siberia, the density of such settlements is quite low (1.1 per 1,000 km²), even though the absolute number of such settlements in Siberia is 2.5 times greater than in European Russia.

Among all the Arctic territories of the Russian Federation, Yakutia has the greatest number of settlements, where outbreaks of anthrax have been registered in the past, which is explained by very intense breeding of reindeer and horses. Between 1906 and 2004, 270 settlements reported outbreaks of this disease (13). The greatest numbers of epizootic events were recorded in 1949, 1951, 1957, 1969, 1970, 1980, 1986–1988, and the last outbreak occurred in 1993. There were 21 casualties among the Yakutia population between 1949 and 1996 due to anthrax contracted mostly from cattle and reindeer (14). The spores of Siberian Anthrax remain viable in permafrost for about 105 years (15). More than 30 years ago, Russian researchers confirmed viability of other microorganisms (fungus, diatoms, etc.) collected in Antarctic glacier samples (16). Other researchers observed metabolic activity of bacteria in permafrost at the temperature of about –20°C (17). The spores of the bacterium anthrax may survive for 50–70 years more in the samples excavated at the depth of 1 m below the level of seasonal thawing in permafrost, as was observed in one Yakutia district (18). Potential hazard of the historic cattle burial grounds was confirmed by the outbreaks of Siberian anthrax among domestic reindeer in the Taymyr region of Russian Arctic in 1969 and 1977 (19). Microbiological tests of 18,000-year-old mammoth tissues confirmed the presence of Bacillus non reactiv (D. sphaericus), B. anthracis, B. cereus, B. anthracoides, and other bacteria (20), but repeated analyses did not detect pX01 and pX02 plasmids in the brain of the grown-up mammoth (the researchers associate virulent properties of Siberian anthrax with these plasmids). Other researchers observed a strain of Bacillus sp. in frozen ground samples dated 3 million years (21).

Strengths, weaknesses, opportunities, and threats analysis in the Archangelsk region of the Russian European North showed that the influence of global warming on the cryolite zone would be insignificant provided that the rates of warming are small enough. However, higher rates of global warming could bring about destructive cryogenic processes (22). Mining, construction, or agricultural development of previously virgin areas around cattle burial grounds may result in infiltration of disease vectors in the organs of people or animals. Consequently, a new natural locus of infection may emerge. The risk of infection is usually greater during dry years when the layer of soil in the cattle grazing areas weathers out and the spores of disease vectors can penetrate into the organs of domestic animals (23). Today, there are 1.2 million domestic reindeer in the Russian North, or 62% of their global population, and about one million wild reindeer.

The objective of this research was to estimate the temperature trends near the burial grounds of cattle that died from anthrax in Yakutia. The territory of Yakutia was chosen for this project because of the greatest number of such sites there, compared to the other northern territories of the Russian Federation.

Materials and methods

Due to the very extensive territory of Yakutia (3,083,000 km²) it is hardly possible to estimate permafrost temperatures at all of its 200 cattle burial grounds, especially because most grounds are situated in very remote and hard-to-reach places. More than 40% of the Yakutia territory is situated above the Polar circle. We therefore used the data of weather stations located in the same administrative districts as the burial grounds to estimate the trends in local air temperatures. The geographical coordinates (latitude, longitude, and altitude) and international identification indexes of all the Yakutia weather stations are listed at the website of Russian Meteorological service (www.meteo.ru); their locations are available on the interactive map at http://www.3planeta.com/googlemaps/karty-google-maps.html. We retrieved the daily temperature data for these weather stations from the US National Climatic Data Centre website and selected the years 1961–2010 as the study period. The NCDC website maintains the most comprehensive archive of meteorological data collected all over the world up-to-date. The analysis of available archive data showed that only 17 out of the 26 selected district weather stations reported their daily temperature data for all years between 1961 and 2010, whereas the data for the remaining nine administrative districts were either incomplete or absent.

Regional models of climate change in Yakutia have been developed only at a very broad geographic scale. There are only two such models: one all territories to the north of 65°N and the other covers all territories to the south of 65°N. The baseline period for both models is
1951–1990. The first model reports the following changes in annual average temperatures relative to the baseline: 0.2°C for 1971–1980; 0.8°C for 1981–1990; and 0.1°C for 1991–2000. The second model reports the following temperature increments: 0.12°C for 1971–1980; 1.6°C for 1981–1990; and 0.3°C for 1991–2000 ([24], p. 14). Such aggregated information was not sufficient to estimate the temperature trends in individual administrative districts. For this purpose, we used the records of daily temperatures for those 17 districts where such data were available. Even these datasets contained several periods of missing data and these were dealt with in the following way. If, for any given year, more than 15% of daily data were missing, we excluded this year from the analysis. If one month of daily data were missing, we used daily temperatures during the same month of the preceding year and calculated the annual average temperature using these ‘proxy’ data. Then, the time series of annual average temperatures between 1961 and 2010 were tested for a linear trend using least squares method. Significance of regression coefficients was measured by Fisher’s F-test. The calculations were performed with STATISTICA 6 software.

Results

The territory of Yakutia can be subdivided into four climate-geographic zones: the west part from the Laptev Sea to the south boundaries of the republic; the central plains part; the northeast part including the Arctic tundra and Novosibirsk islands; and the south highlands part (www.atlas-yakutia.ru). The survey of cattle burial sites showed that most of them were located in the western part (112 sites) and in the central plains part (112 sites), whereas the smallest numbers (43 sites) were located in the eastern part which is mostly occupied by mountains (Fig. 1).

The observed trends in the average annual temperatures in different parts of Yakutia between 1961–2010 are summarized in Table 1. This table contains only those administrative districts where sufficient meteorological information was available. The lowest air temperatures are typical for the eastern part, where the number of cattle burial grounds is the smallest. Statistically significant linear temperature trends were obtained for the eight administrative districts with the highest annual average temperatures. We calculated the change in the mean July temperatures between the ‘historic’ period 1961–1985 and the ‘current’ period 1986–2010. The smallest change was observed in Viluisky district, \( \Delta T = 0.6°C \) (\( T_{\text{historic}} = 17.9°C \) and \( T_{\text{current}} = 18.5°C \)). The greatest change was observed in Churapchinsky district, \( \Delta T = 1.0°C \) (\( T_{\text{historic}} = 17.9°C \) and \( T_{\text{current}} = 18.9°C \)). In Yakutsky district, the change between the mean July temperatures was \( \Delta T = 0.9°C \) (\( T_{\text{historic}} = 18.4°C \) and \( T_{\text{current}} = 19.3°C \)).

It was interesting to observe that the annual warming rate in Viluisky district was also minimal among all studied districts (0.02°C/year), while the annual warming rate in Churapchinsky district was maximal (0.04°C/year).

Another characteristic of climate warming was the relative increase in the number of ‘very hot’ days defined as the days with average daily temperature above the respective long-term average for this date, calculated over the past 50 years. The proportions of such days (\( N \)) were calculated for the ‘historic’ and the ‘current periods’: \( N_{\text{historic}} = 34.5% \) and \( N_{\text{current}} = 52% \) in Viluisky district; \( N_{\text{historic}} = 39.1% \) and \( N_{\text{current}} = 56% \) in Yakutsky district; \( N_{\text{historic}} = 38.9% \) and \( N_{\text{current}} = 52% \) in Churapchinsky district. Average daily temperatures in July 2010 were higher than the long-term average temperature of July during all 31 days of this month.

The ranges of annual average temperatures observed in different parts of Yakutia are shown in Fig. 2.

The most pronounced temperature trend was observed in the administrative districts around Yakutsk city (Fig. 3). There are more than 50 cattle burial grounds in these districts.

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**Fig. 1.** Geographic distribution of burial grounds of cattle that died (+) from anthrax in Yakutia.
Table 1. Descriptive statistics of annual and July average temperatures in 1961–2010 and linear trends in annual average for selected administrative districts of Yakutia with the greatest numbers of anthrax cattle burial grounds

<table>
<thead>
<tr>
<th>Administrative district (number of cattle burial grounds)</th>
<th>Annual average</th>
<th>July average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (°C)</td>
<td>Min (°C)</td>
</tr>
<tr>
<td>West Yakutia (112), including</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Viluisky (13) + Verhneviluisky (10)</td>
<td>−8.6</td>
<td>−11.0</td>
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<td>Bulunsky (1)</td>
<td>−13.0</td>
<td>−17.8</td>
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<tr>
<td>Nurbinsky (17)</td>
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<td>−10.9</td>
</tr>
<tr>
<td>Suntarsky (6)</td>
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<td>−10.2</td>
</tr>
<tr>
<td>Zhigansky (6)</td>
<td>−11.2</td>
<td>−13.7</td>
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<td>Mirminsky (29)</td>
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<tr>
<td>Olekminsky (20)</td>
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<td>Oleneksky (10)</td>
<td>−11.6</td>
<td>−14.3</td>
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<tr>
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<td></td>
</tr>
<tr>
<td>Ust-Maisky (2)</td>
<td>−8.7</td>
<td>−11.5</td>
</tr>
<tr>
<td>Khangalassky (8)</td>
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<td>−10.0</td>
</tr>
<tr>
<td>Yakutsk (7) + Namsky (13) + Ust-Aldansky (20) + Gorny (17)</td>
<td>−9.3</td>
<td>−12.3</td>
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<tr>
<td>East Yakutia (43) including</td>
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<td></td>
</tr>
<tr>
<td>Verkhoyansky (4)</td>
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<td>−17.4</td>
</tr>
<tr>
<td>Omyakonksy (10)</td>
<td>−15.5</td>
<td>−19.0</td>
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</tbody>
</table>

*p < 0.05; **p < 0.01.

Fig. 2. The ranges of annual average temperatures observed in different parts of Yakutia.
Discussion
Statistical analysis confirmed a significant 0.1% level positive trend in the annual average temperatures in Yakutsk. Similar results have been obtained earlier (24): climate warming is more pronounced in Central and South Yakutia than in North Yakutia. The districts with the greatest increments of annual average temperatures also reported the highest numbers of outbreaks of anthrax: between four and 11 cases during the last 80 years. According to veterinary experts, these districts present the greatest risks of anthrax (14). From an epidemiology standpoint, thorough monitoring of anthrax cattle burial grounds is recommended for the entire territory of Yakutia, not just for several selected parts. This monitoring should include regular surveys of cattle burial sites, checks of fences around them, inspections of land-use permits, and other documentation, in addition to detailed measurements of permafrost parameters around such sites. The trends in permafrost temperatures may vary greatly even within a single administrative district (24). Unfortunately, the authors could not find any information about the current condition of Siberian anthrax cattle burial sites, cropping out the remains or soil erosion. The authors recommend thorough monitoring of activity of airborne anthrax both in the northern and southern parts of Yakutia, especially in light of the findings obtained in Central Asia (Kazakhstan), where geographic distribution of \textit{B. anthracis} was studied (25).

Conclusions
More than 200 locations in Yakutia have previously reported outbreaks of anthrax among people. The same locations have burial grounds of cattle that have died from anthrax. Statistically significant positive trends in the annual average temperatures were established in eight out of 17 administrative districts of Yakutia for which sufficient meteorological data were available. These eight districts should be carefully monitored in the first place, but all regions where the outbreaks of Siberian anthrax took place in the past deserves equal attention from epidemiologists.

Gradual phase out of these burial grounds should use modern technologies of utilization of cattle remains. Unfortunately, this is an extremely time-consuming and resource-consuming activity. It is quite important, therefore, to estimate the threshold temperatures above which depreservation of the frozen remains becomes significant. Temperature thresholds of permafrost degradation are estimated on the basis of geomorphological indicators (segregated frost heave mound – palsa), but they provide
only indirect information about the epidemiologic situation. Detailed field surveys on the state of cattle burial grounds and the measurements of air and permafrost temperatures are needed for objective assessment of the epidemiologic threat. Besides, public health authorities should be permanently on the alert with regard to anthrax. Massive vaccination of domestic animals has proven effective to reduce the rates of this disease among both domestic animals and people living in the Russian Arctic.

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Thawing of permafrost may disturb historic cattle burial grounds
The impact of climate change on the expansion of *Ixodes persulcatus* habitat and the incidence of tick-borne encephalitis in the north of European Russia

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**Background:** The increase in tick-borne encephalitis (TBE) incidence is observed in recent decades in a number of subarctic countries. The reasons of it are widely discussed in scientific publications. The objective of this study was to understand if the climate change in Arkhangelsk Oblast (AO) situated in the north of European subarctic zone of Russia has real impact on the northward expansion of Ixodid ticks and stipulates the increase in TBE incidence.

**Methods:** This study analyzes: TBE incidence in AO and throughout Russia, the results of Ixodid ticks collecting in a number of sites in AO, and TBE virus prevalence in those ticks, the data on tick bite incidence in AO, and meteorological data on AO mean annual air temperatures and precipitations.

**Results:** It is established that in recent years TBE incidence in AO tended to increase contrary to its apparent decrease nationwide. In last 10 years, there was nearly 50-fold rise in TBE incidence in AO when compared with 1980–1989. Probably, the increase both in mean annual air temperatures and temperatures during tick active season resulted in the northward expansion of *Ixodes Persulcatus*, main TBE virus vector. The Ixodid ticks expansion is confirmed both by the results of ticks flagging from the surface vegetation and by the tick bite incidence in the population of AO locations earlier free from ticks. Our mathematical (correlation and regression) analysis of available data revealed a distinct correlation between TBE incidence and the growth of mean annual air temperatures in AO in 1990–2009.

**Conclusion:** Not ruling out other factors, we conclude that climate change contributed much to the TBE incidence increase in AO.

Keywords: climate change; tick-borne encephalitis; *Ixodes persulcatus*; subarctic zone

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Tick-borne encephalitis (TBE) is an increasing burden for health protection in many Arctic countries (1–3). The fatality rate of its focal forms exceeds 60%, e.g. in the Far East of Russia, (4). In most of 16 European countries where TBE is being monitored, an increase in its incidence was reported during recent decades notwithstanding the differences between criteria and standards used by different surveillance systems (5).

The source of this trend is still not understood although some factors that may influence it have been discussed already (6). Climate change is one of the factors that may alter the habitat of *Ixodes* ticks, the principal vector of TBE virus (7, 8).
We have investigated the hypothesis within the regions crossed by the limits of *Ixodes* ticks habitat and where both climate and TBE incidence underwent considerable recent changes. We considered Arkhangelsk Oblast (AO) in the subarctic zone of European Russia to determine if the climatic factors indeed influenced the distribution of *Ixodes persulcatus* and TBE incidence in AO.

**Materials and methods**

**Geographical data**
AO is situated in the north of Europe, within the subarctic zone of Russia and includes 306,300 km² (excluding Nenets Autonomous Area and polar islands). AO consists of 19 administrative districts; for the purpose of this study they were divided into three groups according to physiographic regions: northern (A) – north taiga, central (B) – middle taiga, and southern (C) – middle taiga, south taiga border (see Fig. 1).

The AO forested area did not undergo considerable change in the past 20 years: it was 230,600 km² in 1990 and 218,310 km² in 2009.

**Environmental and epidemiological data**
Environmental and epidemiological data were provided by Rospotrebnadzor (Federal Service on Customers’ Rights Protection and Human Well-being Surveillance) and Center for Hygiene and Epidemiology for Arkhangelsk Oblast and included the following information:

- Tick-borne encephalitis incidence rates (annual number of TBE cases per 100,000 of population) in 1980–2009 in AO, and in Russia as a whole.

In Russia, Rospotrebnadzor is notified about each case of TBE. In the TBE suspected cases, medical practitioners always provide the detailed information on the tick bite (place, time, etc.), on visiting of potentially dangerous places, on raw milk consumption, etc.

![Fig. 1. Arkhangelsk Oblast location and AO districts by groups. Districts where ticks were collected are in bold font (Designed in ArcGIS 9.3).](image-url)
TBE virus prevalence in ticks collected in 1996 identified by standard microscopic methods. The unit of measurement was tick/km. Ticks were enumerated and divided by the length of flagged road. Therefore, the unit of measurement was tick/km. Ticks were enumerated and identified by standard microscopic methods.


Unfed adult ticks were collected by flagging a 60 × 100 cm waffle cloth through vegetation every month during tick activity period (April–August) at seven different sites, one each in Kotlassky (61°10’N, 46°22’E), Krasnобorskys (61°18’N, 46°02’E), Velsky (61°02’N, 42°01’E), Verkhnе-Toemsky (62°08’N, 45°04’E), Vilegodysk (61°00’N, 47°58’E), Onezhsky (63°52’N, 38°10’E), and Plesetsky (62°45’N, 40°19’E) districts of AO (see Fig. 1). The tick abundance was the number of collected ticks divided by the length of flagged road. Therefore, the unit of measurement was tick/km. Ticks were enumerated and identified by standard microscopic methods.


A total of 1681 questing adult ticks were collected in Kotlassky district. The TBE virus antigens were detected by ELISA using D-1154 test kits (JSC «Vector-Best», Novosibirsk, Russia) and following the enclosed manufacturer’s recommendations. The results of HI assay and ELISA coincide (9).


In the Russian Federation, mandatory reporting of all cases of tick bites is done by all health care providers to the local Rospotrebнadзор; the report involves the date, place, and circumstances of the incident. Here, we use ‘tick-bite incidence rate’ (BIR) that is the number of tick bites per 100,000 of local inhabitants during the year, and ‘decade-averaged tick-bite incidence rate’ (BIR10) that is the BIR averaged over a 10-year period.

**Meteorological data**

Meteorological data (temperatures in 1960–2009 and precipitations in 1970–2008, AO) collected by 28 meteorological stations in AO (see Table 1) were obtained from the National Climatic Data Center (NCDC) (http://www.ncdc.noaa.gov/oa/ncdc.html).

The product ‘Surface Data: Daily – Global Summary of the Day (GSOD)’ was used for meteorological data extraction. Meteorological information represented in this product is daily mean, minimum, maximum air temperature, air humidity, precipitations, wind speed, and other data on the certain meteorological station.

Our own software was designed to extract air temperature and precipitations from raw data. On the first step, monthly mean air temperature was calculated for the selected meteorological station, and then annual mean air temperature was summarized. Annual mean air temperature for northern, central, southern groups of districts, and whole AO was estimated as a result of primary data processing.

**Population data**

The AO population decreased from about 1.6 million in 1990 to 1.2 million on January 1, 2010 mainly due to exodus by migration (Table 2). Census data on the AO population were obtained from Federal State Statistics Service (ROSSTAT) site (http://www.gks.ru/).

**Statistic analysis**

Statistic analyses of mean values and standard deviations of annual air temperatures, precipitations, TBE incidence rates, and BIR were conducted to estimate the significance of climate changes. Pearson correlation analysis and regression analysis were done to assess correlations between temperature, TBE incidence rate, and BIR.

The adequate development of *I. persulcatus* during its activity season requires sufficient warmth that may be represented by the sum of effective temperatures according to the formula as follows:

\[
S = \sum_{n=1}^{365} ET_n
\]

Here:

- \(S\) – sum of annual effective temperatures for \(t_{\text{min}}\); \(ET_n = (t_n - t_{\text{min}})\) – effective temperature on day ‘\(n\’; \(t_{\text{min}}\) – mean temperature limit, °C (+10°C for *I. persulcatus*); \(t_n\) – mean temperature on day ‘\(n\’; °C (only \(t_n > t_{\text{min}}\) are taken into account); daily mean temperature was extracted from raw NCDC meteorological data (http://www.ncdc.noaa.gov/oa/ncdc.html); and \(n\) – number of days.

**Results**

**Ixodid ticks habitat and active period**

In 1992—2009, questing adult *I. persulcatus* ticks were regularly flagged from surface vegetation in seven districts of AO (see Fig. 1), one site in each district; however, only in Kotlassky district (7, southern group), we had every year findings. In this district, the tick abundance varied considerably in different years. Typically, the findings began in April (11.9% of mean

In the six other districts [1, 2, 3, 8, 13, and 15] in 1992–1995, flagging covered 89 km totally but was fruitless. In districts 1, 2, 3, 8 for the first time, ticks were collected in 1996, in district 13 it occurred in 2000, and in district 15 it happened in 2002.

In district 15 (central group), no ticks were found between 1991 and 2001, when 30.7 km of road were flagged. The first ticks were collected in 2002, and then the number of ticks collected annually increased steadily during 2006–2009 seasons, when 20.0 km of road were flagged. Respectively, during the peak of tick activity (in June), 0.8 tick/km of road was collected in 2006, 1.4 tick/km in 2007, 4.3 tick/km of road in 2008, and 4.7 tick/km of road in 2009. An average, 87% of ticks was collected in May and June of each year.

*Ixodes persulcatus* P. Sch. represented 99.2% of all collected Ixodid ticks, whereas *Ixodes ricinus* represented 0.8%.

### Table 1. The list of meteorological stations in AO

<table>
<thead>
<tr>
<th>Station name</th>
<th>World meteorological organization number</th>
<th>N, dd. dd</th>
<th>E, dd. dd</th>
<th>Elevation, m</th>
<th>AO districts group</th>
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<td>Arhangelsk</td>
<td>225500</td>
<td>64.55</td>
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<td>Dvinskij Bereznik</td>
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<td>46.71</td>
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<td>Lesukonskoe</td>
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<td>40.2</td>
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### Table 2. Census data on the AO population (6)

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<th>Year</th>
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<td>2003</td>
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<td>1999</td>
<td>1,402,242</td>
<td>2009</td>
<td>1,258,242</td>
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</table>
Geographical and seasonal distribution of AO inhabitants bitten by ticks

In AO, the average annual number of tick-bitten inhabitants was 284 in 1980–1989, 1,462 in 1990–1999, and 3,976 in 2000–2009. Respectively, the number of TBE cases increased 40-fold in 30 years: from 162 in 1980 to 6,450 in 2009.

After year 2000, tick bites were reported not only in southern but also in central and even in northern AO districts. In northern districts 14 and 16, BIR reached 10–100, whereas sporadic cases were reported in districts 10, 11.

Therefore, BIR was 18 in 1980–1989, and 309 in 2000–2009, i.e. there was 17-fold increase in the index between two decades compared.

BIR was zero or negligible (<10) in 1980–1989 in four northern and three central districts, in 1990–1999 it was so in four northern districts, but only in two northern districts in 2000–2009.

In 1990–1999 and in 2000–2009, the increase in BIR was not uniform in all areas: increased 2.5-fold in the southern group, whereas 4.8-fold increase was recorded in the central group, and 14-fold increase in the northern group of AO districts.

BIR for the period between 1980 and 2009 is shown in Fig. 2 and Table 3.

The length of tick bite reporting period in 2000–2009 expanded in comparison with 1980–1989 in 20-fold in the northern group, twofold in the central group, and 1.5-fold in the southern group (Table 3).

| Table 3. BIR and the length of tick bite reporting period for groups of AO districts |
|----------------|----------------|----------------|----------------|----------------|
|                | BIR            |                 | Length of tick-bite reporting period, month |
|                | Northern       | Central         | Southern       |
|----------------|----------------|----------------|----------------|----------------|
| 1980–1989      | 0.1            | 36.2            | 44.8           |
| 1990–1999      | 2.3            | 115.1           | 292.3          |
| 2000–2009      | 28.1           | 557.0           | 732.9          |
|                | 0.1            | 1.9             | 3.2            |
|                | 0.7            | 2.5             | 3.3            |
|                | 2.0            | 3.8             | 4.8            |
In 2001–2009, AO inhabitants were bitten by ticks during their vacation or recreational outdoor activities (66.9%), in their garden of summer cottages (20.6%), during their business activities (8.1%), or during land reclamation and development (4.4%).

**TBE virus prevalence in ticks**
In average, 1.6% of questing ticks collected from plants were infected with TBE virus. The maximum TBE virus prevalence (4.5%) was recorded in 1996 when 134 ticks were tested, and in 2002 (3.9%) when 78 ticks were tested. Thus, there is no uptrend in TBE virus prevalence in ticks.

**TBE incidence rate**
In 1980–2009, 920 TBE cases were reported officially in AO. Their temporal distribution evidences an increase in number of cases, despite continuous decrease in AO population. Thus, within the first decade under consideration (1980–1989), only 16 cases were diagnosed, and in some years (e.g. 1981 and 1982) there were none. Within the second decade (1990–1999), there were 207 cases, and 697 cases were reported during the third decade (2000–2009).

TBE mean annual incidence rate was 0.1 in 1980–1989 and 5.4 in 2000–2009. The maximum annual TBE incidence rate of 9.9 was recorded in 2009.

When TBE incidence in AO was compared with the national incidence of TBE in Russia, the following trends were observed.

The incidence of TBE was increasing both in Russia and in AO during 1980–1999; national TBE incidence was significantly higher compared to that observed in AO.

The national TBE incidence plummeted between 2000 and 2008, whereas in AO the TBE incidence continued to increase during the same period. In 2009, TBE incidence in AO was three times higher than that nationally reported in Russia as a whole (Fig. 3 and Table 4).

An increasing TBE incidence in AO parallels the change in geographical distribution of TBE cases. In 1980s, TBE cases occurred only in the southern group districts, but after 2000, cases occurred nearly all over AO territory. The most significant growth in TBE incidence was observed in the central group of districts, where it was <0.1 in 1980–1989, whereas in 2000–2009, it peaked to 1–10 or even 10–100 per 100,000 of inhabitants (Fig. 2).

It is likely that in most cases, patients acquired TBE virus through a tick bite, because a strong correlation was established between BIR and TBE incidence in AO (correlation coefficient is 0.97; p < 0.0001). According to the epidemiological survey data, the prevalence of alimentary acquired infection was small and calculated to be 0% in 1980–1990, 5.2% in 1991–2000, and 1.3% in 2001–2009.

**Climate change and CBE incidence**
In AO, mean annual air temperature between 1960 and 1989 varied from −1.5 to +2.6°C, being +0.7°C in average.

In 1990s, a gradual ascent of AO annual mean temperature started that peaked at +3°C in 2007. In 2000–2009, the mean annual air temperature was +2.0°C, which was +1.3°C above the level of 1960–1989, and TBE incidence increased synchronously with temperature (Fig. 4).

In the southern group of AO districts within the same period, mean annual air temperatures increased from +1.7°C (in 1960–1989) to +3.0°C (in 2000–2009). During 1980s in AO, the TBE incidence was stable.

**Table 4. Comparison of mean for decades TBE incidence rate in Russia and in AO**

<table>
<thead>
<tr>
<th>Time period, years</th>
<th>Russia Mean (standard deviation)</th>
<th>AO Mean (standard deviation)</th>
<th>p value for mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980–1999</td>
<td>3.34 (1.72)</td>
<td>0.73 (0.93)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>2000–2009</td>
<td>3.03 (0.85)</td>
<td>5.76 (2.47)</td>
<td>0.0069</td>
</tr>
</tbody>
</table>

Fig. 3. TBE incidence in AO and in Russia as a whole in 1980–2009.

Table 4. Comparison of mean for decades TBE incidence rate in Russia and in AO.
and negligible but in early 1990s it began to grow and in 2009 it reached 27 per 100,000 of inhabitants (Fig. 5).

Within the same period in the central group of AO districts, mean annual temperature rose from $\pm 1.1$ to $\pm 2.1$°C (with a slightly cooler period in 1970s). Here, the steady growth in TBE incidence began at the end of 1990s; and in 2009 the local TBE incidence exceeded 11 per 100,000 of population (Fig. 5).

In the northern group of AO districts, mean annual air temperature was $\pm 0.2$°C in 1960–1990, and increased to $\pm 1.2$°C in 2000–2009. Some increase in TBE incidence was observed only after 2005, and still did not exceed two per 100,000 of population (Fig. 5).

![Fig. 4. Mean annual temperatures (1960–2009) and TBE incidence rates in AO (1980–2009). Note: AO temperature data for 1971 and 1972 are not available.](image1)

![Fig. 5. Mean annual temperatures (1960–2009) and TBE incidence rates (1980–2009) in the (A) southern; (B) central; (C) northern group of AO districts. Note: AO temperature data for 1971 and 1972 are not available.](image2)
During 1980–1990 in AO, the TBE incidence was stable and low with mean values (standard deviations) as follows: 0.03 (0.11) in the northern districts; 0.25 (0.33) in central districts, and 0.19 (0.24) in southern districts. After 2000, the TBE incidence increased dramatically, and in 2009 it reached 1.65 in the north, 11.38 in the centre, and 27.37 in the south of AO.

The correlation analysis of AO mean annual air temperatures and TBE incidence in 1990–2009 resulted in Table 5. The regression analysis was performed to assess the correlation between the temperature and TBE incidence in AO. It was estimated that TBE incidence was <0.1 at mean annual temperature below +2°C; therefore, in our statistic calculations, those lower temperatures were excluded. The maximum correlation coefficient $R = 0.77$ (0.74–0.80, $p = 0.0013$) was obtained when this exclusion criteria applied (Fig. 6).

It is significant with probability 99.9%.

The complete development cycle of *I. persulcatus* requires that the sum of annual effective temperatures was at least 1,400°C within the period with daily average temperatures exceeding +10°C (10).

The calculation of the sums of annual effective temperatures averaged over the corresponding decades (see Fig. 7) has shown that heat provision in all AO districts during the tick active season increased significantly in 2000–2009 compared with 1980–1989. Its increase was the most remarkable in central and southern districts of AO.

Therefore, the corresponding sums of annual effective temperatures in average were very close to the critical level required for *I. persulcatus* development both in southern and central districts in 1980–1999, and they significantly exceeded temperature requirements in 2000–2009.

The sum of annual effective temperatures was much below 1,400°C during the same periods in the northern districts. It was only during the recent 10 years that the critical level was reached in AO.

In AO, the period of effective temperatures increased certainly: from 82 (north), 102 (centre), and 108 (south) in 1960–1969 to 87, 112, and 121 accordingly in 2000–2009. It means that within 50 years, the increment of favorable period was 5 days in the north, 10 days in the centre, and 13 days in the south of AO.

Total atmospheric precipitations in AO increased not much: from 548 mm in 1970–1980 to 641 mm in 2001–2008. Such growth in total atmospheric precipitations is not significant for ticks’ ecology, as AO has humid climate where average annual precipitation exceeds average annual evapotranspiration.

### Discussion

The climate change may impact directly on Ixodid ticks habitats because both temperature and humidity are of great importance for their life cycle (8, 10).

In 1960s, the northern distribution of *I. persulcatus* in AO was limited by 62nd parallel, and those ticks were found a little further northward only along Northern Dvina River (11). In 2000s, *I. persulcatus* started to be found every year in the central districts of AO; and the findings tended to increase. The tick invasion into AO central districts became possible due to considerable increase of both mean annual air temperatures and number of days with ‘effective’ temperatures (exceeding 10°C); the corresponding sums of effective temperatures increased as well.

Currently, the centre of AO has adequate temperature conditions for the establishment of *I. Persulcatus*, whereas the temperature regimen at AO northern districts is yet not optimal for the life cycle of *I. persulcatus*.

It should be mentioned that moisture regimen in AO was adequate and even favorable for *I. persulcatus* life cycle at least within recent 30 years.

The tick encroachment on the territory of AO central and northern districts is fortified by BIR figures estimated over last 30 years. The data on tick bite incidence are rarely found in international publications [see, however, (12, 13)], as, in contrast to Russia, they do not trace it in most of other countries. Of course, BIR figures do not give the real number of tick bite victims, because considerable portion of tick-bitten population never seeks medical care. However, the many year surveillance of BIR in AO contributes significantly to our knowledge of the changes in Ixodid ticks habitats. Therefore, in 1980—1989, BIR was low both in the southern and central districts, and <0.1 in the northern zone. In contrast to that in 2000—2009, BIR was very high in the southern, and rather high in all central and even in some northern districts. Even having in mind that BIR uptrend to some extent may be attributed to the increased TBE awareness of AO population (and throughout Russia), and hence more frequent seeking of medical care, we cannot ignore considerable difference in BIR increments in different AO zones. We believe that during the 1980s, many AO districts were entirely free of *I. persulcatus*, and hence

<table>
<thead>
<tr>
<th>Territory</th>
<th>Correlation coefficient</th>
<th>Confidence interval</th>
<th>$p$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>AO</td>
<td>0.50</td>
<td>0.36 - 0.64</td>
<td>0.0248</td>
</tr>
<tr>
<td>Northern districts</td>
<td>0.50</td>
<td>0.36 - 0.64</td>
<td>0.0248</td>
</tr>
<tr>
<td>Central districts</td>
<td>0.71</td>
<td>0.62 - 0.81</td>
<td>0.0005</td>
</tr>
<tr>
<td>Southern districts</td>
<td>0.45</td>
<td>0.30 - 0.60</td>
<td>0.0465</td>
</tr>
</tbody>
</table>
nobody suffered of tick bites. Subsequent invasion of Ixodid ticks resulted in significant BIR increase.

It was also established that the average tick aggression period expanded with the mean air temperatures in AO. The similar situation was reported in Komi Republic adjacent to AO; in its northern districts, there was a dramatic growth both of BIR and TBE incidence after 2000 as to compare with the earlier period (14).

Those data on AO and Komi Republic support the assessments of the changes in I. persulcatus habitats based on simple empirical models that relate temperature regimen and precipitations with the establishment of Ixodid ticks habitats (15).

Northward invasion of I. ricinus related to the temperature increase was reported in Sweden. Several factors were responsible for higher TBE incidence: the growth of tick abundance, their longer life cycle, more frequent visiting of TBE-endemic forests by humans, and the growth in number of animal hosts (16, 17). A similar picture was observed in Czech Republic, where TBE virus-infected I. ricinus, started to be found much higher in mountains than in earlier period, and TBE in humans started to be registered correspondingly (18, 19). It should be noted that the aforementioned studies were inspired by TBE incidence increase due to I. ricinus bites.

The data from Estonia provide more evidence that the warming climate promotes the growth of vector population and prolongs the active period of the vectors. It provides favorable conditions for TBE virus circulation in their natural foci (20).

The present study differs from those cited earlier, because it was carried out in a region where Ixodes persulcatus dominates absolutely. Its biological properties are quite different from those of I. ricinus, because it is much more cold-resistant tick and hence its habitat may expand much further northward. In general, the TBE virus load in I. persulcatus exceeds significantly that in I. ricinus (10).

The vast majority of TBE cases in AO occurred due to tick bites, consequently considerable increase in TBE incidence might result from the expansion of I. persulcatus habitat. Strong correlation between BIR and TBE incidence was established in AO.

TBE virus prevalence in I. persulcatus should not be considered as a significant factor in AO as it remained actually unchanged within the period under consideration.


In the central group of AO districts, very high correlation coefficients between TBE incidence and mean annual air temperature are descriptive of strong and synchronous variations of air temperatures and TBE incidence.

The similar uptrend in TBE incidence was observed in Komi Republic that is an eastern neighbor of AO.

The climate warming may have impact on human behavior as it allows longer and more comfortable stay under the open sky. Variation in human activities may impact on both the enzootic cycles and the degree of human exposure to those cycles also providing explanations for TBE upsurges, e.g. in some European countries (21).

The vaccination against TBE is still not sufficient in Russia (22) (AO including); however, the number of vaccinated AO inhabitants increased from 204 in 1990 to 20,987 in 2009. It means that TBE incidence grew in spite of vaccination improvements (data by Rospotrebnadzor in AO). The effect of some other factors influencing TBE incidence in AO cannot be
ruled out, and a separate publication should be devoted to them. 

The northward expansion of Ixodid ticks necessitates the updating of preventive measures against tick-borne diseases. Earlier, it was already shown that taiga ticks collected in AO were commonly infected with the pathogens of tick-borne borreliosis (23) and by *Anaplasma* and *Ehrlichia* species (24). Those findings advocate the needs for further development of improved and sophisticated laboratory diagnosis tools, and, for continuous education of population about proper attitudes and prevention of tick bites and tick-borne infections, including TBE.

**Conclusions**

1. The pronounced northward expansion of *I. persulcatus* had occurred during 1980–2009 in AO, in the north of European Russia.
2. The expansion of ticks correlated with considerable increase of both the mean annual air temperatures and the sums of effective temperatures that determine compatible temperature conditions for *I. persulcatus* establishment at new territories.
3. The obvious uptrend in TBE incidence in AO is related considerably to the expansion of *I. persulcatus* habitat. The territory where TBE cases are reported enlarged significantly. Climate changes contribute much to the TBE incidence increase.

**Acknowledgements**

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**References**


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Indications of decreasing human PTS concentrations in North West Russia

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Background: The Russian Arctic covers an enormous landmass with diverse environments. It inhabits more than 20 different ethnic groups, all of them with various living conditions and food traditions. Indigenous populations with a traditional way of living are exposed to a large number of anthropogenic pollutants, such as persistent organic pollutants (POPs) and toxic metals, mainly through the diet. Human monitoring of persistent organic pollutants (POPs) and heavy metals in the Russian Arctic has only been performed on irregular intervals over the past 15 years, thus, there is still a lack of baseline data from many ethnic groups and geographical regions. The aim of the current study was to investigate concentrations of POPs and toxic metals in three groups of indigenous people from the Russian Arctic. Plasma concentrations of POPs were measured in one of the locations (Nelmin-Nos) in 2001–2003 which gave the unique opportunity to compare concentrations over time in a small Russian Arctic community.

Methods: During 2009 and early 2010, 209 blood samples were collected from three different study sites in North West Russia; Nelmin-Nos, Izhma and Usinsk. The three study sites are geographically separated and the inhabitants are expected to have different dietary habits and living conditions. All blood samples were analyzed for POPs and toxic metals.

Results: PCB 153 was present in highest concentrations of the 18 PCBs analyzed. p, p’-DDE and HCB were the two most dominating OC pesticides. Males had higher concentrations of PCB 138, 153 and 180 than women and age was a significant predictor of PCB 153, 180, HCB and p, p’-DDD. Males from Izhma had significantly higher concentrations of HCB than males from the other study sites and women from Usinsk had significantly higher concentrations of p, p’-DDE. Parity was a significant predictor of p, p’-DDE. Hg and Pb concentrations increased with increasing age and males had significantly higher concentrations of Pb than women. The study group from Izhma had significantly higher concentrations of Cd when controlling for age and gender and the study group from Usinsk had higher concentrations of Se than the others. Compared to the results from Nelmin-Nos in 2001–2003, a clear decrease in p, p’-DDE concentrations for both women and men was observed.

Conclusions: The current study indicates a significant reduction of several PTSs in human blood samples from North West Russia over the past 10 years.

Keywords: PTS; human blood; decreasing levels; North West Russia

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The Russian Arctic covers an enormous landmass with diverse environments. It is inhabited by more than 20 different ethnic groups, all of them with various living conditions and food traditions (1). It is described that indigenous people with a traditional way of living are exposed to a large number of anthropogenic pollutants, such as persistent organic pollutants (POPs) and toxic metals, mainly through the diet (2-4).

Persistent organic pollutants refer to a large group of organic compounds that are highly lipophilic and persistent to degradation (2-4). Many of these compounds have been used in industrial applications (e.g. polychlorinated...
biphenyls (PCBs)) or as pesticides (e.g. dichlorodiphenyltrichloroethane (DDT) and hexachlorobenzene (HCB)). Due to their chemical properties, many POPs biomagnify in the food chain and high concentrations are therefore found in species at the top of the food web. Toxic metals, such as Lead (Pb) and Mercury (Hg), are naturally occurring substances. Through human activities, for example mining and the use of leaded gasoline, large amounts of these metals have been released into the environment where they bioaccumulate in organisms and biomagnify in food webs. As many indigenous people in the Russian Arctic live from subsistence hunting and fishing and sometime close to point sources, they are likely to be exposed to elevated concentrations of POPs and toxic metals. High concentrations of \( p,p'-\text{DDE} \) (metabolite of DDT; dichlorodiphenyl dichloroethylene) has, for example, been monitored in blood from people residing in Chukotka in eastern Russia and high levels of toxic metals, e.g. Pb, have been reported among several ethnic groups in Russia (1-4).

There are many potential effects of human exposure to persistent toxic substances (PTSs) e.g. endocrine disrupting effects, neurodevelopmental, and immunological effects (5-7). However, the evidence base is sometimes weak (8, 9). Recently, POP exposure was linked to the increasing incidence of cancer and diabetes (7-9). Accidental release of Hg, has shown that exposure to this metal has deleterious effects on human health (9). The effects of environmental pollutants on human health are, often subtle, long term, sometimes transgenerational, and difficult to measure even in long-term epidemiological studies in large populations. There is therefore a need for comprehensive research that monitors the concentration and distribution of toxic substances in different geographical regions in humans over time (4).

Human monitoring of POPs and heavy metals in the Russian Arctic has only been performed on irregular intervals over the past 15 years; thus, there is still a lack of baseline data from many ethnic groups and geographical regions (1-4). To be able to properly evaluate the health-related effects of contaminants, high-quality baseline data is crucial.

The aim of the current study was to investigate concentrations of POPs and toxic metals in three groups of indigenous people from the Russian Arctic. Plasma concentrations of POPs were measured in one of the locations (Nelmin-Nos) in 2001-2003 that gave the unique opportunity to compare concentrations over time in a small Russian arctic community (10, 11).

Materials and methods

Study participants and blood collection

During 2009 and early 2010, 209 blood samples were collected from three different study sites in North West Russia; Nelmin-Nos, Izhma, and Usinsk (Table 1). Nelmin-Nos is a community of about 800 inhabitants located in the Pechora River Basin in the Nenets Autonomous Okrug. The inhabitants of this area are Nenets, except 14 adult participants who are of Russian ethnicity. Izhma is a rural inland district in the Komi Republic. All of the participants from Izhma reported that they were Komi of ethnicity. People in this area are mainly reindeer herders. Fifty blood samples were also collected in the city of Usinsk (44,000 inhabitants) in the Komi Republic. Usinsk is the center for oil and gas production in the Komi Republic. Eighty-eight percent of the study participants from Usinsk reported that they were Komi of ethnicity.

The blood samples were collected from the participants at the same time as they took part in a general health examination. The study participants were invited to the health survey through advertisement in various public areas (medical center, shops, school, school canteen, day care center, museum, and public wash place). An informed consent was signed before inclusion, and the study was accepted by the ethical committees of the different regions.

Chemical analysis

Persistent organic pollutants

The blood samples were analyzed for POPs in the scientific production facility ‘Typhoon’ at the Center for Environmental Chemistry in Obninsk in Russia. The methods used were described in detail by Konoplev (11). In brief, all samples were spiked with mass-labeled internal standards (six PCBs and six pesticides) before extraction. One to four milliliters of serum was extracted using liquid–liquid extraction with 20–35 ml (depending on sample volume) of methyl tertiary butyl ether as solvent. The extraction procedure was repeated twice. The extracts were dried on anhydrous sodium sulphate and up-concentrated to 10 ml on a rotary evaporator. Lipids were removed using gel permeation chromatography with Bio Bead SX-3 as sorbent and a 1:1 mixture of hexane and dichloromethane (DCM) as solvent. After further volume reduction to 0.5 ml, the extracts were cleaned up on precleaned deactivated silica (3%) columns using hexane and DCM/hexane (1:1) as solvent.

Metals

The analyses of metals in full blood were also performed in the scientific production facility ‘Typhoon’ at the Center for Environmental Chemistry in Obninsk in Russia. Only samples from the Komi Republic were analyzed for metals due to limited sample volumes from Nelmin-Nos. The methods used have been described elsewhere (11). In brief, samples for Pb and cadmium (Cd) analysis were prepared using 0.1% triton X-100 and 2N nitric acid. The samples were analyzed with atomic
absorption spectrometry. In advance of the Hg analysis, full blood samples were prepared using 5% potassium permanganate and concentrated nitric and sulfuric acid (1:3). The mixture was heated at 60°C for 4 hours and analyzed with the ‘cold vapor’ technique on a spectrophotometer. Full blood samples for selenium analysis were prepared by adding ascorbic acid, 5% sodium molybdate (aq.), and a mixture of concentrated nitric acid and sulfuric acid (3:4). The solution was heated in 15 min at 120°C and afterwards to 160°C to complete decomposition. After cooling and filtration, 1% of 1,2 diamino-4 nitrobenzene was added. One hour later, 5-nitro-2,1,3-benzoselendiazol was extracted using chloroform. Selenium concentration was later analyzed by electrothermal atomic-absorption spectrometry.

**Determination of lipids**

The content of cholesterol, triglycerides, and phospholipids were determined enzymatically and total lipids were calculated according to the formula:

\[ TL = 1.677(TC - FC) + FC + TG + PL \]

TL, total lipids, TC, total cholesterol, FC, free cholesterol, TG, triglycerides, and PL, phospholipids, after Akins et al. (12).

**Quality control of chemical analysis**

The recovery of each analyte was calculated in spiked serum samples and varied between 65 and 110% for both the PCBs and the pesticides. Blank samples containing matrix and reference samples were analyzed for each batch of samples with successful results. The current laboratory also participates in the AMAP interlaboratory comparison program for POPs organized by Institut National de Santé Publique du Québec, Canada thrice each year. Results from the interlaboratory comparisons indicate that the uncertainties of the analysis are well within ±20% of the assigned values. The analytical QA/QC for the two time periods of analyses was identical, and both time windows performed very good in the AMAP QA/QC Ring Test (2, 4).

There were some analytical challenges linked to the analyses of POPs in the dataset. The samples from the Komi Republic were prepared using 3–5 ml of serum, whereas only 1 ml was used from the samples from Nelmin-Nos, due to limited serum volumes. Larger sample volumes result in lower limit of detections (LOD). To avoid systematic errors, the LODs for the smaller sample volumes from Nelmin-Nos were also applied to the data from the Komi Republic.

**Statistical analysis**

Statistical analysis was performed using the freely available software R, version 2.12.1 (http://cran.r-project.org), and the NADA package for R. Kaplan-Meier methods and ROS were used for finding central tendency for analytes with more than 10% non-detects (Table 2). All contaminant data were right skewed and log transformed by the natural logarithm before analyses in order to achieve normality. Significant predictors were evaluated by linear models controlling for potential confounding factors. Diagnostic plots of the residuals were evaluated to ensure that model assumptions were met. In order to avoid misclassification, statistical analyses were only performed on analytes with more than 60% detected (PCB 138, PCB 153, PCB 180, \( p,p\prime\)-DDE, and HCB).

**Results**

The detection frequencies and the method LOD in the dataset are reported in Table S1 in the supporting information. Blood concentrations of POPs and metals among the study participants are provided in Tables 2–4.

Of the 18 PCBs analyzed, PCB 153 was present in highest concentrations in samples from all three study sites, whereas \( p,p\prime\)-DDE and HCB were the two most dominating OC pesticides. The PCB pattern among men at all three study sites was as follows: PCB1 53 > PCB 180 > PCB 138 > PCB 118. For women, the PCB pattern varied between study site; Nelmin-Nos: PCB 153 > PCB 180 > PCB 118 > PCB 138, Izhma, and Usinsk; PCB 153 > PCB 118 > PCB 138 > PCB 180.

Males had significantly higher concentrations of PCB 138, 153, and 180 than women (\( p < 0.05 \)). Older people had also higher concentrations of PCB 153, 180, HCB and \( p,p\prime\)-DDE (\( p < 0.001 \)). When adjusting for age and gender, there was no difference in PCB 138, PCB 153, and PCB 180 concentrations between the three study locations; however, males from Izhma had significantly higher concentrations of HCB than the others (\( p = 0.003 \)). Among women, the participants from Usinsk had higher concentrations of \( p,p\prime\)-DDE when adjusting...
### Table 2. Concentrations of OCs (ng/g) lipid weight in women

<table>
<thead>
<tr>
<th>Concentration (ng/g) l.w</th>
<th>Nelmin-Nos ((n = 87))</th>
<th>Izhma ((n = 25))</th>
<th>Usinsk ((n = 25))</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCB 28/31 AM(min-max)</td>
<td>38 (&lt;LOD-396)</td>
<td>N/A</td>
<td>18 (&lt;LOD-45)</td>
</tr>
<tr>
<td>Median</td>
<td>16</td>
<td>N/A</td>
<td>12</td>
</tr>
<tr>
<td>PCB 52 AM(min-max)</td>
<td>38 (&lt;LOD-277)</td>
<td>14 (&lt;LOD-31)</td>
<td>25 (&lt;LOD-35)</td>
</tr>
<tr>
<td>Median</td>
<td>22</td>
<td>11</td>
<td>15</td>
</tr>
<tr>
<td>PCB 99 AM(min-max)</td>
<td>31 (&lt;LOD-304)</td>
<td>16 (&lt;LOD-56)</td>
<td>25 (&lt;LOD-35)</td>
</tr>
<tr>
<td>Median</td>
<td>20</td>
<td>9.4</td>
<td>25</td>
</tr>
<tr>
<td>PCB 101 AM(min-max)</td>
<td>35 (&lt;LOD-294)</td>
<td>22 (&lt;LOD-77)</td>
<td>29 (&lt;LOD-43)</td>
</tr>
<tr>
<td>Median</td>
<td>12</td>
<td>13</td>
<td>25</td>
</tr>
<tr>
<td>PCB 105 AM(min-max)</td>
<td>28 (&lt;LOD-99)</td>
<td>18 (&lt;LOD-38)</td>
<td>18 (&lt;LOD-41)</td>
</tr>
<tr>
<td>Median</td>
<td>17</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>PCB 110 AM(min-max)</td>
<td>34 (&lt;LOD-152)</td>
<td>26 (&lt;LOD-49)</td>
<td>27 (&lt;LOD-50)</td>
</tr>
<tr>
<td>Median</td>
<td>19</td>
<td>19</td>
<td>24</td>
</tr>
<tr>
<td>PCB 118 AM(min-max)</td>
<td>48 (&lt;LOD-268)</td>
<td>41 (&lt;LOD-66)</td>
<td>44 (&lt;LOD-106)</td>
</tr>
<tr>
<td>Median</td>
<td>30</td>
<td>35</td>
<td>40</td>
</tr>
<tr>
<td>PCB 128 AM/median</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>PCB 138 AM(min-max)</td>
<td>46 (&lt;LOD-169)</td>
<td>32 (&lt;LOD-61)</td>
<td>40 (&lt;LOD-66)</td>
</tr>
<tr>
<td>Median</td>
<td>35</td>
<td>31</td>
<td>37</td>
</tr>
<tr>
<td>PCB 153 AM(min-max)</td>
<td>98 (&lt;LOD-534)</td>
<td>65 (&lt;LOD-156)</td>
<td>72 (&lt;LOD-137)</td>
</tr>
<tr>
<td>Median</td>
<td>78</td>
<td>59</td>
<td>67</td>
</tr>
<tr>
<td>PCB 156 AM/median</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>PCB 170 AM(min-max)</td>
<td>21 (&lt;LOD-288)</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Median</td>
<td>9</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>PCB 180 AM/median</td>
<td>16 (&lt;LOD-286)</td>
<td>23 (&lt;LOD-108)</td>
<td>30 (&lt;LOD-113)</td>
</tr>
<tr>
<td>Median</td>
<td>47</td>
<td>8.5</td>
<td>25</td>
</tr>
<tr>
<td>PCB 183 AM/median</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>PCB 187 AM(min-max)</td>
<td>16 (&lt;LOD-243)</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Median</td>
<td>6</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>HCB AM(min-max)</td>
<td>135 (&lt;LOD-373)</td>
<td>122 (32-297)</td>
<td>117 (35-320)</td>
</tr>
<tr>
<td>Median</td>
<td>110</td>
<td>102</td>
<td>103</td>
</tr>
<tr>
<td>a-HCH AM/median</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>b-HCH AM/median</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>g-HCH AM/median</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Heptachlor AM/median</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Oxychlordane AM/median</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>trans-Chlordane AM/median</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>cis-Chlordane AM/median</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>trans-Nonachlor AM/median</td>
<td>N/A</td>
<td>N/A</td>
<td>3.6 (&lt;LOD-21)</td>
</tr>
<tr>
<td>Median</td>
<td>N/A</td>
<td>N/A</td>
<td>1.3</td>
</tr>
<tr>
<td>cis-Nonachlor AM/median</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Dieldrin AM/median</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>o,p′-DDE AM/median</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>p,p′-DDE AM(min-max)</td>
<td>246 (&lt;LOD-1342)</td>
<td>127 (41-517)</td>
<td>234 (91-600)</td>
</tr>
<tr>
<td>Median</td>
<td>163</td>
<td>107</td>
<td>203</td>
</tr>
<tr>
<td>o,p′-DDD AM/median</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>p,p′-DDD AM/median</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>o,p′-DDT AM/median</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>p,p′-DDT AM/median</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Mirex AM/median</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>
### Table 3. Plasma concentrations (ng/g) lipid weight of organochlorines among men

<table>
<thead>
<tr>
<th>Concentration (ng/g) l.w</th>
<th>Nelmin-Nos ((n = 22))</th>
<th>Izhma ((n = 25))</th>
<th>Usinsk ((n = 25))</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCB 28/31 AM(min-max)</td>
<td>50 (&lt;LOD-218)</td>
<td>9.7 (&lt;LOD-96)</td>
<td>19 (&lt;LOD-72)</td>
</tr>
<tr>
<td>Median</td>
<td>18</td>
<td>3.2</td>
<td>7.5</td>
</tr>
<tr>
<td>PCB 52 AM(min-max)</td>
<td>56 (&lt;LOD-203)</td>
<td>13 (&lt;LOD-120)</td>
<td>23 (&lt;LOD-62)</td>
</tr>
<tr>
<td>Median</td>
<td>28</td>
<td>3.3</td>
<td>17</td>
</tr>
<tr>
<td>PCB 99 AM(min-max)</td>
<td>36 (&lt;LOD-136)</td>
<td>29 (&lt;LOD-175)</td>
<td>33 (&lt;LOD-70)</td>
</tr>
<tr>
<td>Median</td>
<td>26</td>
<td>22</td>
<td>31</td>
</tr>
<tr>
<td>PCB 101 AM(min-max)</td>
<td>73 (&lt;LOD-266)</td>
<td>32 (&lt;LOD-285)</td>
<td>34 (&lt;LOD-79)</td>
</tr>
<tr>
<td>Median</td>
<td>45</td>
<td>11</td>
<td>28</td>
</tr>
<tr>
<td>PCB 105 AM(min-max)</td>
<td>42 (&lt;LOD-385)</td>
<td>24 (&lt;LOD-268)</td>
<td>20 (&lt;LOD-59)</td>
</tr>
<tr>
<td>Median</td>
<td>14</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>PCB 110 AM(min-max)</td>
<td>45 (&lt;LOD-308)</td>
<td>26 (&lt;LOD-370)</td>
<td>37 (&lt;LOD-82)</td>
</tr>
<tr>
<td>Median</td>
<td>21</td>
<td>3.6</td>
<td>29</td>
</tr>
<tr>
<td>PCB 118 AM(min-max)</td>
<td>57 (&lt;LOD-532)</td>
<td>43 (&lt;LOD-478)</td>
<td>39 (&lt;LOD-106)</td>
</tr>
<tr>
<td>Median</td>
<td>26</td>
<td>15</td>
<td>28</td>
</tr>
<tr>
<td>PCB 128 AM/median</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>PCB 138 AM(min-max)</td>
<td>58 (&lt;LOD-291)</td>
<td>54 (&lt;LOD-270)</td>
<td>53 (&lt;LOD-104)</td>
</tr>
<tr>
<td>Median</td>
<td>36</td>
<td>36</td>
<td>55</td>
</tr>
<tr>
<td>PCB 153 AM(min-max)</td>
<td>104 (&lt;LOD-222)</td>
<td>123 (&lt;LOD-297)</td>
<td>110 (36-236)</td>
</tr>
<tr>
<td>Median</td>
<td>92</td>
<td>106</td>
<td>97</td>
</tr>
<tr>
<td>PCB 156 AM(min-max)</td>
<td>23 (&lt;LOD-164)</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Median</td>
<td>6</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>PCB 170 AM(min-max)</td>
<td>24 (&lt;LOD-89)</td>
<td>33 (&lt;LOD-85)</td>
<td>19 (&lt;LOD-67)</td>
</tr>
<tr>
<td>Median</td>
<td>10</td>
<td>28</td>
<td>10</td>
</tr>
<tr>
<td>PCB 180 AM(min-max)</td>
<td>64 (&lt;LOD-152)</td>
<td>79 (&lt;LOD-170)</td>
<td>63 (&lt;LOD-158)</td>
</tr>
<tr>
<td>Median</td>
<td>57</td>
<td>73</td>
<td>59</td>
</tr>
<tr>
<td>PCB 183 AM/median</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>PCB 187 AM(min-max)</td>
<td>12 (&lt;LOD-43)</td>
<td>13 (&lt;LOD-45)</td>
<td>11 (&lt;LOD-66)</td>
</tr>
<tr>
<td>Median</td>
<td>7</td>
<td>3.7</td>
<td>4.4</td>
</tr>
<tr>
<td>HCB AM(min-max)</td>
<td>98 (&lt;LOD-203)</td>
<td>183 (46-361)</td>
<td>122 (53-427)</td>
</tr>
<tr>
<td>Median</td>
<td>86</td>
<td>160</td>
<td>107</td>
</tr>
<tr>
<td>a-HCH AM/median</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>b-HCH AM/median</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>g-HCH AM/median</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Heptachlor AM/median</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Oxychlordane AM/median</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>trans-Chlordane AM/median</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>cis-Chlordane AM/median</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>trans-Nonachlor AM/median</td>
<td>N/A</td>
<td>N/A</td>
<td>8.9 (3.1-26)</td>
</tr>
<tr>
<td>Median</td>
<td>N/A</td>
<td>N/A</td>
<td>4.6</td>
</tr>
<tr>
<td>cis-Nonachlor AM/median</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Dieldrin AM/median</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>o, p’-DDE AM/median</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>p,p’-DDE AM(min-max)</td>
<td>245 (51–732)</td>
<td>168 (20-428)</td>
<td>228 (53–782)</td>
</tr>
<tr>
<td>Median</td>
<td>176</td>
<td>138</td>
<td>190</td>
</tr>
<tr>
<td>o, p’-DDD AM/median</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>p,p’-DDD AM/median</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>o, p’-DDT AM/median</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>p,p’-DDT AM/median</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Mirex AM/median</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>
HCB and Cd concentrations were significantly higher in the rural reindeer district Izhma, whereas Se and \( p,p'-\)DDE (women only) concentrations were significantly higher in the urban area Usinsk, where most people make their living as oil and gas workers. Differences could possibly be a result of different dietary habits (most likely a higher intake of reindeer liver in Izhma) or an historical point source being present in the local environment (paint, alloys, batteries, plastics, impregnated wood, etc.). It is evident that humans are exposed to PTSs mainly from their diet and that indigenous people with a traditional way of living often are exposed to high concentrations of POPs and some heavy metals, especially if they feed from the marine food web. The village Nelmin-Nos is located at the outlet of the river Pechora and people in that area are expected to have a high intake of fish and seafood. Despite of that, their concentrations of PTSs were not higher than the other study groups from the inland Komi republic, indicating either similar diets or other, more important exposure routes than the diet. It must be emphasized that marine mammals are not an important part of the diet in Nelmin-Nos. The usual mixture of imported food, local sea food, and reindeer meat will not contribute with contaminant levels comparable to a diet based on marine mammals.

During the years of 2001–2003, blood samples were collected from 31 women (mean age: 37) and 13 men (mean age: 25) from Nelmin-Nos as part of the PTS project in the Russian North (1). The samples were analyzed for POPs and heavy metals and the results were published in the AMAP Assessment 2009: Human health in the Arctic (4) and by Sandanger et al. 2009 (10). By comparing the results from the current study with the study in Nelmin-Nos in 2001–2003, a unique opportunity to investigate differences in POP concentration over time within a Russian indigenous population is allowed.
addition, only 2% of all samples from 2010 contained detectable concentrations of $p,p'$-DDT. The low $p,p'$-DDT levels in 2010 can partly, but not fully, be explained by low sample volumes perhaps insufficient for such sensitivity of the analytical instrument. In 1996, high concentrations of $p,p'$-DDE and $p,p'$-DDT were reported in breast milk from Arkhangelsk (1,687 ng/g lipid weight of $p,p'$-DDE and 344 ng/g l.w. of $p,p'$-DDT) (2). The DDE/DDT ratio was 4.9 in the breast milk samples from 1996; thus, they indicated a recent source of DDT. In the samples from 2001–2003, the DDE/DDT ratio varied between 12.6 and 17.9 (different laboratories) indicating a reduction of DDT sources from 1996 (1). In the current study, it was not possible to calculate the DDE/DDT ratio due to the majority of samples having concentrations of $p,p'$-DDT below the LOD. Taken together, the current results combined with old data indicate a reduction of DDT compounds in the environment in some areas of the Russian Arctic and thus, confirm national and international restrictions on chemicals and metals.

Fig. 1 also indicates decreased HCB concentrations in Nelmin-Nos over the past 7–9 years. This is especially pronounced among men. PCB 138 and 153 show no distinct difference over time; however, a small increase in PCB 180 concentration for both gender, but especially for women, was observed when comparing the two datasets. It has to be emphasized that the datasets have not been adjusted for possible confounders. However, the participating women in 2010 were older than the women participating in 2001–2003 (46 years vs. 25 years). For men, the participants in 2001–2003 were slightly older (37 years vs. 32 years in 2010) (1). The decreasing concentrations of POPs over time could therefore not be confounded by age. Similar reductions in POP levels have also been reported in other parts of the Arctic (4).

In 2001–2003, heavy metals were measured in whole blood from indigenous men and women from the Kola Peninsula (Sami, Komi, and Nenets in Lowosero and Krasnoschelye) (1). Fig. 2 compares the concentrations of Hg from that study with the concentrations among Komi people from 2010. There has been observed large variations in Hg concentrations within the Russian Arctic (1, 3, 4), which is also reflected in the results from 2001–2003 (Fig. 2). The 2010 results from the Komi Republic are comparable between genders and regions. Together, the two datasets from 2001–2003 and 2010 indicate a decrease, rather than an increase in Hg concentrations over the past 7–9 years. However, the results should be interpreted carefully because samples sites are geographically separated. In the Canadian Arctic, levels of Hg have declined up to 50% in human populations over the last 8–15 years and are likely a further indication of broadly applied domestic and international controls on chemicals and metals. Despite that, there are still large geographical differences within the Canadian Arctic with some areas having very high concentrations of Hg.

Lead and Cd were also analyzed in that same study in 2001–2003 (1). There are indications that the Pb concentrations were higher in 2001–2003; (women = 31–38 µg/L in 2001–2003 vs. 23–27 µg/L in 2010 and men = 58–72 µg/L in 2001–2003 vs. 32–33 µg/L in 2010). The same

Fig. 1. Differences in blood concentrations of POPs in Nelmin-Nos from 2001–2003 to 2009.

Fig. 2. Differences in blood concentrations of Mercury in North West Russia from 2001–2003 and 2010.

CONCLUSIONS

The current study indicates a reduction of several PTSs in human blood samples from North West Russia over the past 10 years. The results point out the importance of systematic follow-up studies to observe trends in human exposure to protect the health of the people of the Russian Arctic.

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References


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Frostbites in circumpolar areas

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Circumpolar areas are associated with prolonged cold exposure where wind, precipitation, and darkness further aggravate the environmental conditions and the associated risks. Despite the climate warming, cold climatic conditions will prevail in circumpolar areas and contribute to adverse health effects. Frostbite is a freezing injury where localized damage affects the skin and other tissues. It occurs during occupational or leisure-time activities and is common in the general population among men and women of various ages. Industries of the circumpolar areas where frostbite occurs frequently include transportation, mining, oil, and gas industry, construction, agriculture, and military operations. Cold injuries may also occur during leisure-time activities involving substantial cold exposure, such as mountaineering, skiing, and snowmobiling. Accidental situations (occupational, leisure time) often contribute to adverse cooling and cold injuries. Several environmental (temperature, wind, wetness, cold objects, and altitude) and individual (behavior, health, and physiology) predisposing factors are connected with frostbite injuries. Vulnerable populations include those having a chronic disease (cardiovascular, diabetes, and depression), children and the elderly, or homeless people. Frostbite results in sequelae causing different types of discomfort and functional limitations that may persist for years. A frostbite injury is preventable, and hence, unacceptable from a public health perspective. Appropriate cold risk management includes awareness of the adverse effects of cold, individual adjustment of cold exposure and clothing, or in occupational context different organizational and technical measures. In addition, vulnerable population groups need customized information and care for proper prevention of frostbites.

Keywords: cold; frostbite; injury; circumpolar; vulnerable; population

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The circumpolar environments are characterized by considerable fluctuations in temperature and photoperiod with long, cold and dark winters and short cool but bright summers. Winter, as defined by the number of days when the mean daily temperature decreases below 0°C, is the longest season in high-latitude environments lasting for several months depending on the region. The cold environmental conditions in winter-time are often further aggravated by wind and precipitation. Moreover, darkness, snow, and ice further modify the environment and the risks associated with it (1).

Arctic areas are warming as a result of climate change. Different climate changes projections predict a ‘polar amplification’ where especially winter warming is several fold in the Arctic compared to the global annual mean (2). It is estimated that the increase in mean temperature and precipitation will be combined with an increase in the frequency of very warm and wet winters and summers (2). Despite the warming, cold spells continue to be a problem in northern latitudes, where very low temperatures can be reached in a few hours and extend over long periods. Moreover, the expected increase in wintertime precipitation and changing cryosphere (e.g. retreat of arctic sea ice, earlier breakup of river, and lake ice) can indirectly contribute to human health. Therefore, despite the global warming, cold remains in its various forms (3) and is significantly present in the everyday life of all circumpolar residents. Cold exposure can result in decreased performance, increased morbidity, and mortality and increased rates of injuries causing different types of functional limitations, sick leaves, hospitalization, and in the worst case, death (1, 4, 5). The present article focuses on the occurrence, treatment, and prevention of frostbites occurring in circumpolar areas. The history and research on frostbite are old and several reviews are available (5–13). A few of them are cited here and more can be found in other publications by the authors (14, 15).

Cold exposure

Types of cold exposure
The type of cold that people experience may be exposure to cold air, immersion in water, or through touching (sitting,
lying, or standing) cold surfaces. Accordingly, cooling is targeted to different areas of the body. Sometimes cooling may also involve specific body regions, such as the respiratory tract. Respiratory tract cooling can be especially pronounced during heavy exercise in cold weather (4). Prolonged exposure to cold, often associated with insufficient clothing or physical activity, may result in whole body cooling and a decrease in core temperature. This type of cooling is further enhanced by exposure to wind or cold water, which increases heat loss from human to the environment. Cooling can also be restricted to the extremities (head, hands, and feet) and is often enhanced by touching or handling cold objects. This type of cooling is common both in occupational and leisure-time activities and pose a significant risk of cold injury.

**Occupational and leisure time cold exposure**

Cold exposure occurs on average, for short yet repeated periods and includes commuting to work, occupational, and leisure-time exposure. A population study conducted in Finland demonstrated that the average self-reported cold exposure time is approximately 4% of the total time, and most of the cold exposure (71%) was reported to occur during leisure time (16). The degree of exposure to cold is dependent on several factors such as occupation, gender, age, health, physical activity, and education. For indoor workers, cold exposure is probably limited to commuting to work and leisure-time activities.

Although the reported average cold exposure at work among this Finnish population was less than 1 hour per week, cold exposure is substantial in industries such as agriculture, forestry, mining, factory work, construction work and related occupations (16). Cold exposure may also be significant among native northern populations, who are for example reindeer herding, hunting, or fishing. However, the development of vehicles and protective clothing may have to some extent diminished the amount of cold stress (1). One population group that is also exposed to significant cold stress is the military. The duration of outdoor cold exposure in winter during military training can be significant, equaling, or exceeding that of other cold outdoor occupations.

**Frostbites**

Cold injuries are divided into freezing injuries, nonfreezing injuries, and hypothermia (14, 15). Frostbite is the medical condition where localized damage is caused to skin and other tissues as the result of freezing of the tissue. Frostnip is distinct from frostbite but may precede it. It is a superficial cold injury associated with intense vasoconstriction on exposed skin. However, ice crystals do not form in the tissue, nor does tissue loss occur. Nonfreezing cold injuries often occur as a result of prolonged exposure to temperature above freezing and are associated with wet conditions. The most common nonfreezing cold injuries are trenchfoot and chilblains. Frostbite most commonly occurs in the extremities (hands, feet) and head region (14, 15). However, even genital areas have been reported to be affected by frostbite in Arctic military operations (17).

Frostbite injuries are often classified by the depth of injury and amount of tissue damage based on acute physical findings and advanced imaging following rewarming of the tissue (14, 18). A first-degree injury is characterized by partial skin freezing, erythema, mild edema, lack of blisters, and occasional skin desquamation several days later. Symptoms of stinging and burning, followed by throbbing may be experienced. A second-degree injury is characterized by full-thickness skin freezing, edema, erythema, and formation of clear blisters rich in thromboxane and prostaglandins. The blisters extend to the end of the digit, and usually desquamate and form black hard eschars over several days. Complaints of numbness, followed later by aching and throbbing are common. A third-degree injury is characterized by damage that extends into the reticular dermis and beneath the dermal vascular plexus. Hemorrhagic blisters form and are associated with skin necrosis and a blue-gray discoloration of the skin. The injured extremity may feel like a ‘block of wood,’ followed later by burning, throbbing, and shooting pains. A fourth-degree injury is characterized by extension into subcutaneous tissues, muscle, bone, and tendon. There is little edema and the skin is mottled, with nonblanching cyanosis, and eventually forms a deep, dry, black, mummified eschar. Vesicles often present late, if at all, and may be small, bloody blebs that do not extend to the digit tips. The patient may complain of a deep, aching joint pain (14). In addition to the acute injury, frostbite is often associated with different post symptoms, sequelae that include altered vasomotor function, neuropathies, joint articular cartilage changes, and, in children, growth defects caused by epiphyseal plate damage (19, 20). These may cause different forms of discomfort and functional limitations that can persist for several years.

**Pathophysiology of frostbite**

The pathophysiology of frostbite is described in detail previously (14, 18). It can be divided into four overlapping pathologic phases: prefreeze, freeze–thaw, vascular stasis, and a later ischemic phase (18). The prefreeze state is characterized by a considerable decrease in blood flow as a result of skin cooling and vasoconstriction. However, this phase does not involve the formation of actual ice crystals. In the freeze–thaw phase, ice crystals form intra or extracellularly causing protein and lipid derangement, cellular shifts of electrolytes, and dehydration as well as cell membrane lysis and death. The thawing process may initiate ischemia–reperfusion injury and the inflammatory response. In the vascular stasis
phase, vessels constrict and dilate or blood may leak from vessels. The later phase of a frostbite injury is characterized by tissue ischemia and infarction due to an inflammation response, intermittent constriction of arterioles and venules, and a continued reperfusion injury (18). The necrosis of tissue following frostbite is due to either cellular injury or secondary to a vascular lesion (14).

Occurrence of frostbites in circumpolar areas

The occurrence of frostbite in different populations has been previously described (7, 8, 13). Frostbite occurs commonly in the general population among men and women of various ages (21–23). For example, in Finland the proportion of annually occurring mild frostbite was 13% (330/2550) and severe frostbite 1% (95/8788) (13). Of note, these injuries are commonly observed already among adolescents (23).

Occupational

The circumpolar environment itself is a hazardous work setting, with special risks posed by great distances, permafrost, cold waters, high wind speeds, ice, blizzards, and darkness. The abovementioned features contribute to higher occupational risks of frostbite compared with other areas (24). Summaries of the occurrence of occupational cold injuries have been previously reported (4, 14, 21). A study analyzing cold injuries using workers’ compensation claims in the United States reported highest rates of injury occurring in agriculture, oil and gas extraction, trucking and warehousing, professional services, and interurban transportation. Vehicle breakdown or contact with water, gasoline, alcohol, or cold water were noted as contributing factors on many of the compensation claims (25). In a Finnish study, frostbites were reported in occupational groups such as skilled agricultural and fishery workers, craft and related trade workers, plant and machine operators, assemblers and technicians, and associate professionals. Work-related risk factors included employment in certain industries, high physical strain, and high reported weekly cold exposure at work (21).

A specific occupational group at high risk for frostbite is reindeer herders, where the annual incidence of frostbites was 22% (26). The amount of snowmobile driving, area of operation, and white finger symptoms were related to an increased risk of frostbite. Furthermore, vibration white finger syndrome associated with snowmobile use further increased the risk of frostbite in reindeer herders (26).

Frostbites are also reported commonly during military training and operations (27–31). The Finnish Defense Forces documented an annual incidence of frostbite of 0.4% between 1976 and 1989 (30). In Alaska, the annual occurrence of medically investigated frostbite among soldiers ranged from 0.2% to 1.2% between 1990 and 1995 (27). Arctic military operations in Norway resulted in several frostbites, and the observed individual differences in the cold-induced vasodilatation response could explain individual susceptibility to cold injuries (31). Reports indicate that the incidence of cold weather injuries among US military personnel decreased from 38.2/100,000 in 1985 to 0.2/100,000 in 1999. Reasons for this decline are multifactorial (29).

Although there are no scientific reports, one could also assume that frostbite injuries occur in the oil and gas industry, fishing industry, tourism, transportation, and forestry which involve special occupational risks related to the circumpolar environment (24).

Leisure time

As most of the cold exposure occurs during leisure time, it is likely that frostbites are associated with different outdoor activities. A population study showed a relatively high incidence of frostbite among students, pensioners, and the unemployed, which may be related to long times spent in the cold during the leisure time in these groups (16, 21). Also, the occurrence of frostbite among office workers suggests that these had occurred during the leisure time.

Significant cold exposure during leisure time occurs in different outdoor sports activities such as among joggers, during Alpine and Nordic skiing, mountaineering, cold-weather distance running and cycling, speed skating, and luge, or while playing outdoor team sports (32). Cold injuries are common in mountaineering (33, 34). Epidemiological evidence indicates that frostbite risk is clearly increased above 5,182 m (33). Also recreational or occupational use of snowmobiles is associated with frostbites (26, 35).

Frostbite is a common theme in historical descriptions of arctic explorers (3, 36–38). There are several reports of cold injuries (frostbite, trenchfoot) during Arctic expeditions or ski treks (36, 39, 40). These expeditions involve several stressors in addition to the cold environment (cold temperatures, wind, and snowfall) including for example fatigue, nutritional deficits, dehydration, hormonal changes, and psychological stressors. More recent studies have examined the occurrence of cold injuries among personnel overwintering in Antarctica where the occurrence of frostbites was 65.6 per 1,000 per year (41). The increasing tourism to the Polar regions may also involve risk of frostbites injuries (42).

Risk factors of frostbites

Several environmental and individual risk factors increase the risk of frostbites (Table 1) and these are described in more detail underneath.
Environmental-risk factors

The incidence of frostbite is related to the intensity and duration of cold exposure. Exposure times for injury vary from minutes to several days depending on the magnitude of exposure, degree of protective clothing, and physical activity level. According to experimental research, the risk of frostbite on the bare skin is minor at environmental temperature above \( -10^\circ C \) (43). The latitude of residence (i.e. the annual number of cold days) as well as the length of daily cold exposure affect frostbite risk (23). It also seems that people living in urban areas are at higher risk of frostbite, and possibly related to inexperience and inappropriate protection (44). Wind markedly increases the cooling rate by increasing convective heat loss and reducing the insulation value of clothing, thus increasing the risk of frostbite. The windchill temperature (WCT) provides the relative risk for frostbite occurring on the bare skin and predicted time for freezing risk at given air temperatures and wind speeds (45). Currently, the threshold predicting frostbite risk is being discussed, including pain and numbness thresholds predicting adverse cooling (46). The risk of frostbite is less than 5% when the ambient temperature is above \(-15^\circ C\), but increased surveillance is warranted when the WCT falls below \(-27^\circ C\) (47). In addition to ambient temperature and wind, merely touching cold materials (e.g. metal) is a risk factor for frostbite. The degree of cooling while touching cold materials is dependent on the surface temperature, type of material, duration of contact, and several individual factors. Safe limits values for gripping or touching cold objects have been developed (48, 49). As an example, frostbite can develop within 2–3 seconds when touching metal surfaces that are at or below \(-15^\circ C\) (49). Other factors that increase heat loss and cooling rate and increase the risk of frostbite are wetting the skin. Also, case studies have demonstrated frostbites or ‘cold burns’ when handling cooled liquids such as liquid oxygen (50) or liquid petroleum while refuelling car (51) or from contact with butane or propane canister (52). Finally, high altitudes and hypoxia increase frostbite risk (33, 34).

Individual factors

Several individual factors related to physical features, behavior, and health affect the risk of frostbites (Table 1). A recent population study demonstrated that health-related factors such as diabetes, white fingers in the cold, cardiac insufficiency, angina pectoris, stroke as well as depressive feelings increase the risk of frostbite (21). In addition, certain disease states, such as peripheral vascular disease, atherosclerosis, arteritis, Raynaud’s phenomena, vibration-induced white finger (VIWF), hypovolemia, diabetes, vascular injury secondary to trauma or infection, and previous cold-related injuries, may predispose to cold-related injury (22, 30, 33, 53). Psychiatric disorders are commonly detected among frostbite patients (14, 53). Any immobilizing injury for example impairing the distal circulation predisposes persons to frostbite (53). Although there are no scientific reports available, certain age groups that are susceptible to cooling, may also be at higher risk to receive a cold injury. Children have larger surface-to-mass ratio compared with adults, and lesser possibility for producing heat, which explains the lower thermoregulatory capacity in the cold and higher risk of cold injuries. Also, the elderly people have a lowered heat production capacity (diminished muscle mass) as well as weakened ability to

<table>
<thead>
<tr>
<th>Table 1. Factors predisposing to frostbite</th>
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<tbody>
<tr>
<td><strong>Environmental</strong></td>
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<tr>
<td>Temperature</td>
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<tr>
<td>Wind</td>
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<td>Wetness</td>
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<td>Contact with cold objects or liquids (e.g. petroleum, oil, and lubricants)</td>
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<td>Duration of cold exposure</td>
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<td>Geographical area</td>
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<td>Hypoxia</td>
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<td>Altitude</td>
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<td><strong>Individual</strong></td>
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<td>Physical/anthropometric</td>
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<tr>
<td>Age</td>
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<td>Gender</td>
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<td>Race</td>
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<tr>
<td><strong>Behavioral</strong></td>
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<tr>
<td>Cold acclimatization</td>
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<td>Alcohol use</td>
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<td>Fatigue</td>
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<td>Dehydration</td>
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<td>Smoking</td>
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<td>Use of protective ointments</td>
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<tr>
<td>Inappropriate/wet clothing</td>
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<td>Constrictive clothing (e.g. tight boots)</td>
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<td>Prolonged stationary posture</td>
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<td><strong>Health related/physiological</strong></td>
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<tr>
<td>Raynaud’s phenomenon</td>
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<td>Vibration-induced white finger</td>
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<td>Cold induced vasodilatation reactivity</td>
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<td>Other peripheral vascular diseases</td>
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<tr>
<td>Diabetes</td>
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<td>Peripheral neuropathies</td>
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<td>Medication (e.g. vasoconstrictive drugs)</td>
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<tr>
<td>Previous cold injury</td>
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<td>Psychiatric disorder or altered mental status</td>
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Reproduced with permission from Tintinalli, et al. (15).
sense cold (54, 55). Furthermore, elderly persons have commonly one or more chronic diseases or use medication that may affect their thermoregulation in cold. Overall medications such as β blockers, sedatives, and neuroleptics may affect thermoregulation and increase the risk of frostbite (53). Health care personnel should recognize these health conditions and provide appropriate advice and treatment to prevent frostbite from occurring.

Several behavioral factors influence the risk of cold-related injuries. Alcohol consumption and smoking increase the occurrence of frostbite (21, 22, 33). The previously mentioned psychiatric disorders increase unsafe behavior and frostbite risk (53). Inappropriate clothing (e.g., lack of gloves, headgear, scarf, or wet clothes) and/or constrictive clothing, and prolonged stationary posture increase the incidence of frostbites. Interestingly, the use of protective ointments is associated with an increased risk of frostbite of the head and face (30). Among military personnel, lower level of education/training or military rank, as well as situational misjudgments, accidental situations, fatigue, and insufficient nutrition are associated with a higher incidence of frostbite. US Military studies suggest that African-American soldiers and those from warmer climatic regions are more susceptible to frostbite (29). The association between cold acclimatization and frostbite is unclear. The blunted vasoconstriction of for example regions are more susceptible to frostbite (29). The prevention of local cold injuries includes increasing awareness of cold injury prevention and treatment. Fortuine (36) described experiences from the Arctic exploration of Edward Parry in 1821–1823 where Inuit prevented cold injuries by warming their hands against their body, rather than rubbing the extremities with snow that has been a common misbelief. The indigenous populations have also applied their own treatment against frostbite such as topical applications of nasal secretions, seal oil, and whale blubber (58). A case report even describes that urine help preventing the development of a contact frostbite (59).

The details of frostbite care have been described in several publications (15, 53) and are not discussed in detail in this article. In summary, the core hospital treatment of frostbite includes rapid rewarming of the injured area in warm water, gentle early conservative treatment (leave most blisters intact, no early surgery, or amputations), meticulous local care, adequate pain relief, and physical therapy.

**First aid and treatment**

The treatment of frostbite has been described in detail previously (15, 18, 53, 57) and is distinguished to first aid in the field as well as medical therapy provided in a hospital. Initial field management of frostbite includes prevention of further cold injury, hypothermia, and dehydration. The patient should be covered, protected against wind, and any wet and constrictive clothing should be removed and replaced with dry ones. Heating of the frozen area should be avoided. Thawing should be deferred until the risk of refreezing is eliminated. The risk of refreezing and causing even more severe damage is a real concern. Frozen extremities should be immobilized, elevated, and handled gently. ‘Home remedies’ such as rubbing snow on frostbitten tissue increase tissue damage (15, 18, 53).

Arctic indigenous populations have long-term experience with cold injury prevention and treatment. Fortuine (36) described experiences from the Arctic exploration of Edward Parry in 1821–1823 where Inuit prevented cold injuries by warming their hands against their body, rather than rubbing the extremities with snow that has been a common misbelief. The indigenous populations have also applied their own treatment against frostbite such as topical applications of nasal secretions, seal oil, and whale blubber (58). A case report even describes that urine help preventing the development of a contact frostbite (59).

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**Prevention**

**Increasing awareness**

The prevention of local cold injuries includes increasing public awareness of the adverse effects of cold exposure, attention to related potential risks, and implementing risk management and prevention strategies. For this purpose, advice for the public related to preventing adverse cold effects is being prepared by the WHO and will be published shortly. The special needs of susceptible population groups who may not be able to adequately care for themselves, such as the elderly, the very young, socially or economically deprived people, and those with mental impairments, should be taken into account when providing individual recommendations. Also, people suffering from chronic diseases may be at higher risk to receive frostbite. Individuals must be educated to recognize warning signals such as sensations of cold, pain, and numbness and to prevent further cooling by protective clothing or by seeking shelter. Special training and education about injury prevention must be provided to persons who work or spend recreational time in cold conditions. Efficient behavioral means for preventing frostbites from occurring include careful planning of activities (and taking into account the expected environmental conditions), maintaining adequate nutrition and hydration, and avoiding alcohol. Cold protective clothing is necessary for maintaining a thermal balance and for slowing or preventing adverse cooling. Some principles for appropriate clothing are discussed underneath.
Clothing
Multilayer clothing should be used and adjusted according to the prevailing environmental conditions (temperature, wind, precipitation) as well as the physical activity level. Sweating should be avoided in cold conditions, as this increases heat loss when the physical activity level is suddenly lowered. Clothing should be dry and noncompressing and wet clothes should be changed to dry ones as soon as possible. Headgear should be adjustable to cover maximal areas of the head. If necessary, a face mask can be used. The face can also be protected by a wide hood that leaves the face uncovered, but provides protection. Mittens provide better hand protection than gloves. The smaller surface area of mittens combined with the presence of air and all fingers together in one compartment decreases heat loss. Thin inner gloves may be used if manual dexterity during contact with metal objects is required. Shoes, boots, and socks should be dry and sufficiently loose (15).

Occupational management of cold injuries
Advice on the appropriate occupational cold risk management is provided in an international standard (60). Cold risk management at workplaces includes organizational and technical measures. Metal tools and instruments can be coated which is an efficient method for reducing conductive cooling and frostbite risk. Insulation may also be added to the specific site of garment contact, e.g. to the palm side of the glove. Additionally, external heating sources can be used to warm the work or recreational environment. Organizational injury prevention consists of appropriate advance planning of activities, adjusting scheduling to expected weather conditions based, and knowing where safe and warm shelters exist.

Conclusions
Global warming and the changing climate are likely to bring not only warmer average temperatures, but possibly also a greater frequency of extreme weather events, changing ice covers, and increased amounts of precipitation which contribute either indirectly or directly to human health. Therefore, the need for appropriate cold risk management to prevent cold injuries is emphasized. The populations that are at the greatest risk for frostbites are the children, elderly, homeless people, or persons suffering from chronic diseases. Ageing populations, urbanization and the variable housing and socio-economic conditions are all factors that contribute to cold-induced health problems in circumpolar regions.

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Cold injuries in the Arctic


59. Adler AI. Arctic. Cold workplaces


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