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Reindeer Husbandry

Adaptation to the Changing Arctic, Volume 1

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Editors

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Editors
Svein Disch Mathiesen
International Centre for Reindeer Husbandry
Kautokeino, Norway

Sámi University of Applied Sciences
Kautokeino, Norway

Ellen Inga Turi
International Centre for Reindeer Husbandry
Kautokeino, Norway

Sámi University of Applied Sciences
Kautokeino, Norway

Mikhail Pogodaev
Arctic State Agrotechnological University
Yakutsk, Russia

Inger Marie Gaup Eira
Sámi University of Applied Sciences
Kautokeino, Norway

Anders Oskal
International Centre for Reindeer Husbandry
Kautokeino, Norway

Marina Tonkopeeva
International Centre for Reindeer Husbandry
Kautokeino, Norway

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Preface

Reindeer Husbandry: Adaptation to the Changing Arctic, Volume 1 is the first of two books published by Springer Nature. This first book consists of ten peer-reviewed chapters with each chapter reviewed by two to six renowned international researchers and scientists. The authors express their immense gratitude to the reviewers and deeply acknowledge their unique contribution.

This book addresses the critical issue faced by Indigenous peoples in the Arctic: climate change, the ways in which it affects their societies and livelihoods, environment, and economies. It is important that all available forms of knowledge – academic, traditional, Indigenous, and local – are included when addressing the adaptation and resilience of reindeer husbandry in the Circumpolar North. The two volumes provide novel insights into the Arctic Indigenous reindeer herding communities and how resilience can be built locally through the use of traditional knowledge and co-production.

Kautokeino, Norway	Svein Disch Mathiesen
Kautokeino, Norway	Inger Marie Gaup Eira
Kautokeino, Norway	Ellen Inga Turi
Kautokeino, Norway	Anders Oskal
Yakutsk, Russia	Mikhail Pogodaev
Kautokeino, Norway	Marina Tonkopeeva

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About the Editors

Svein Disch Mathiesen PhD, is a head of the University of the Arctic Institute for Circumpolar Reindeer Husbandry at the International Centre for Reindeer Husbandry, and a professor and researcher at Sámi allaskuvla/Sámi University of Applied Sciences, Guovdageaidnu, Norway. Between 2007 and 2011, Prof. Mathiesen was a project leader at the IPY EALAT research project on Reindeer Husbandry and Climate Change. Prof. Mathiesen's research experience includes working in Svalbard, Russian Siberia, Mongolia, South Georgia, Alaska, and Sápmi. A co-author of more than 130 papers, he supervised a number of master's and doctoral students. Today, his main research interest is interdisciplinary knowledge on adaptation to climate change in the Circumpolar North and building competence locally in Indigenous communities in the northern areas through international cooperation.

Inger Marie Gaup Eira PhD, is an associate professor at Sámi Allaskuvla, Guovdageaidnu, Norway. Her main scope of research is traditional knowledge and reindeer husbandry, which also became the basis for her doctoral research. Dr. Eira has developed the study "Theoretical approaches for traditional knowledge and methods for documentation and dissemination" and has since 2013 been leading the studies in this area. Eira works in academia and is an Indigenous reindeer herder from Norway.

Ellen Inga Turi PhD, belongs to the Sámi reindeer herders' family with reindeer pastures in Guovdageaidnu, Norway. Turi is an associate professor and postdoctoral researcher at Sámi allaskuvla/Sámi University of Applied Sciences where her research work is focused on Indigenous traditional knowledge and governance of reindeer herding. Dr. Turi has also been the chair of the Arctic Council Indigenous Peoples Secretariat as a Sámi Council representative during the Icelandic chairmanship of the Arctic Council 2019–2021.

Anders Oskal is the Secretary General of the Association of World Reindeer Herders (WRH) and the Executive Director of the International Centre for Reindeer Husbandry in Guovdageaidnu, Norway. Oskal is a reindeer-herding Sámi from Northern Norway, with a graduate degree in Business. Throughout his professional career, Oskal has worked with Indigenous reindeer herding both on the international and national levels. He has led several Arctic Council and UN projects and contributed to a range of scientific articles. He was a co-author of IPCC AR5 WG II, is a member of the Civil Society and Indigenous Peoples' Mechanism for the UN Commission on Food Security, and is a member of the Norwegian Government's Nature Risk Commission. Prior to his current position, he worked for a number of years in business development in reindeer herding and Indigenous livelihoods.

Mikhail Pogodaev PhD, is Even from a reindeer herding family, born in Tomponsky district of the Sakha Republic (Yakutia). Dr. Pogodaev is the deputy minister for the Development of the Arctic and Indigenous Peoples Affairs of the Republic of Sakha (Yakutia). In 2021, he was appointed as the Special Envoy on Indigenous Peoples' Issues and Regional Cooperation. Dr. Pogodaev is an associate professor in the Department of Economic Theory at the Arctic State Agrotechnological University and a lecturer at M.K. Ammosov North-Eastern Federal University, Yakutsk, Russia.

Marina Tonkopeeva MA, PhD candidate in Linguistics, is a project leader at the International Centre for Reindeer Husbandry in Guovdageaidnu, Norway. Between 2016 and 2022, Tonkopeeva has been working as a project manager and coordinator for the Open School of Sustainable Development and the Coalition for Sustainable Development. As a language professional, Tonkopeeva has contributed to the work of the Arctic Council, DOCIP, and UNDP. She was a lecturer in the School of International Relations at St. Petersburg State University from 2017 to 2020. Her scope of research includes sustainable development, technologies for Indigenous languages, and knowledge co-production.

Contributors

Iulie Aslaksen Statistics Norway (SSB), Oslo, Norway

Svetlana Avelova M.K. Ammosov North-Eastern Federal University, Yakutsk, Russia
International Centre for Reindeer Husbandry, Guovdageaidnu, Norway

Rasmus E. Benestad Norwegian Meteorological Institute, Oslo, Norway

Mathis Persen Bongo Sámi High School and Reindeer Husbandry School, Kautokeino, Norway

Philip Burgess Arctic Global Change and University of Lapland, Rovaniemi, Finland

Robert W. Corell International Centre for Reindeer Husbandry, Guovdageaidnu, Norway
University of Miami, Coral Gables, FL, USA
Global Environment and Technology Foundation, Arlington, VA, USA

Inger Marie Gaup Eira Sámi University of Applied Sciences, Guovdageaidnu, Norway

Isak Henrik Eira Protect Sápmi and International Centre for Reindeer Husbandry, Guovdageaidnu, Norway

Eirik J. Førland Norwegian Meteorological Institute, Oslo, Norway

Per Arild Garnåsjordet Statistics Norway (SSB), Oslo, Norway

Alena Gerasimova International Centre for Reindeer Husbandry, Guovdageaidnu, Norway

Inger Hanssen-Bauer Norwegian Meteorological Institute, Oslo, Norway

Kathrine I. Johnsen Norwegian Institute for Water Research (NIVA), Oslo, Norway

Matthias Kaiser Centre for the Study of the Sciences and Humanities, University of Bergen, Bergen, Norway

Valeriy Aleksandrovich Kibenko Arctic Research Center of the Yamal-Nenets Autonomous Region, Salekhard, Russia

Julia Lutz Norwegian Meteorological Institute, Oslo, Norway

Rosa-Máren Magga International Centre for Reindeer Husbandry, Guovdageaidnu, Norway

Svein Disch Mathiesen International Centre for Reindeer Husbandry, Guovdageaidnu, Norway
Sámi University of Applied Sciences, Guovdageaidnu, Norway

Nancy G. Maynard University of Miami, Coral Gables, FL, USA
Goddard Space Flight Center, NASA, Greenbelt, USA

Anisiia Moiakunova Arctic Research Center of the Republic of Sakha (Yakutia), Yakutsk, Russia

Anders Oskal International Centre for Reindeer Husbandry, Guovdageaidnu, Norway

Alexandra Petrova M.K. Ammosov North-Eastern Federal University, Yakutsk, Russia
International Centre for Reindeer Husbandry, Guovdageaidnu, Norway

Alexander Nickolaevich Pilyasov Lomonosov Moscow State University, Moscow, Russia

Mikhail Pogodaev Arctic State Agrotechnological University, Yakutsk, Russia

Lena Popova M.K. Ammosov North-Eastern Federal University, Yakutsk, Russia

University of Manitoba, Winnipeg, Canada

Vyacheslav Shadrin Institute for Humanities Research and Indigenous Studies of the North – Siberian Branch of the Russian Academy of Science, Yakutsk, Russia

Anna N. Shishigina Arctic Research Center of the Republic of Sakha (Yakutia), Yakutsk, Russia

Michaela Stith Native Movement, Dgheyhey Kaq' / Anchorage, Alaska, USA

Pavel Svyashchennikov St. Petersburg State University, St. Petersburg, Russia

Arctic and Antarctic Research Institute, St. Petersburg, Russia

Marina Tonkopeeva International Centre for Reindeer Husbandry, Guovdageaidnu, Norway

Ellen Inga Turi International Centre for Reindeer Husbandry, Guovdageaidnu, Norway

Sámi University of Applied Sciences, Guovdageaidnu, Norway

Johan Mathis Turi International Centre for Reindeer Husbandry, Guovdageaidnu, Norway

Wilbert van Rooij Plansup, Lochem, the Netherlands

Dagrun Vikhamar-Schuler Norwegian Meteorological Institute, Oslo, Norway

Anatoly V. Zhozhikov M.K. Ammosov North-Eastern Federal University, Yakutsk, Russia

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Chapter 1
Reindeer Husbandry in the Circumpolar North

Svein Disch Mathiesen

Abstract Reindeer husbandry is the primary livelihood for over 24 Indigenous peoples. Reindeer herding culture and civilization are unique in the Arctic; today, however, they no longer form the foundation for economies of the Indigenous peoples in some Circumpolar regions. Modern reindeer husbandry is experiencing challenges such as climate change, loss of pastures, loss of languages and cultures, and opportunities through new technologies. This chapter introduces reindeer husbandry, Indigenous leadership, traditional knowledge, and adapting capacity discussed further in this volume.

Keywords Arctic civilization · Reindeer herders' voice · Knowledge

1.1 Introduction

Reindeer husbandry is the primary livelihood for over 24 Indigenous peoples in the Circumpolar North and involves close to 100,000 Indigenous peoples and about 2.5 million domestic reindeer (Degteva et al., 2017). Climate change is now evident in the traditional areas of reindeer husbandry in the Circumpolar North (Chaps. 2, 7 and 8). Furthermore, the loss of grazing areas combined with the effect of increased air temperature challenges the Indigenous peoples economically and their cultural

S. D. Mathiesen (✉)
International Centre for Reindeer Husbandry, Guovdageaidnu, Norway

Sámi University of Applied Sciences, Guovdageaidnu, Norway
e-mail: svein.d.mathiesen@reindeercentre.org

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practices (Chaps. 3 and 9). Reindeer husbandry should therefore develop its own adaptation strategies (Chaps. 2 and 5) where the value of traditional knowledge is recognized and where the reindeer herder knowledge is actively used in the management and control (Chap. 4). It is important that all available forms of knowledge are included when developing the reindeer husbandry's adaptation strategies (Chaps. 2 and 6). In Norway, there are barriers to the use of traditional knowledge for nature management and in the development of reindeer husbandry, which must be resolved (Chap. 3). Adaptation to future climate change in reindeer husbandry areas requires training of reindeer husbandry youth related to long-term sustainable thinking which should include a future Master program in reindeer husbandry (Chaps. 2, 5 and 6). Protection of reindeer pastures is the most important adaptation strategy during the ongoing climate change (Chaps. 2 and 9).

Much of this knowledge is disappearing if it is not documented and used (Chaps. 3, 5 and 6). We propose a new approach to the sustainability of reindeer husbandry, where we define the limitations and opportunities of reindeer husbandry based on traditional knowledge (Chap. 4). We have identified several limitations that are important for future reindeer husbandry with a focus on adaptability (Chaps. 2 and 3). The use of Sámi snow concepts mirrors reindeer herders' traditional knowledge of the management of the herd on snow-covered ground and how herders deal with these complex systems (Chaps. 3 and 4).

It is important that now we do everything to increase the adaptive capacity of reindeer husbandry to the effect of global warming so that reindeer husbandry remains an ecologically and economically robust civilization in the future as well (Chap. 10). Erosion of the reindeer husbandry knowledge base might have affected the reindeer husbandry vulnerability to change (Chap. 4). It is therefore important to build a bridge between academia and Indigenous societies so that the adaptation strategies follow Arctic realities (Chaps. 2, 3 and 5). The environment, climate and biodiversity are changing in the Circumpolar North in ways that are unique in the long history of the region, challenging traditional lifestyles, well-being, food security, and posing a legitimate concern for the future of traditional Indigenous economies (Chaps. 7, 8 and 9). This book analyzes adaptation to change essential for reindeer husbandry (Figs. 1.1, 1.2a, 1.2b, 1.3, 1.4, 1.5, 1.6, 1.7 and 1.8).

1.2 Indigenous Voices from the Circumpolar North

1.2.1 Maria Pogodaeva

Even reindeer herder, Republic of Sakha (Yakutia), born in 1951, 71 years old. Deputy of the Supreme Council of the USSR, YASSR, Honored Worker of Agriculture of the Russian Federation, Republic of Sakha (Yakutia) Excellence in Education of the Republic of Sakha (Yakutia), Vice President of the Association of World Reindeer Herders in 1997–2009, Head of the nomadic family and Indigenous Evens tribal community named after P.E. Pogodaev.

Fig. 1.1 Map of the Circumpolar reindeer husbandry pastures and Indigenous Peoples discussed in the book

Fig. 1.2a Illustration of change in reindeer herders' pastures and migration routes. Photo of the vegetation at the Guovdageaidnu river, Norway in 1882 (First International Polar Year). (Photo: Sophus Tromholdt, University Library, University of Bergen)

Fig. 1.2b Illustration of change in reindeer herders' pastures and migrations routes. Photo of the vegetation at the Guovdageaidnu river, Norway in 2021. (Photo from the site as in Fig. 1.2a). (Photo: Svein Disch Mathiesen)

Fig. 1.3 Ways of knowing about snow change: Dr. Fikret Berkes University of Manitoba, Canada and Dr. Inger Marie G Eira, Sámi University of Applied Science, in front of the reindeer herd in Guovdageaidnu, Norway (2009) discussing the role of Sámi reindeer traditional knowledge in the future governance of reindeer husbandry. (Photo: Svein Disch Mathiesen)

Fig. 1.4 Milking of reindeer has been an important way to transfer Even reindeer herders' traditional knowledge from generation to generation. Even reindeer herder Maria Pogodaeva, Republic of Sakha (Yakutia) demonstrates traditional knowledge of milking in the Verkhoyansk Mountains (1990). (Photo: Svein Disch Mathiesen)

Fig. 1.5 Family-based reindeer husbandry of the Nenets Indigenous peoples in Yamal-Nenets Autonomous Okrug is nested within a unique system of traditional knowledge and private ownership of reindeer. North of Nadym, Yamal-Nenets Autonomous Okrug, Russia (1997). (Photo: Svein Disch Mathiesen)

Fig. 1.6 Nenets Indigenous reindeer herders on the Yamal peninsula maintain long migration routes (700 km) as part of their adaptation to seasonal pastures use. The photo shows a reindeer husbandry brigade outside Bovanenkovo in Yamal crossing the gas pipeline to Europe (2009). (Photo: Svein Disch Mathiesen)

Fig. 1.7 The petroglyphs of reindeer, people, and fences outside Alta, Finnmark, Norway are believed to have been made in the period from approx. year 5000 BC and express a knowledge perspective between people, pastures, and animals which hitherto remains to be analyzed. (Photo: Svein Disch Mathiesen)

Fig. 1.8 Karen Anna L Gaup, 84 years old, marking her reindeer, June 2022. (Photo: Mia Carine Eira)

Reindeer husbandry today is no longer the foundation in some regions of the circumpolar civilization of the Indigenous peoples of the Russian Federation and has practically been lost

The reason is that, since the penetration of other peoples into the respective territories of the 16 reindeer herding peoples back in the sixteenth century, no one has ever asked them anything. Reindeer herding nations have never been treated as equal partners. Other nations made decisions that destroyed their traditional way of life: forced transition to a settled way of life, destruction of small settlements, separation of children from their parents, deprivation of ownership of reindeer through collectivization, loss of traditional knowledge, language, and culture.

Reindeer husbandry can still be restored. Yet this process requires active, free, and meaningful participation of the reindeer herding peoples and recognition of their rights:

- gratuitous use of lands that they traditionally occupied and owned.
- exclusive rights to herd reindeer, which they traditionally practiced.
- rights to own reindeer as an incentive to facilitate reindeer herding.
- the right to a traditional way of life and recognition of a year-round nomadic lifestyle for all members of the reindeer herders' families as a prerequisite for reindeer herding preservation and development.
- sustainable development of reindeer husbandry, aimed at continuous improvement of the herders' welfare and fair income distribution.
- equal opportunities for the access of reindeer herding peoples to basic resources, education, health care, nutrition, housing, and technological advances with respect to the nomadic way of life.

Traditional reindeer husbandry has been successfully preserved only in Yamal, Russia because the Nenets have always owned many animals.

Until recently, in Russia, the fact that reindeer herders own reindeer privately is considered a barrier to the reindeer husbandry development. Private owners and households do not receive subsidies while collective units receive funding.

Experts write that the transfer of reindeer herds to public ownership was very painful for the peoples of the North during collectivization, especially at the initial stage. They passively resisted, but gradually got used to it. This is not true. Collectivization caused enormous moral damage, from which the peoples of the North did not recover even after several generations. My grandfather was very upset about the transfer of his reindeer to the collective unit. It was not a voluntary act; he was forced to give the reindeer away. Earlier, my uncle's family was deprived of all their reindeer and had to leave. It was forbidden to even just communicate with them, let alone help in any way. Either a hundred years ago or today, reindeer herders want to own their reindeer and have as many animals as possible.

After the adoption of federal laws to protect the rights of the Indigenous peoples of the North, the number of private reindeer in Russia has increased. Today, privately-owned animals account for almost 59% of the total available livestock.

Reindeer husbandry in Russia is widespread in the most remote, hard-to-reach places, and a nomadic lifestyle using reindeer is the only way to maintain reindeer husbandry. All family members should migrate with the herd: parents, grandparents, children, schools, kindergartens, teachers, paramedics, and mobile slaughterhouses.

This type of reindeer husbandry is certainly expensive, but it addressed the issues of national security. It provides for the production of environmentally friendly food, protection and use of the Arctic territories, and preservation of the Indigenous peoples of the Russian Federation.

Today in the Republic of Sakha (Yakutia), reindeer herders restored the traditional practice of reindeer husbandry through the bottom-up approach. Reindeer herding communities and Indigenous peoples were represented in the legislative and executive authorities, and NGOs, therefore, took part in decision-making.

A total of 63 TTNUss (Territories of Traditional Nature Use) have been established in all national *naslegs* (settlements), which makes more than a half of the territory of the Sakha Republic. Schools and kindergartens do not operate between April and September when children join their families at the remote pastures. Children help their parents and receive a salary from the budget. The state allocates funds for wages, transportation of children, construction of corrals, fences, and housing on the nomadic reindeer routes for all forms of reindeer ownership. An International Center for Nomadic Schools has been established at the branch of the Federal Institute of Native Languages. The plans include the creation of the International Nomadic Center for the Education of Reindeer Peoples of the Republic of Sakha (Yakutia).

There are already communities that offer live reindeer for sale. Public organizations of reindeer herders – the Union of Reindeer Herders and the Union of Communities – have been in operation for many years. Authorities allocate grants to support reindeer herders' dynasties and introduce holidays such as the Reindeer Herder Day. An annual event is largely celebrated in many regions engaging all members of the reindeer herders' families to participate in reindeer races, sports competitions, cultural events, conferences, etc.

There are many positive changes in the development of reindeer husbandry, but for sustainable development, there is a need to change the paradigm from paternalism to partnership. There is a need to use the knowledge of reindeer herders to develop their way of life.

1.2.2 Dr. Sergey Kharuchi

Yamal Nenets AO, from Nenets reindeer husbandry, born in 1950, 72 years old, elected President of the Association of World Reindeer Herders (2017)

Reindeer herding culture and civilization is a unique phenomenon

Reindeer herding culture, reindeer herding civilization, and Indigenous peoples, together with their reindeer, have learned over the centuries to adapt to all the natural disasters, climate changes, and natural phenomena. Therefore, there should not be much concern here. Today, however, reindeer herders have to coexist with man-made, European civilization. Therefore, it is necessary to provide countermeasures that would help the Indigenous population to adapt to the ongoing processes. Indigenous peoples are used to the life on their pastures, fishing grounds, and ancestral lands, which are usually rich in natural resources. The economies of countries and regions flourish through the development of natural resources in the areas inhabited by the Indigenous peoples, the primary land users. Time and again, reindeer herders understand the necessity and importance of their countries' development and cede their pastures for industrial development, to the detriment of their families and clans. They are forced to move from their own lands and abandon the best pastures. Finding other grazing lands is always problematic and difficult. It always takes time and effort. In this regard, I think it is necessary for national governments and organizations of Indigenous peoples to act together and develop measures that would not be detrimental to the Indigenous populations. Coordinated actions promote sustainable development of the Arctic territories. This book pinpoints the perspective and vision of the Indigenous peoples to promote adaptation in the face of a warming climate and environmental change.

Each author offers their vision based on the specific features of their territories. Therefore, it is not possible – and not necessary – to develop a uniform 'fit-for-all' approach. Each national state and each region have its legislation, practices of survival in natural conditions, and unique climatic and geographical features. Therefore, a case-by-case framework that would accumulate recommendations for national governments and authorities seems a more feasible solution. The regions will eventually adapt these to the needs of Indigenous peoples. Industrial companies should also attend to this because the state alone cannot tackle these issues. Moreover, addressing these issues requires a significant amount of time and financing. All stakeholders interested in achieving sustainable development of their regions and creating a favorable environment for the traditional Indigenous livelihoods must act soon.

1.2.3 Karen Anna L Gaup

Sámi reindeer herder, born 1938, 84 years old

It's so much fun with reindeer

In the future, I expect the situation with reindeer husbandry to improve as it has already become better. We need politicians who understand the Sámi and especially reindeer husbandry, which is difficult to understand.

Recently, I was visited by the Oslo journalists, who wanted to interview me. However, they failed to do so because they did not understand my way of life. For example, I wear Sámi clothes every day, and I have never had Norwegian clothes. Nowadays in the Sámi village of Kautokeino, one hardly sees people in Sámi clothes on weekdays. Once I was in the hotel restaurant here in the village. There were a lot of people at the hotel, but only one person, besides me, would wear Sámi clothes. It struck me that at a party with so many people only two were wearing Sámi clothes. Not so long ago, at the fair in Kautokeino, some people would wear Norwegian clothes and sell Sámi clothes.

I think it is difficult to get young people interested in traditional clothes. Today I teach courses on traditional sewing to the girls in our *Siida*. But I see it as a good sign. In my youth, I used to sew myself and now I design courses for the girls. Today, there is so much else to do besides sewing. Gadgets, and devices take too much time. It can affect reindeer husbandry.

Despite the changes in the way I dress, I am positive about the future, especially when I think about the future of reindeer husbandry. Our reindeer husbandry community is affected by all the new things in Norwegian society. The youth also do not wear Sámi clothes while working in the mountains, but I wear a *beaska* and a *gákti* when I'm in the mountains. Sometimes, when I feed the reindeer herd, it gets too hot, so I take the *beaska* off. Modern clothes are not so comfortable to work in. I see how costumes have altered over the years. The reindeer do not like the new clothes that produce too much noise. Traditional Sámi clothes are silent. Yet today, it is easier to get hold of Norwegian clothes than Sámi clothes. The new 'plastic' clothes have come to stay. However, we must look ahead and move forward. One must not be so negative as to believe that the world would just perish tomorrow.

In 1958, no reindeer feeding was available, and the grazing was poor even back in the 1950s. Today, we can feed the reindeer. I see it as a future for the reindeer husbandry. Feeding is the best thing that has happened: you feed the animals and all reindeer can survive. The weather is so unstable now, we cannot do anything about that. First, it is mild in winter, then it freezes and then there is a layer of crust. The

Ministry of Agriculture agreed that feeding should be free and subsidized by the state.

Modern reindeer husbandry is experiencing both pitfalls and advances. Unlike in the past, it does not take much time to build up the herd anymore, and it is easier to get hold of the reindeer. We must maintain the reindeer number which is decided by the state. It is my responsibility as a reindeer owner to keep the herd alive, even if the expenses increase enormously.

The modern herd structure has a large share of females. With the better supplement feeding of females, we have to slaughter more of the calves. Some reindeer grazing districts have high calf numbers. When there are 93% females and 7% males in the herd, all old females are kept alive. In this case, the herder would only slaughter the calves. The state subsidy should also apply to other animals, not just calves. If the older Sámi reindeer herders had seen the current herd structure, they would have torn their hair out. Today's youth and Norwegians, in general, do not know what a good herd looked like before. They know little about what it should look like today. Sámi reindeer husbandry and clothing have changed. Both are changing quickly as does the rest of society. I think the state is willing to help with regard to supplementary feeding because they think we would accept less grazing area. It's so much fun with reindeer! On my birthday[1] I would always go to the herd. When I am with the reindeer, I am calm, and I feel harmony with nature. It is so exciting to go into the reindeer herd even if you are not going to do anything there. Observing and recognizing the reindeer is fun. Observing how the calf follows the female is important. I would never ever give away my reindeer earmark. The day I no longer have reindeer would mean it is no longer fun. The state understands that they must support reindeer husbandry, and politicians are getting better and better.

1.2.4 Johan Mathis Turi

Sámi reindeer herder, born 1952, 68 years old. Founding president of the Association of World Reindeer Herders, first Chair of the Board of International Centre for Reindeer Husbandry, and the first Secretary-General of World Reindeer Herders, former vice-president of Norwegian Sámi Reindeer Herders Association.

Traditional leadership and management system in the Sámi reindeer husbandry.[2] As far as I know, there is no documentation about leadership and the traditional system. From my own experiences working with reindeer, I will try to define what is Sámi leadership and management system, and what is the philosophy behind it. I would say the system is a horizontal leadership, it's not my words, it was a very successful Swedish businessman who introduced it, named Jan Carlzon. He was a leader of Scandinavian Airlines. As he defined it, it's a leadership and

[1] Ed: March 5.

[2] Interview is available at https://youtu.be/pg5Z_BUeicQ

management system that is transmitted into the traditional reindeer husbandry. Because it's opposite to the ordinary leadership and management system where you have one boss on the top and workers who follow his orders. So, instead, you give people responsibility and authority; and authority is very important. In my opinion, it is the only system that functions in reindeer husbandry where you have unpredictable situations with the weather, grazing, the environment change, and so on. So, let's see how it functions in practice. I have a story from my childhood. I was a little boy, maybe 8 or 9 years old. And at that time, we had been out. It was September or October. We had a family camp up on the tundra. We herded reindeer every day, 24 h a day and 7 days a week. In the daytime, we would bring reindeer into the reindeer herd into the family camp. And then we would start milking females; and of course, it was very boring for a little child. But then one day, one morning the herd was delayed. We were looking for the herd, it had been rainy and foggy in there, and we could not hear any bells or any dogs, nothing. The elders started to be worried as my mother said if it went for too long, they would not be milking the females because the calves would suck it. So, one of my cousins said okay, he would go and look for the herd and he disappeared. After approximately one hour or one and a half hours, we could hear the herd was coming and he conveyed the herd alone; he told me that when he went out to find the herd, it was gathered, and the herders had their rest. So, he only took the herd and brought it into a family camp. After 1 h, the herders came. There were two of my sisters and two of my cousins. Four girls. And of course, they were wet and, they were tired, and they both were very sad. And when I recognized that, of course, I was laughing, but then it was recognized by my father and my uncle, the elders in the herd and in this family group. They were also very sad. And they said to my cousin: "*you'll never do this again, you are old enough to understand that, to know not to understand, but to know that herder, who has the herd, is the boss. It's a boss and you are not allowed to take away the herd before the herders give you permission. What if there were no elder reindeer, the herd could have been lost today*". And of course, this is very important. Even I, as a child, understood why it was so important. With horizontal leadership, the herders have authority, all authority when they herd reindeer. So that was a very good day when I learned something. And I remind myself of this all the time.

1.3 Adaptation to Changing Arctic in Reindeer Husbandry

Adaptations are reflected in a rich vocabulary of Sámi peoples about ecosystems health and integrity in the understanding of snow, reindeer, and environmental factors (Chaps. 2 and 4). Adaptation knowledge is nested in and governed within the Indigenous society and is based on Indigenous peoples' traditional knowledge, perspectives, and insights and in this book we discuss different definition of adaptation (Chap. 2). Some regions of reindeer husbandry are close to their tipping points and already experienced loss of adaptive capacity and consequently reached its tipping point (Chaps. 2 and 7). It is therefore worth noting that the use of terms like 'overgrazing' has been debated within a reindeer herding context (Chap. 10). Unlike the dominant point of view blaming irresponsible reindeer herders for the depletion of pastures, chap. 10 see the problem as an institutional one – the result of public policies that created wrong incentives for reindeer herding entrepreneurs in recent decades. It would be immoral to assign the solution to the problem of overgrazing only to the most politically weak participant in the conflict – the private reindeer herder (Chap. 10). The background and content of the chapters in this book is the result of several projects focused on reindeer husbandry, traditional knowledge, resilience and adapting capacity. Since 2007, the *EALÁT,* a Sámi concept of 'a good pasture' (Nielsen, 1979), research project funded by Norwegian Research Council grant № 176078/S30: "Reindeer Herders Vulnerability Network Study: Reindeer pastoralism in a changing climate" has been a comprehensive, multidisciplinary, and multicultural study focused on resilience and climate change. An evaluation by Norwegian climate research showcased the *EALÁT* place and community-based approach as an example of bridging the gap between universities and societies, and between science and traditional knowledge (Rosswall et al., 2012).

The ongoing *RIEVDAN* research project "Rapid change – challenges and/or opportunities for sustainable reindeer husbandry?" is focused on the necessity to invest resources in the research of cultural capacity to change and the opportunities embedded in traditional knowledge and scientific knowledge. *Rievdan* is a Sámi concept that means change, be distinguishable from, or be able to manage (Nielsen, 1979).

The project has engaged students and researchers from Indigenous communities and leading scientific institutions over many years. The *RIEVDAN* Project is supported by the Research Council of Norway under grant № 238326, supporting the chapters published in the book to be used as a Project outcome for the foundation of a future master's program in reindeer husbandry. The contribution to the book was also made through Research Council of Norway grant № 270819: "Opportunities and Challenges for Integrating Sámi Reindeer Herding Traditional Environmental Knowledge in Environmental Governance", the NordForsk Project № 97299 "Feasibility study on co-production of knowledge between researchers and Indigeneous communities for climate change adaptation" and President of the University of the Arctic, and the Nordregio Project № A 18010 "Training of Arctic Indigenous Youth for Climate Change", and Nomadic Herders project funded by the Norwegian Ministry of Climate Change and Environment, and Arctic Council project "EALLU Arctic Indigenous Youth: Traditional Knowledge and Food Culture – Navigation Towards Sustainability through New Approaches for Addressing Arctic Change and Globalisation", International Centre for Reindeer Husbandry, Ministry of Local Government and Regional Development, Norway and Ministry of Foreign Affairs, Norway. Volume 2 of Reindeer Husbandry will focus on resilience to the changing Arctic.

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Chapter 2
Framing Adaptation to Rapid Change in the Arctic

Marina Tonkopeeva, Robert W. Corell, Nancy G. Maynard, Ellen Inga Turi, Inger Marie Gaup Eira, Anders Oskal, and Svein Disch Mathiesen

Abstract A safe operating space for Indigenous reindeer herders in the Circumpolar North must be the main priority for the governance of the Arctic and sub-Arctic territories in times of rapid changes on reindeer pastures. It also includes establishing reindeer herders' adaptive capacity to these changes. Anthropogenic impact on the earth system has reached a scale where it is no longer possible to exclude abrupt global environmental change. Indigenous reindeer herders' sustainability implies adaptive capacity that allows reindeer herders to operate safely. The Intergovernmental Panel on Climate Change highlights that the protection of grazing lands represents the most important adaptive strategy for reindeer herders under climate change. While the Arctic is rapidly integrating into the global economy, reindeer herders must face multiple socio-economic conditions and effects of assimilation past and present. This chapter addresses adaptation perspectives important for the future of reindeer husbandry and frames adaptation to rapid change for reindeer husbandry via Indigenous perspectives, insights, and knowledge.

Keywords Adaptive capacity · Climate adaptation · Resilience · Indigenous knowledge

M. Tonkopeeva (✉) · A. Oskal
International Centre for Reindeer Husbandry, Guovdageaidnu, Norway
e-mail: mt@reindeercentre.org

R. W. Corell
International Centre for Reindeer Husbandry, Guovdageaidnu, Norway

University of Miami, Coral Gables, FL, USA

Global Environment and Technology Foundation, Arlington, USA

N. G. Maynard
University of Miami, Coral Gables, FL, USA

Goddard Space Flight Center, NASA, Greenbelt, USA

E. I. Turi · S. D. Mathiesen
International Centre for Reindeer Husbandry, Guovdageaidnu, Norway

Sámi University of Applied Sciences, Guovdageaidnu, Norway

I. M. G. Eira
Sámi University of Applied Sciences, Guovdageaidnu, Norway

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2.1 Introduction

> By listening to each other with respect and with a sincere desire to understand, together we can create an even better society. In October, I was in Kautokeino during a ceremony where a historical treasure of great value to the Sámi people was returned to the Sámi, where it belongs. It was a reminder of the importance of culture, language, and history for a people's identity. It also reminded me of something that always strikes me in conversations with Indigenous peoples – whether it is in Norway, Canada, Australia, or the Amazon: Indigenous peoples have for thousands of years been dependent on the interaction with nature and all living things to survive. They possess valuable knowledge that is important to all of us. Large societies and Indigenous peoples around the world benefit from listening to each other and working together to safeguard what must be a common goal: To manage the earth's resources in a way that allows the generations after us to live good lives. (King Harald V of Norway 31.12.21)

Climate change has created unprecedented extreme temperatures in the Circumpolar North, such as in Eastern Siberia, where the temperature has increased by more than 6 °C in the past 30 years. Further, the surface air temperature in Kautokeino has increased by 3.7 °C in the spring in recent decades (Hanssen-Bauer et al., this volume; Popova et al., this volume). The increase in the frequency of the freeze-thaw and rain-on-snow events – *Goavvi* in Sámi or "the bad year caused by the ice and snow on the reindeer grazing pastures" – has increased from once every 50–100 years to frequencies on decadal times (Eira et al., 2018; Johnsen et al., this volume). These events have devastating consequences with losses of reindeer as the herd cannot reach their food: the lichen beneath the frozen surface contains the essential carbohydrates of life. These conditions are exacerbated by the fact that the ~1 °C increases in global surface temperatures are incrementing at rates ~4 times in the high north (Jacobs et al., 2021; Rantanen et al., 2022), and particularly in the Circumpolar Arctic (Hanssen-Bauer et al., this volume). The temperature in June 2020 set a record of 38 °C in the city of Verkhoyansk, in the Sakha Republic of Russia, where a record Arctic temperature was observed by the World Meteorological Organization (WMO). This led to wildfires in Siberia which were documented to be larger in area than all the rest of the world's wildfires combined. (Popova et al., this volume; Gerasimova et al., 2022). These scientific observations and studies in the Siberian Arctic are replicated in Western Canada, where in June 2021, the city of Lytton recorded an extreme temperature of 49.6 °C that burned the city to the ground and ignited a series of wildfires.[1] Parallel similar occurrences are reported in Alaska, Canada, and the Scandinavian region (Sjostrom & Granström, 2020).

Indigenous reindeer herders in the Circumpolar North are facing climate and socio-economic changes already impacting the economies and cultures of reindeer husbandry (Degteva et al., 2017; Hanssen-Bauer et al., this volume). A safe operating space (Rockström et al., 2009) for the herders must be the main priority for the governance of the Arctic and sub-Arctic territories in times of rapid changes in reindeer pastures. Loss of grazing land and biodiversity threaten the economic

[1] https://www.bbc.com/news/world-us-canada-57678054

and cultural well-being of the herding societies. Competing land use and climate change are threats to the pasture lands of Sámi reindeer herding. Reindeer pasture areas are exposed to the development of infrastructure, hydropower, mineral exploration, recreational cabin areas, and wind power (van Rooij et al., 2022).

Since 2011, about 50% of the biodiversity of reindeer calving grounds has been lost. It is expected to be reduced by another 10% in the scenario for 2030 in Finnmark in Norway (van Rooij et al., 2022). Infrastructure development on the Barents Euro-Arctic region depleted 25% of former reindeer pastures; in Finnmark, the figure reaches 35% (Jernsletten & Klokov, 2002). Every year the coastal areas in the north of Norway lose 1% of the traditional Sámi summer pastures; it is approximately the amount of grazing land used by one nomadic family in summer (Magga et al., 2011).

Reindeer husbandry management in Fennoscandia showcases social-ecological systems incorporating social, cultural, ecological, and economic values (Mathiesen et al., 2013). Landauer et al. (2021) reviewed the comprehensive literature and interviews with herders revealing that land use, climate change, and governance drive the emergence of social-ecological systems' tipping points in Finland's reindeer husbandry. Successful management depends on the quantity and quality of pastures to secure animals' health and welfare (Landauer et al., 2021). Thresholds for traditional boundaries for Indigenous reindeer husbandry in the Circumpolar North have not yet been identified, nor has their adaptive capacity.

Pasture conditions, climate, and societal changes are transforming the reindeer husbandry's operational environment. These inescapable facts lead to a central reality: it is essential to develop and implement adaptation strategies and practices that explicitly address the consequences of the unprecedented weather and climate changes in the Circumpolar Arctic. Adaptation strategies should directly address the challenges faced by the Indigenous reindeer husbandry cultures. Nymand-Larsen et al. (2014: 1594) refer to the protection of grazing land as "the most important adaptive strategy for reindeer herders under climate change". This chapter seeks to set a framework that details the reindeer husbandry's traditional knowledge, culture, and language as a central foundation for adaptation (Fig. 2.1).

2.2 Defining Adaptation

Sámi reindeer herder Mathis N. Eira, from Karasjok in Norway, spoke about the effects of climate change in the Sámi Parliament in 2021: "*reindeer herders in Norway have through their history adapted their practice repeatedly to the extent that they are not able to adapt any further*". In nature, adaptability requires variability because one never knows who, in a changing environment, has the capacity to take us into the future. In many businesses, for example, the chief bottlenecks to growth and adaptability are often the quality and distribution of leadership. Our organizations and communities need distributing leadership, with and without authority (Heifetz et al., 2009). Adaptation "usually refers to a process, action, or outcome in a system (household, community, group, sector, region, country) in

Fig. 2.1 Yamal Nenets reindeer herders working with the herd during spring migration. (Photo: E.I. Turi)

order for the system to better cope with, manage or adjust to some changing condition, stress, hazard, risk, or opportunity" (Smit & Wandel, 2006). The Intergovernmental Panel on Climate Change (IPCC) defines adaptive capacity as "*the ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences*" (IPCC, 2014). Because "adaptive capacity" refers to the underlying capacity to adjust to changing conditions, it can be considered an important expression of resilience (Arctic Resilience Report, 2016: 9). "Transformative capacity", on the other hand, implies a capacity to embrace more fundamental and far-reaching changes (Folke et al., 2010). This should not, however, be confused with transformation in societal resilience (Arctic Resilience Report, 2013). In this sense, resilience can be described as an essential underpinning of both adaptive and transformative capacity. An inability to adapt or transform implies a lack of resilience, and therefore an inability to successfully navigate a chosen trajectory in pursuit of goals within the broader cycles of social-ecological change. IPCC (2022) defined adaptation as the "*process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities*". Nelson et al. (2007) refer to *"...a process of deliberate change in anticipation of or in reaction to external stimuli and stress*." Climate adaptation capacity in Norway is defined by NOU (2010) as the ability of a system to adapt to climate change, including natural climate variations and extremes to limit potential damage, exploit any benefits and opportunities that arise, or deal with consequences. Climate adaptation implies autonomous adjustments through ecological and evolutionary processes.

There is a growing interest across the science community (National Research Council, 2002) and in the assessments of knowledge communities (Sullivan, 2019) to fully integrate the knowledge gained in the classical scientific community (Wolinsky, 2008) with the insights (Degteva & Nellemann, 2013) contained in Indigenous Traditional Knowledge (ITK) (UN FCCC, 2013). IPCC (2014, 2022) integrates the findings of the Fifth Assessment Report (AR5) and Sixth Assessment

Report (AR6) and emphasizes the increasing importance of Indigenous, local, and traditional knowledge as providing vital knowledge-based perspectives in international assessments and as insightful resources and practices to adapt to climate and global change, stating:

> Adaptation planning and implementation at all levels of governance is contingent on societal values, objectives, and risk perceptions (high confidence). Recognition of diverse interests, circumstances, social-cultural contexts, and expectations can benefit decision-making processes.... Indigenous, local, and traditional knowledge systems and practices, including Indigenous peoples' holistic view of community and environment, are a major resource for adapting to climate change, but these have not been used consistently in existing adaptation efforts. Integrating such forms of knowledge with existing practices increases the effectiveness of adaptation [...] There is increasing recognition of the value of social (including local and Indigenous), institutional, and ecosystem-based measures and of the extent of constraints to adaptation. (IPCC, 2014: 19)

Developing the capacities to frame adaptation strategies to address rapid change in the Arctic depends on using foundational scientific perspectives and insights from Indigenous and Traditional Knowledge.

2.3 Reindeer Herder's Perspectives on Adaptation and Developing Resilience

Adaptation knowledge is nested in and governed within the Indigenous society in the Circumpolar North and is based on Indigenous peoples' traditional knowledge, perspectives, and insights. The Sámi traditional knowledge of terrestrial ecosystems' health and integrity in northern Norway is based on the Norwegian and Sámi ways of knowing as described by Meløy (1989). Sámi adaptive knowledge perspectives have rarely been included in research about resources and management of ecosystems, in local planning for change, or in impact assessments in Norway. Ruong (1967) pioneered studies of the Sámi traditional knowledge. Eira (1994) started a discussion on traditional knowledge of reindeer herding and Magga et al. (2009) – on environmental conditions of reindeer husbandry. Magga et al. (2001) investigated Sámi perspective on animal welfare. Reindeer herding practices represent sustainable exploitation and management models originating in the terrestrial ecosystems of the North. They are based on generations of accumulated experience, conserved, developed, and adapted to the climatic and administrative systems of the Arctic (Oskal et al., 2009). Various aspects of these observations and adaptations are reflected in a rich vocabulary of Sámi terms and concepts about ecosystems health and integrity in the understanding of snow, reindeer, and environmental factors (Eira, 2012a). People describe the environment in terms of their local experience and their routine daily interactions with it (Eira, 2012a, b). These descriptions are incorporated into Indigenous languages constituting unique reindeer herders' terminology (Eira et al., 2013; Eira et al., this volume). For Sámi reindeer herders, snow is a prerequisite for mobility, tracking, visibility, and availability of pasture plants during seasonal migrations. Eira et al. (2013) discovered that herder's snow knowledge is more holistic and integrated into the ecology of the herd and pastures than the international standard snow terms. The analysis stressed the richness and accuracy of Sámi snow terminology and concluded with the two snow change knowledge systems: the Sámi traditional knowledge and scientific knowledge (Eira et al., 2013). Turi and Keskitalo (2014) and Turi (2016a) discussed major barriers to using traditional knowledge in the Norwegian governance of Sámi reindeer husbandry. It is necessary to integrate traditional knowledge at the early stages of policy formation to overcome such barriers. Sectorial fragmentation in national and regional government administration challenges cumulative long-term effects of land-use changes in decision-making. The extensive character of reindeer pastoralism and its dependence on different pasture types requires monitoring and recording of any changes in land use. Institutional governance, economic conditions, and other regulatory practices affect reindeer herding cultures and traditional knowledge (Eira, 2012b; Turi, 2008, 2016b; Eira, 2012a). Eira et al. (2016) documented the social traditional knowledge of Sámi reindeer pastoralism. In Finland, Magga (2014) described the two types of reindeer husbandry: Sámi and Finnish. The latter reports the overriding rationality of meat production (Heikkilä, 2006), while on the former presents a reindeer husbandry family enterprise, which is versatile in its use of the surrounding natural resources, and the internal Sámi herding management system of customary rights and the local reindeer herding communities.

When Norway started the modernization of reindeer husbandry in the late 1970s, Sámi women were in danger of losing their traditional right to own their animals (Margit Hansen Krone and Karen Anna Logje Gaup, personal discussion). In the Sámi culture, the women had always been strong and continued to keep reindeer even after getting married. In *siida*, a traditional Sámi management system, each family member had individual reindeer marks. In 1978, Norway introduced reindeer husbandry licenses to make the industry more profitable. The original plan was that only one person in the family could keep the reindeer earmark, which became a critical starting point for the mobilization of the Sámi women's movement (Margit Hansen Krone and Karen Anna Logje Gaup, personal discussion). The change of just one reindeer mark per operating unit would have favored the men in the reindeer husbandry. As a result of this process, Sámi women might have lost the right to an independent business base, therefore, weakening their economic and social rights. According to Margit Hansen Krone (personal discussion), a compromise was made: those women who had already had their marks could continue to have them if, for example, they were married to the primary owner of the license (Halsaa, 2013). Such gender role changes in Sámi reindeer husbandry reduced the adaptive leadership of the reindeer herders.

Arctic change implies a synergy of challenges and opportunities. Indigenous communities, however, often find themselves at a disadvantage. The negative impacts of the cumulative land use and socio-economic conditions often overshadow possibilities for positive local development in terms of the communities' capacity to be proactive and lead local actions (Oskal et al., 2017).

Reindeer herders' adaptation strategies are focused on applying flexibility (Arctic Resilience Report, 2013), continuous adaptations to changing environmental and weather conditions (following Turi, 2008; Reinert et al., 2009, Eira et al., 2018), and minimization of risk through fostering diversity in social organization, economy and through understanding biological diversity (following Magga et al., 2011; Arctic Resilience Report, 2013; Benjaminsen et al., 2015). Increased knowledge about the food culture of Arctic Indigenous peoples is the key to adaptation to Arctic change, building resilience, and maintaining the cultures and societies (Fig. 2.2).

Indigenous reindeer herders' resilience is about finding ways to strengthen their societies – from within. It is about using their own knowledge and developing their own societies. For example, local opportunities can be achieved if food governance networks, regulations, and praxis of those regulations are aligned with the Arctic realities (Oskal, 2022; Oskal et al., 2017, 2021; Oskal & Pogodaev, 2019). When reindeer herders talk about resilience – *Dávggas* – which in Northern Sámi means elastic, resilient, flexible, and tough, we are fundamentally talking about socio-ecological systems as recently defined by Reyers et al. (2022). If the theory of resilience is not correctly understood and applied, there is a danger that programs and practices touted to be about resilience may be misleading, unethical, or even eroding resilience (Reyers et al., 2022). In the concept of resilience, socio-ecological systems can withstand changes as shocks and still recover, but only up to certain limits (Arctic Resilience Report, 2013). In addressing resilience, one must ask: resilience of what? and resilience to what? These elaborations must be very concrete, and therefore, questions about the "resilience of Indigenous peoples" quickly end up meaningless. When discussing the resilience of reindeer herding in Norway, we could, e.g., discuss the introduction of the oil-based economy as a shock, or unpredictable critical events (Eira, 2012b). What are the effects of reindeer herders' resilience to the effects of the transition to the oil economy? How could reindeer herders uphold sustainability after oil? There is a danger that the concept of resilience could be disconnected from nature and used for other purposes. How could reindeer herders bounce back from shocks and disturbances, or perhaps even

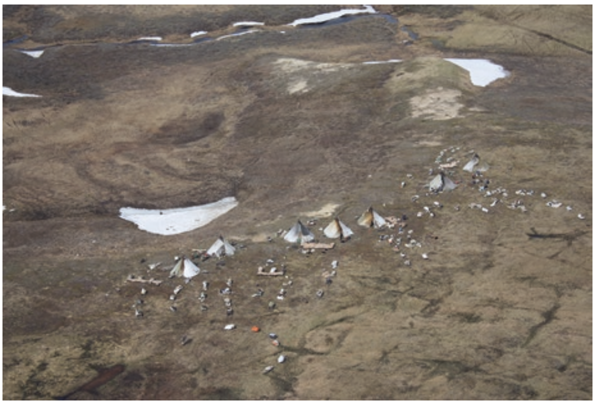

Fig. 2.2 Nenets reindeer herding brigade on the Yamal peninsula in early June 2009. Drying bread on the sleds after a long spring migration showcases the importance of a family-based economy. (Photo: S.D. Mathiesen)

develop forward? Inherent in change are both challenges and opportunities, producing both winners and losers. The reality of reindeer herders however is that they are not in a good position to utilize arising opportunities, being swamped in the current problems of the day (Oskal, 2022).

2.4 Adaptation as a Solutions Strategy

Reindeer pastoralism, the ancient model that maintained sustainable exploitation and management is based on accumulated experience and adaptation strategies to the climatic and political/economic transformations. In the research project, EALÁT (Magga et al., 2011), research focuses on understanding the adaptive capacity of reindeer pastoralism to climate variability and change and on the integration of reindeer herders' knowledge in the study and analysis of their ability to adapt to environmental variability and change (Oskal et al., 2017). The EALAT research highlighted that temperature variations lead to more "freeze-thaw-freeze" cycles that in turn result in the icing of the forage plants. Therefore, having more animals in the herd, for instance, sterilized ones, also becomes a more widespread practice in reindeer husbandry as an adaptation tool for herd structure management (Eira et al., 2018). Castrated males serve a special purpose in the herd in icy conditions because, due to their larger size, they are more able to easily break through ice layers in the snow, facilitating access to food for females and calves (Mathiesen et al. 2022). In addition, the presence of these males has a calming effect on female reindeer and calves, making herds easier to control (Tyler et al., 2007). Regulation of the herd structure through male reindeer castrations represents an integral strategy for future climate change adaptation.

Empowering Indigenous peoples through self-government and self-determination arrangements, including ownership and management of land and natural resources, is key to addressing the challenges of climate and other environmental and globalization changes (Fondahl et al., 2015). Increasingly, there are compelling reasons for the national governments of the Arctic states to work toward Indigenous peoples with the powers, resources, information, and responsibilities they need to adapt to climate change (Corell et al., 2019: 44).

The Arctic Climate Impact Assessment (ACIA, 2005) states that the vulnerability and resilience-building capacity engages various cultural perspectives. Corell et al. (2019) note: "*A reindeer herder will most likely define the vulnerability of their communities differently than would an outsider assessing the same socio-economic community. Evaluation of the exposure, sensitivity, and adaptive capacity of the human–environment system will require the scientific and Indigenous knowledge perspectives, observation, and participation of Indigenous peoples who are part of the human-environment system. These local perspectives can help identify important locally-oriented stresses, local human-environment challenges, and outcomes* *that they seek to obtain. Indigenous reindeer herders will inevitably identify changes in their cultural system, describe coping and adaptive capacities, monitor environmental and social phenomena and articulate their perspectives and findings*" (Corell et al., 2019: 44).

Some Arctic peoples already have political and management systems that could assess the impacts of climate change. These systems allow local and regional governments to act and deal with its consequences: for instance, land claims in Alaska and Canada and the establishment of regional governments in Greenland and Nunavut (Corell et al., 2019). Such political changes change the ways of management of the living and non-living resources with more local involvement and decision-making authority at the local or regional levels. Eurasian Arctic Land Cover and Land Use in a Changing Climate study explored the interactions of the land-cover and land-use change in the Arctic which is experiencing the most profound consequences of global warming (Gutman and Justice, 2011). The climate warming in the Circumpolar North and the Arctic region affects both the landscape and human activities, and hence human dimensions are an important aspect of the topic (Maynard et al., 2010). Environmental pollution and climate warming produce irreversible damage to the Arctic ecosystems. State-of-the-art remote satellite sensing combined with GIS is used for monitoring current land-cover changes and potential scenarios for the future (Maynard & Conway, 2007).

Innovative co-management regimes that allow for the sharing of responsibility for resource management between Indigenous and other users in the Arctic states are allowing the nations of the Arctic region and Indigenous peoples of the North to manage and regulate resource use in a way that incorporates Indigenous views and traditional resource use systems (Heininen & Southcott, 2010). MEMA Database provides examples of documentation regarding the 'meaningful engagement' of the Indigenous and local communities in the Arctic. Indigenous communities, scientists, and policymakers can work together to tackle the Arctic climate change challenges and embrace the opportunities caused by globalization. The rapid change in the Arctic continues to pose new challenges to managing and regulating societies that live in the region leading to the following adaptation strategies in the reindeer herding societies:

Co-production of knowledge is an adaptation strategy in which the academia and Indigenous reindeer herding peoples can apply an ethical and systematic co-production framework for sustainable adaptation (Näkkäläjärvi & Juntunen, 2022; Stith et al., this volume).

Adaptation through feeding in winter. Reindeer are highly adaptable ruminants with digestive mechanisms that enable them to utilize large seasonal changes in the nutritional quality and availability of forage that are a characteristic of northern habitats (Mathiesen et al., 2005). Reindeer pastoralism in Norway was based on the sustainable use of natural pasture (Mathiesen et al., 2000). Especially in winter, when access to forage is restricted by crusted snow or ice, feeding has been more common, and therefore the reindeer husbandry is adapting to new feeding strategies. The provision of small amounts of supplementary feed can improve survival in winter and increase the degree of tameness of the herd. The consequences of increased use of expensive feed for the resilience of the system have yet to be investigated (Johnsen et al., this volume; Mathiesen et al., 2022).

Adaptation through changing the herd structure. Reindeer herders have traditionally maintained a high phenotypic diversity in the herds. The Sámi concept of a "beautiful" reindeer herd – *čáppa eallu* – encompasses diversity, which reflects an adaptation strategy aimed at reducing vulnerability to the consequences of unfavorable and unpredictable conditions (Magga, 2006). In this way, the so-called unproductive animals have special roles, which contribute to the productivity of a herd: creating a serene atmosphere in the herd, digging up snow and icy crust, and improving animal welfare. For example, reindeer herds in Finnmark in the 1960s would include up to 50% of adult male reindeer, many of which were castrates. Today, reindeer herds in Finnmark have about 10% bulls. Another example of adaptation practice is castration. Castrated male reindeer do not come into a rut, are calmer, heavier, and are better at finding lichen in the snow. We suggest that the reintroduction of castrates in Norway could be a strategy for the survival of individual animals and the herd (Skum et al., 2016; Mathiesen et al. 2022). The adaptive consequence is the transition from calf slaughtering to the slaughtering of the 1.5 years old males and old females.

Adaptation through the protection of critical grazing land and migration routes. Adaptation involves maintaining nomadic pastoralism. A continuous loss of pastures and critical migration routes has and will lead to a situation in which there will always be "too many" reindeer and herders in an area. Movement beyond this negative focus requires lifting the general level of competence locally through research and training. This will also involve a paradigm shift in terms of the perception of and importance attached to reindeer herders' traditional knowledge and landscape management (Vistnes et al., 2009). It is important to develop courses in the training of Indigenous peoples to adapt to the degradation of grazing land.

Adaptation through an improved economy. For reindeer herders, adaptation is about securing their own control over the most valuable parts of their value chain (Krarup Hansen et al., 2022; Eira et al., this volume; Reinert & Oskal, 2022), Recently, Reinert et al. (2022) investigated the adaptation potential in *Entrepreneurship in a Changing Arctic*: by analyzing Siberian Reindeer Herders and access to the Northern Sea Route (NSR) and new markets. The researchers see potential in developing reindeer herding in the NSR region through the creation of local products rather than competing with imported industrial beef and pork production (Reinert & Oskal, 2022). Adaptation to an improved economy should include a strengthening of the family-based reindeer husbandry (Fig. 2.3).

Fig. 2.3 Adaptation to climate change in reindeer husbandry must include protection of grazing land and avoid blocking of migration routes and calving ground. (Photo: S.D. Mathiesen)

2.5 Institutions as Essential Elements of Addressing Change and Adaptation Strategies

Climate change, along with other environmental changes of significant importance, has brought forth a wide array of pilot projects and experimental programs as well as proposed actions, roadmaps, and pathways toward the future. These solution-oriented ideas have brought forth new initiatives by industry and businesses, actions to limit fossil fuel emissions, and studies of adaptation strategies at local and regional levels by Indigenous cultures and have raised significant political attention pro and con. The outlined below is posed as a potential framework that seeks to structure solutions in what might be called a "Solutions Space". This framework argues that there are five basic elements, inter alia, within which solutions to climate and environmental change might be more effectively managed and implemented, including:

Type 1 Solutions based on Enhanced Knowledge: Advancing knowledge and understanding by embracing and using both scientific and Indigenous reindeer herder's knowledge to frame the collective understanding of the future of the nexus between humans and the natural world and by structuring deeper understandings and monitoring, including comprehensive and integrative assessments which should include a master program in reindeer husbandry.

Type 2 Solutions based on Extending Adaptive Capacities: Developing enhanced and innovative adaptive capacities by understanding the consequences of the change and building resilience into natural and socio-economic systems in regions of reindeer husbandry.

Type 3 Solutions by Understanding Root Causes of Change: Identifying and addressing the root causes of the change and developing mitigation strategies and implementation practices together with the reindeer herders and Indigenous knowledge holders.

Type 4 Solutions that Inform and Extend Understandings: Change requires enhanced strategies and practices in reindeer husbandry that diffuse and communicate broadly fundamental causes of and strategies to build resilience in the Indigenous societies.

Type 5 Solutions that support Decision-Making: Develop methodologies and practices that support policy development, governance practices, and best-practice dialogue with appropriate real-time analysis of options and alternatives. One example is the GIS based "Reindeer Mapper" by NASA for Environmental observations by reindeer Herders (Maynard et al., 2010) and the Arctic Council Circumpolar Local Environmental Observer Network (CLEO).[2]

2.6 Future Adaptive Leadership

Climate and socio-economic change are now evident across the Arctic and are particularly evident in reindeer herding cultures and their traditional areas (McCarthy et al., 2005; Magga et al., 2011; Larsen et al., 2014) and will require immediate adaptive solutions for societal opportuni ties (Burgess et al., 2018). Reindeer herding cultures and their traditional knowledge are affected by institutional governance, economic conditions, and other regulatory practices. It is important to increase the flow of information and insights about Circumpolar reindeer herding and how resource conflicts could be avoided by including local Arctic societies and rights holders at an early stage of planning in the industrial development projects (United Nations Economic and Social Council (ECOSOC), 2012). Anthropogenic pressures on the reindeer pastures have reached a scale where abrupt global environmental change can no longer be excluded (Tyler et al., 2007, 2021).

Reindeer herding communities have challenges to develop their knowledge and insights into practical adaptation strategies. In Finland, reindeer herders report that forestry has massive impacts on reindeer husbandry. It has reduced the quality of pastures. "They have been logging everywhere. There is no lichen anymore! It is gone. We could only keep about 500 reindeer if they were left on their own. They would starve in January without supplementary feeding", one reindeer herder reported (Landauer et al., 2021). Supplementary feeding requires more time by reindeer herders in Finland, workforce, and money. For financial reasons – an economic tipping point – in particular, large-scale supplementary feeding is not always possible, only emergency feeding (Turunen & Vuojala-Magga, 2014; Landauer et al., 2021).

When a system of reindeer husbandry has lost its adaptive capacity and consequently reached its tipping point, it is described as a sharp or abrupt change in the climate variables or biological variables where one after the tipping point often enters a state that one cannot say in advance what will happen. With the

[2] https://oaarchive.arctic-council.org/handle/11374/2608

supplementary feeding of reindeer in Finland, there is the risk of diseases involved, and reindeer are becoming tame and more dependent on herders (Turunen & Vuojala-Magga, 2014). Landauer et al. (2021) note that this is how one of their interviewees perceives an economic tipping point which, in this case, is determined by the financial capacity to have supplementary feeding and workforce given that old-growth forests decrease due to extensive land use:

> It would be extremely costly to feed our 8,000–9,000 reindeer in this area, and it would also require an additional workforce. But if there are no arboreal lichen pastures, we must feed our reindeer. Reindeer have difficulties with digging in very harsh conditions when there is an icy snow cover. Arboreal lichen is the only natural forage in winter. If it disappears, we will reach a critical point in reindeer management in this area. (Turunen & Vuojala-Magga, 2014)

Yet expanding the number of herders is perceived as redundant because it results in the alternative tipping point. However, some might see this as a source of additional income (Heikkinen, 2006; Dana & Åge Riseth, 2011; Landauer et al., 2021).

Heifetz et al. (2009) explored the distinctive theory of adaptive leadership: Why is change difficult for example in Sámi reindeer husbandry in Western Finnmark in Norway? Many know the adage: people resist change. In fact, this is not entirely true. People do not resist change, per se; people resist loss (Heifetz et al., 2009). Change can involve various kinds of losses, yet when people know that change is good for them, they embrace it. In nature, adaptability requires variation because one never knows who, in a changing environment, has the capacity to take us into the future. In many businesses, for example, the biggest bottlenecks for growth and adaptability are often the quality and distribution of leadership. Our organizations and communities need distributing leadership, with and without authority (Heifetz et al., 2009).

Berkes & Jolly (2002) analyzed the adaptive capacity of Indigenous communities and featured integral long-term coping strategies of the Arctic Indigenous Peoples:

(1) group size mobility and flexibility; (2) seasonal harvest and resource cycles flexibility; (3) knowledge of the local environment; (4) networking and information-sharing mechanisms for risk mitigation; and (5) trade between communities (Berkes & Jolly, 2002). Arctic human and environment systems have a long history of coping with and adapting to social and natural changes (McCarthy et al., 2005).

In 2004, Arctic Council Ministerial meeting in Reykjavik, Iceland adopted the Arctic Climatic Impact Assessment (ACIA) where one chapter was written in co-production of knowledge with the team around Association of World Reindeer Herders (WRH) and Harvard University researchers: "Climate change in the context of multiple stressors and resilience" (McCarthy et al., 2005). One direct follow-up of the ACIA report was the Norwegian Government's establishment of the International Centre for Reindeer Husbandry (ICR) in close cooperation with the Association of World Reindeer Herders in Kautokeino in 2005. It is an example of adaptive leadership that made it possible to lift the reindeer herders' traditional knowledge in research, education, and development of adaptation strategies for reindeer husbandry.

Founding president of WRH Johan Mathis Turi has expressed reindeer herders' perspectives of adaptation in the following way:

> We have some knowledge about how to live in a changing environment. The term «stability» is a foreign word in our language. Our search for adaptation strategies is therefore not connected to «stability» in any form but is instead focused on constant adaptation to changing conditions. (Oskal et al., 2009)

Furthermore, Johan Mathis Turi has expressed his reflection on adaptation: "*At one of the Arctic Council meetings, the head of ACIA, Dr. Robert Corell, presented a preliminary report on climate change and its effects. For my part, I did not get much of what he said since I do not speak English as well. Eventually, however, he came up with a formula that was so simple and informative that even I began to sense the scope of what he was saying. It showed a universal concept of adaptation. It struck me then that this simple formula, which by the way looked like this:* ***V (vulnerability/raššivuohta) = I (impact/váikkuhus) – AC (adaptive capacity/heivehanmunni)*** *was an exact and precise description of the concept that reindeer husbandry has traditionally built its existence on. The most amazing thing about the formula, however, was that in all its simplicity it also contained instructions on the most common way to respond to changes"* (Mathiesen et al., 2007 as adapted from Turner et al., 2003).

The International Polar year 2007–08 (IPY) provided a clear mandate for the participation of Arctic Indigenous knowledge. Furthermore, the ICARP II conference in Copenhagen in 2015 concluded that there had been a paradigm shift in Arctic research towards a holistic and multidisciplinary approach, which includes the human dimension, Indigenous insights, and a more integrated understanding of the Arctic as part of the world (Eira, 2012a, b). IPCC (Larsen et al., 2014; IPCC, 2022) allowed authorship from Indigenous communities within the Arctic, which resulted in the IPY EALAT initiative – Reindeer Herders Vulnerability Networks Study, which brought forth new adaptive knowledge and insights (Eira, 2012a, b; Turi, 2016a, b; Magga et al., 2011; Maynard et al., 2010; Oskal et al., 2009) (Fig. 2.4).

Fig. 2.4 Indigenous reindeer herders from the Circumpolar North met in Guovdageaidnu for a joint training program on the use of traditional knowledge to protect biodiversity at the Sámi University of Applied Science and International Centre for Reindeer Husbandry (2017). (Photo: S.D. Mathiesen)

In 2020, the Association of World Reindeer Herders, the International Centre for Reindeer Husbandry, and the University of the Arctic EALÁT Institute signed a new agreement with the Belfer Center for Science and International Affairs at Kennedy School of Government at Harvard University to establish a platform for discussing the most pressing Arctic challengers, bringing together Indigenous and non-Indigenous stakeholders, and developing leadership training for Indigenous youth.

Emerging Indigenous leaders and Indigenous scholars across the Arctic as well as communities on the frontlines of Arctic climate change and globalization are working in three vital areas:

Arctic Indigenous Youth Leadership Seminar Program: in 2021, a joint effort by the International Centre for Reindeer Husbandry, the Arctic Initiative at the Harvard Kennedy School, the Association of World Reindeer Herders, Arctic Council Indigenous Peoples Secretariat, and the UArctic EALÁT Institute building on earlier cooperation, resulted in a training seminar for Indigenous leaders. Hold in memory of Professor James McCarthy and his strong dedication to the Arctic, the seminar addressed resilience, adaptation, and leadership, and aimed at competence and confidence building for Arctic Indigenous youth for a more sustainable future in the Arctic and beyond.

Arctic Knowledge Systems Study Group: Working with the Harvard Arctic Initiative and groups of Harvard graduate students investigating how especially traditional Indigenous knowledge and knowledge systems can strengthen society resilience (i.e., robustness towards shocks and crisis).

Arctic Resilience Forum: The Arctic Resilience Forum 2020, co-organized by the Arctic Council and the Arctic Initiative at Harvard Kennedy School's Belfer Center, hosted an Indigenous Youth Leadership session, which was focused on Indigenous resilience leadership, representing Indigenous youth leaders from Alaska to Yamal and linking with the ongoing EALLU project.

The Northern Sustainable Development Forum, a permanent international platform for discussing sustainable development in the Arctic and the High North, hosted an international seminar on the Intellectual Property Rights of Indigenous Peoples' Knowledge, Cultures, and Languages in the time of digitalization supported by the World Intellectual Property Organization (WIPO). The seminar discussed different types of knowledge of the Arctic Indigenous peoples including food heritage and new approaches to the adaptation in the Arctic concluding with the following needs:

1. to the Arctic Council to promote closer cooperation of all Permanent Participants on Indigenous peoples' intellectual property issues.
2. to develop more specific international legal norms regarding intellectual property, protection of the use of traditional knowledge, and other elements of culture, taking into account the specifics of the Indigenous peoples' knowledge.
3. to the scientific community, when documenting the traditional knowledge of Indigenous peoples, obtain the prior and informed consent of native speakers of the language and culture, which reflects a specific intention to use the materials received.
4. to conduct workshops on the protection of intellectual property rights of Indigenous peoples with the WIPO support. (International Centre for Reindeer Husbandry, 2021)

Both scientific, traditional, and Indigenous experience-based knowledge, knowledge transformation, education, and training of the future Arctic leaders are key factors for the future sustainability of reindeer herders' societies and their adaptation (United Nations Economic and Social Council (ECOSOC), 2012). It is imperative that all available forms of knowledge are included when developing adaptation strategies to climate change in reindeer husbandry. Renewable industrial activities and new strategies for ecosystem services in the Arctic must respect the rights of Indigenous reindeer herders. The Indigenous peoples of the Arctic must be awarded the possibility to adapt to the changing environment and seek sustainable societal opportunities.

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Chapter 3
'Leaving No One Behind' – Sustainable Development of Sámi Reindeer Husbandry in Norway

Kathrine I. Johnsen, Inger Marie Gaup Eira, Svein Disch Mathiesen, and Anders Oskal

Abstract Within pastoral systems there is deep knowledge of the dynamics of the landscape and nature; and the Sámi traditional reindeer herding understanding of sustainable reindeer husbandry holds adaptive mechanisms for dealing with changing conditions in nature and extreme weather events. The Norwegian state has had policies for sustainable reindeer husbandry since the early 1990s. This chapter discusses two conceptualizations of sustainable reindeer husbandry – that of the state and that based on Sámi traditional reindeer herding knowledge. Based on public documents and empirical data from a workshop where herders shared observations and reflections from an extreme winter event (*goavvi*) in Finnmark 2019/2020, we discuss the different knowledge systems and tools for dealing with change embedded in the two conceptualizations. Norway is a strong supporter of the global 2030 Agenda for Sustainable Development building on the principle of 'leaving no one behind', yet herders argue that policies and regulations for sustainable reindeer husbandry policies make their livelihoods vulnerable to climate change and other types of environmental change. The gap between the state's and the participating herders'

K. I. Johnsen (✉)
Norwegian Institute for Water Research (NIVA), Oslo, Norway
e-mail: kij@niva.no

I. M. G. Eira
Sámi University of Applied Sciences, Guovdageaidnu, Norway

S. D. Mathiesen
International Centre for Reindeer Husbandry, Guovdageaidnu, Norway

Sámi University of Applied Sciences, Guovdageaidnu, Norway

A. Oskal
International Centre for Reindeer Husbandry, Guovdageaidnu, Norway

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understanding of 'sustainability' and tools for maintaining the wellbeing of the herd create misunderstandings and mistrust between the actors. Moreover, state decisions undermine the traditional knowledge and practices and push herders to practice a 'Norwegianized' type of pastoralism. In the current public management of reindeer husbandry, Sámi traditional reindeer herding knowledge and practices have been left behind.

Keywords Reindeer husbandry · Sustainable development · Traditional knowledge · Climate change · Adaptation

A young reindeer herder follows the reindeer herd during Spring migration - leaving no one behind. (Photo: Inger Marie Gaup Eira)

3.1 Sustainable Reindeer Husbandry in an Unpredictable Environment

Like other extensive pastoral systems, reindeer husbandry requires large areas, migration routes and access to seasonal pastures. Climate and environment have always determined the conditions by which reindeer herding is practiced. Through mobility, reindeer herders take advantage and adapt to the temporal and spatial changes in nature – an adaptive mechanism they share with pastoralists all around the world (Scoones, 1994; Niamir-Fuller, 1999; Fernandez-Gimenez, 2000; Krätli

& Schareika, 2010; Behnke et al., 2011; Johnsen et al., 2019; Turner & Schlecht, 2019; Gillin, 2021). Traditional reindeer herding knowledge contains strategies for structuring a herd and moving through the landscape to benefit from the seasonal changes and the pastures' diverse grazing resources, and to minimize the negative impacts of the harsh climate, insect plagues and threats from predators (Paine, 1996). Like other local and indigenous livelihoods in the Arctic, reindeer husbandry is affected by climate change (Eira et al. 2018). Warmer temperatures are driving changes in flora, fauna, and the physical appearance of the northern landscapes. The mean winter temperatures are increasing, and consequences include changes in the snow structure, reductions in lake and river ice cover and increases in winter thaw events – all of which affects the reindeer's mobility and access to forage (Hanssen-Bauer et al., this volume, Chap. 8).

While reindeer husbandry is adjusted to annual differences and changes in nature, they sometimes face events that are especially challenging, such as a *goavvi*. *Goavvi* is a Northern Sámi term that refers to a snow condition that appears during extreme weather events (Eira, 2012). *Goavvi* is caused by ice layers on top of or in the snow (*jiekŋa*), ice frozen into the vegetation (*bodneskárta*), deep snow (*gassa muohta*), packed snow drifts (*čearga*) or a combination of these. These conditions can cause impenetrable pastures – often referred to as 'locked' pastures. The degree of *goavvi* is determined by precipitation, temperature and wind which forms the snow metamorphism and layers of ice (melt-freeze crusts). However, even when the snow is deep and there are ice layers in the snow, the grazing conditions can be good. Whether the reindeer can dig through and access the vegetation depends on the thickness of the ice layers, how hard the snow is, and whether the snow is loose to the ground where the vegetation is.

According to the dictionary, *goavvi* means 'ruthless weather and seasons' (Kåven et al., 1995). The term *goavvi* denotes the effects of extreme weather conditions which make pastures inaccessible and cause animal starvation and death. It is a condition that affects both the livelihood and the psychosocial well-being of herders. In the years following a *goavvi*, the calf production (*miesehis jagit*) decreases, the calves born are more vulnerable because the females produce less milk, and the herd is more vulnerable to diseases (Eira, 2012). There is no word for *goavvi* in the Norwegian language; a term often used is *beitekrise* (grazing crisis). The term refers to poor grazing conditions but does not contain an explanation for why the conditions are poor. Over the last hundred and some years, herders in Guovdageaidnu have experienced *goavvi* sixteen times (Fig. 3.1); most severe in 1917/18, 1967/68 and 1996/97 (Eira, 2012). The most recent occurrence was in 2022, and climate change scenarios predict that the occurrences of *goavvi* will likely increase (Hanssen-Bauer et al., this volume, Chap. 8).

Within pastoral systems there is deep knowledge of the dynamics of the landscape and nature; and within the Sámi traditional reindeer herding knowledge about and understanding of sustainable reindeer husbandry, there are built in mechanisms for coping with and adapting to unpredictable and extreme weather events that threaten their livelihood. The traditional knowledge differs, however, from the knowledgebase of the state policies for sustainable reindeer husbandry. And the state policies provide a different set of tools to maintain the well-being of reindeer in times of crisis. The case presented in this chapter is sustainable development in the context of Sámi reindeer husbandry in Norway. It compares and discusses the two conceptualizations of 'sustainable reindeer husbandry', their knowledgebase for understanding 'sustainability' and their embedded adapting mechanisms considering climate change.

The analysis presented in this chapter is informed by accounts of the 2019/2020 *goavvi* event shared by 11 reindeer herders from 11 winter *siidas* in West Finnmark. The herders' accounts were shared via photos and text messages in March/April 2020 and a participatory workshop with six of these herders in June the same year. Figure 3.2 presents the reindeer herding regions of Norway and the geographical area covered by the study. The workshop assessed the *goavvi* event and the emergency response provided by the state. First, each herder shared his observations and concerns, and then, these inputs were discussed and analysed. Jointly, the workshop participants and the authors of this chapter developed a timeline presenting decision-making and herders' observations during the *goavvi* winter in Finnmark (see Table 3.1). The main language of the workshop was Northern Sámi. The research was conducted in accordance with ethical research standards (ICR, 2007; NESH, 2019). Perspectives and knowledge shared by the herders have been anonymized and are reflected in this text with the participants' written consent. In this text we use the term 'herder' to refer to both reindeer herders and owners. Translation of Norwegian quotes are made by the authors.

We start, however, by providing a backdrop through a brief review of two milestones in the global discourse concerning 'sustainable development' – the Brundtland Report (1987) and the 2030 Agenda (2015) – and how they present the role of indigenous peoples and traditional knowledge in achieving sustainable development and shaping a common future where no one is left behind.

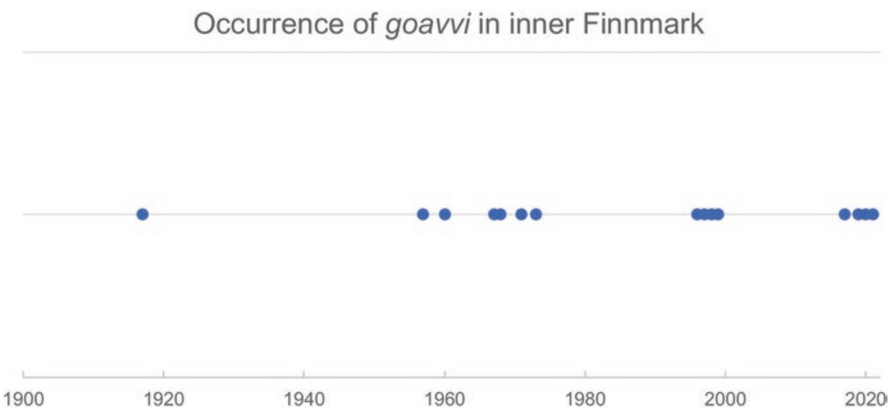

Fig. 3.1 Occurrence of *goavvi* in inner Finnmark. Based on Eira (2012) and conversations with reindeer herders

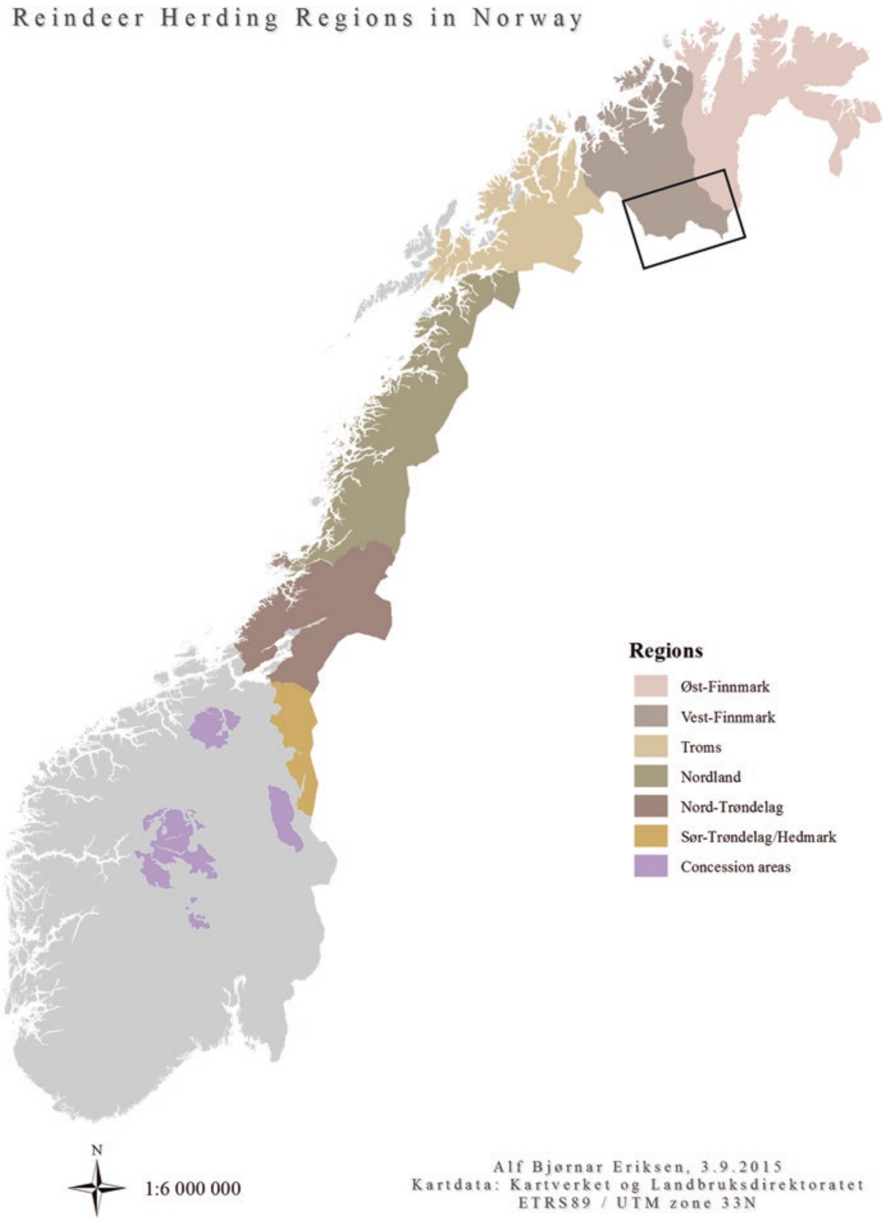

Fig. 3.2 Reindeer herding regions in Norway. The lines roughly frame the winter pastures of West Finnmark

Table 3.1 A timeline presenting decision-making and herders' observations during the *goavvi* winter in West Finnmark 2019/2020

Timeline of the *goavvi* winter in West Finnmark 2019/2020	
November 2019	At the beginning of November, the first reindeer herding districts report to the County Governor's office about difficult grazing conditions.
January 2020	**10/01** Several *siidas* report about challenging grazing conditions. **22/01** The Emergency Preparedness Committee (EPC) inspects one of the three herding zones of inner Finnmark (30B). **24/01** The EPC ascertains grazing crisis in parts of inner Finnmark. **28/01** Norwegian Agriculture Agency announces that there are challenging grazing conditions in inner Finnmark. **31/01** The government states that reductions in reindeer numbers have resulted in a clear improvement of the reindeer grazing conditions in inner Finnmark.
February 2020	**6/02** Reindeer herders of inner Finnmark (30A, 30B and 30C) meets with the EPC about the grazing crisis. **10/02** The County Governor's office approves the use of the districts' emergency savings and issues a press release about the grazing crisis in parts of Finnmark. **21/02** The County Governor's office announces a grazing crisis in two of three herding zones of inner Finnmark (30B and 30C). **25/02** The EPC inspects the third herding zone of inner Finnmark (30A). **27/02** The government increases the state emergency preparedness fund by NOK 10 million.
March 2020	**13/03** First payment of emergency grants for supplementary feed for reindeer; the County Governor's office encourages the herding districts to apply for emergency grant for supplementary feed. **20/03** The government informs that NOK 2.8 million has so far been distributed for feeding reindeer. **24/03** Mayors from 35 municipalities in northern Norway send a joint letter to the government asking for more support towards the immediate grazing crises and its long-term consequences.
April 2020	**3/04** Helicopter transport of supplementary feed to the winter pastures has started. **4/04** Grants issued to reindeer herding districts in Finnmark, Troms and Nordland. **7/04** The state emergency fund is increased by NOK 20 million. **17/04** The County Governor's office informs the herding districts that emergency funds will be granted beyond the period first announced.
May 2020	**5/05** The Minister of Agriculture and Food and the Minister of Regional Development and Digitalisation make a joint statement where they acknowledge the difficult conditions for reindeer husbandry. **8/05** The County Governor's office encourages again the herding districts to apply for emergency grant for supplementary feed. **19/05** The Minister of Agriculture visits Finnmark to look at the grazing conditions. **29/05** Helicopter transport of supplementary feed continues.
June 2020	**4/06** The last feed sack of supplementary feed is flown out to herding districts Finnmark and the state emergency fund is further increased by NOK 10 million.
July 2021	**19/07** The regional newspaper *Ságat* reports that the County Governor's office has reclaimed emergency grants from many reindeer herders and thereby adding an extra stone to the burden of families who were hit hard by the grazing crisis in the winter of 2019/20.

Sources: Eira M (2020); conversations with herders in Spring 2020

3.2 A Common Future Where No One Is Left Behind

Sustainable development' became part of common political jargon in the aftermath of the launch of "Our common future" in 1987, a report by the UN World Commission on Environment and Development (WCED). The report – often referred to as the Brundtland Report in recognition of former Norwegian Prime Minister Gro Harlem Brundtland's role as Chair of WCED – presented environment and development as a single issue in the concept of 'sustainable development'. The Brundtland Report provided several definitions of sustainable development, the most recognized being development which "meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987, p. 8).

To ensure a fair distribution of the benefits of development, the Brundtland Report promoted political systems that secure effective citizen participation in decision-making. WCED argued that all sectors of society should actively participate in consultation and decisions relating to sustainable development and recognised the special position of tribal and indigenous peoples. It stated that while development would, in most cases, lead to a gradual integration of local communities into a larger social and economic framework, some communities – such as the indigenous or tribal peoples – might not benefit from this development. On the contrary, WCED was concerned that insensitive development could threaten these peoples' knowledge and rights (WCED, 1987, p. 12):

> Tribal and indigenous peoples will need special attention as the forces of economic development disrupt their traditional lifestyles – lifestyles that can offer modern societies many lessons in the management of resources in complex forest, mountain, and dryland ecosystems. Some are threatened with virtual extinction by insensitive development over which they have no control. Their traditional rights should be recognized, and they should be given a decisive voice in formulating policies about resource development in their areas.

The WCED members from Canada (the founding Executive Director of the UN Environment Programme, Maurice Strong, and the Commission's Secretary General, Jim MacNeill) played important roles in formulating the dilemma that indigenous peoples' livelihoods and rights could be threatened by economic development in society at large. The Canadian members were informed by the situation of Canada's indigenous peoples as industrial development increasingly encroached upon their traditional lands (Robinson, 1999).

Since 1987, the concept of sustainable development has altered to incorporate a greater focus on social inclusion (Sachs, 2015). The 2030 Agenda for Sustainable Development, adopted by the UN General Assembly in 2015, builds on the principle of 'leaving no one behind'. The 2030 Agenda includes 17 goals that jointly will secure a better and more sustainable future for all. The goals have an overarching focus on the human rights principles, justice, and the need for empowering vulnerable people. The 2030 Agenda does not have a strong explicit focus on indigenous peoples, but it encourages participation of indigenous peoples in the implementation and evaluation of the Sustainable Development Goals (SDGs) at country level (United Nations, 2015).

3.3 Norwegian Adoption of 'Sustainable Development' for Sámi Reindeer Husbandry

In Norway, there is a sectoral responsibility for following up on national commitments on sustainable development, and the responsibility for ensuring sustainable reindeer husbandry is placed within the Ministry of Agriculture and Food (MAF). The Norwegian follow up of the Brundtland Report was outlined in the report called "Environment and development" issued by the Ministry of Environment (St. meld. 46, 1988–1989). A main focus of this report, however, was Norway's international development aid. National sustainable development got less attention. The report included a chapter on agriculture, but there was no reference to Sámi pastoralism or other Sámi livelihoods.

The first White Paper which addressed sustainable reindeer husbandry was published 3 years later by MAF (St. meld. 28, 1991–1992). The White Paper was informed by the Brundtland Report, but it emphasised two aspects which it presented as vital to the continuation of reindeer husbandry as a livelihood and a basis for Sámi culture: (1) Reindeer grazing had to adapt to the pasture resources; and (2) the reindeer industry had to become economically self-sufficient to a greater extent. The White Paper refers to an assessment conducted by researchers at the Norwegian Institute for Urban and Regional Research (NIBR) which discussed 'sustainability' in relation to Sámi reindeer husbandry (Karlstad et al., 1990). This assessment argued that there were too many reindeer in Finnmark, and it presented the herders' "inherited legal notions, institutional arrangements and practices" as obstacles rather than solutions on the path to sustainable development (Karlstad et al., 1990, p. ix). The assessment refers to the herders' traditions, but there is no reference to their knowledge.

It is worth noting that also prior to the Brundtland Report, the government's political objective was a 'rationalization' of reindeer husbandry to both reduce the number of reindeer and to ensure a higher income among reindeer owners (see e.g., NOU 1972:33, 1972, pp. 65–66; St. meld. 13, 1974–1975). The concerns were that the Sámi reindeer husbandry was ineffective and that the herders had – compared with the development of wages within other Norwegian occupational groups – been left behind. The policies that followed the first White Paper on sustainable reindeer husbandry built upon the same notion of rational reindeer husbandry and introduced a threefold political objective: To develop a reindeer husbandry industry that was ecologically, economically, and culturally sustainable. The goals were presented as interrelated; ecological sustainability provided the basis for economic sustainability, and together ecological and economic sustainability provided an opportunity to safeguard and develop cultural sustainability (Innst. S. nr. 167, 1991–1992).

In 2007 the Reindeer Husbandry Act was renewed with a more inclusive focus: "ecologically, economically and culturally sustainable reindeer husbandry based on Sámi culture, tradition and custom" (Reindriftsloven, 2007). However, the Norwegian reindeer authorities were concerned about increasing reindeer numbers and alleged overgrazing, and this led to an emphasis on 'ecology' in a second White

Paper related to reindeer husbandry published in 2011. The threefold policy objectives continued, but special emphasis was put on the need for ensuring ecological sustainability (St. meld. 9, 2011–2012, p. 181). Another objective of the White Paper was the continuation reindeer husbandry as a nomadic form of pastoralism (St. meld. 9, 2011–2012, p. 183).

The third and most recent (2017) White Paper on reindeer husbandry continued the threefold policy objectives. In addition, it expressed "a political objective of developing the reindeer husbandry industry as a rational, market-oriented industry that is sustainable in a long-term perspective" (Meld. St. 32, 2016–2017, p. 7). To facilitate this objective, the White Paper suggested supporting those herders whose main income is from reindeer husbandry. Further, it presented the government's effort to change the overall purpose of the 2007 Reindeer Husbandry Act to give 'ecological sustainability' priority (Meld. St. 32, 2016–2017, p. 9). In this White Paper 'nomadism' was no longer among the policy objectives.

Where the Brundtland Report presented environmental, economic, and social sustainability as the three fundamental pillars of sustainable development, the Norwegian policies for a sustainable development of reindeer husbandry identified slightly different conceptual pillars of sustainability: ecology, economy, and culture. However, the wish to rationalise Sámi pastoralism led to an emphasis on the pillars of ecology and economy, and gave these pillars meanings that supported MAF's thinking of 'rational reindeer husbandry'. And in this context 'rational' meant herding practices that (1) are within the carrying capacity of the pastures (the number of reindeer which available pastures can support without environmental degradation), and (2) enhance the reindeer meat production (Meld. St. 32, 2016–2017; Prop. 99 S, 2019–2020).

Thus, in policymaking, 'sustainability' and 'rationality' become synonyms. And to ensure the sustainability and rationality of reindeer husbandry, the MAF issued in 2009 guidelines for estimating ecological sustainable reindeer numbers (LMD, 2008). The guidelines present standardised quantitative indicators and targets, such as production (living calves and carcass weights), reindeer numbers and animal densities, that could be used to monitor and evaluate the performance of reindeer herders (Reindriftsstyret, 2011, 2012). The guidelines were informed by the equilibrium ecology, estimates for how many reindeer the pastures can sustain (carrying capacity) and mathematical models for how to maximize meat production per animal. The rationale is that there is a correlation between the state of the pastures, animal density, animal well-being and production. The same theories informed the decision-making for rational reindeer husbandry in 1972 (NOU 1972: 33, 1972, p. 66), when a specific sex and age composition of the reindeer herds were promoted to ensure an optimal production of calves. The state monitors carefully how the herding units perform against the indicators.

3.4 Sustainable Reindeer Husbandry According to Traditional Knowledge

Traditional Sámi reindeer husbandry is not informed by reindeer numbers and carcass weights as indicators for sustainability; rather, through observing the behaviour and condition of the reindeer, the herders know when and how to interfere with the herd to maintain its well-being. Herders monitor the condition of the reindeer by observing its behaviour and features, such as the muscle mass and building, the antlers' structure and density, and the hair quality. The notion of sustainable reindeer husbandry as reflected in Sámi herding practices was first published by Eira et al. (2016). These authors identified and explained nine components that form the basis of sustainable reindeer husbandry. Here, we provide a shortened presentation of these components:

***Vuođđoolbmot* – People.** The long succession of Sámi reindeer herding people. The group of people that belong to the herding community, with entitlement to and understanding of the land, and knowledge about the reindeer's needs and behaviour.

***Báikevuođđu* – Basis for the household.** The members of the household and its practices led jointly by the husband and wife. The household consists of a core family that is often extended by close relatives and others that assist in reindeer husbandry. The household organize its human resources (who does what and when) and its belongings (houses/dwellings, vehicles, money); it makes strategic decisions about what animals to slaughter; it maintains subsistence and income-generating activities (sell reindeer, preserve food, make duodji, etc.); it makes strategies for maintaining a herd that fits the household's needs; and it is a place for knowledge transfer and socialising new generations into reindeer husbandry.

***Siidavuođđu* – Basis for the *siida*.** The *siida* is the core unit in Sámi reindeer husbandry management. It consists of a community of people, a reindeer herd, and the customary lands. The *siida* has deep knowledge of the landscape. It manages the use of seasonal pastures, when and where to migrate, maintenance of fences, and organizes the herding and gathering of animals for slaughter and earmarking. It maintains a herd structure that utilizes available pastures and as such, maximises production per square kilometre. The *siida* also manages its relations to the surrounding environment, such as the larger landscape, climatic factors and variations, and disturbances, as well as the neighbouring *siidas* and their land-use.

***Eallovuođđu* – Basis for the herd.** The reindeer herd is the basis of people's livelihood, culture and relationship to land and climate. The herd represents the people (each reindeer is owned by a person), land-use practices, the production needs of the *siida* households, breeding strategies and human relations (reindeer are given as gifts at special occasions). An ideal herd is robust and functional – that is, it reflects diversity (variety among the reindeer) and the landscape (use of pastures and migration routes), and it has continuity and a certain size that secures the herd's well-being and desired animal behaviour.

***Mearkavuođđu* – Basis of the earmark.** Earmarks are cuts in the reindeer's ears and is an identification marker for the individual who owns the reindeer and what family and *siida* it belongs to. The earmark is cut according to specific rules that communicate the heritage of the reindeer owner. Having earmarked reindeer gives access to decision-making (about the reindeer and herd) and a prospect of learning reindeer husbandry and establishing a vital herd.

***Birgenvuođđu* – Resource base.** The resources needed to sustain the welfare of the household or the *siida* (including work force, money, and pasture areas) and the practices of using and maintaining these resources. For example, utilizing the full potential of the reindeer and natural resources for producing food, clothes, and equipment for one's own use and for generating an income; knowing when the resources are available and have the best quality; and knowing how to preserve the resources. The household's practices and maintenance of resources relates to its obligations towards the *siida*.

***Vuoigatvuohtavuođđu* – Basis for rights.** The legal basis for and customs includes the *siida* right to pastures and migration routes, as well as when and how to use these. Further, it includes the individual rights to own an earmark and develop a herd; to acquire knowledge and skills to practice reindeer husbandry; and to belong to a *siida*. The parents, household and *siida* are responsible for transferring knowledge to the next generation. There is also the individual obligation to attend to all *siida* members' reindeer and contribute to knowledge transfer. There are three levels of decision-making: The individual (reindeer owner), the household and the *siida*.

***Vuođđoipmárdus* – Worldview.** The worldview and ethics that navigate the holistic relationship with the reindeer, the herd and nature. This is a relationship based on negotiations and compromises. The reindeer is *boazu* – an animal that largely lives freely in its natural surroundings. People interact but should not seek complete control over the reindeer or nature. Rather, herders follow the reindeer, they facilitate the animal's natural behaviour, its adaptation to the natural environment, and the annual cycles and weather conditions, and they protect the reindeer from external threats. Herders that fulfil these obligations can harvest from the herd and make use of the reindeer. The people's relationship with the reindeer is part of a larger socio-ecological system that is both predictable and unpredictable; there are repetitions, as well as continuous changes. Also, people's understanding of the landscape, seasons, climate and other (human) beings is strongly influenced by their relationship with the reindeer.

***Máhttovuođđu* – Knowledgebase.** The accumulated knowledge transferred between individuals within the household and the *siida* through Sámi reindeer herders' language and with a high level of precision for descriptions. This knowledge is related to the other eight components of sustainable reindeer husbandry – knowing what to do, how and when. It includes extensive knowledge about the nature of the reindeer, the topography, weather and climate, skills in observing the reindeer and its surroundings, and an understanding of the mutual relationships between these. Knowledge about how to develop and maintain a robust and functional herd adjusted to local landscape and climate.

Summarized, these nine components present a complex model for understanding sustainable Sámi reindeer husbandry which is very different to that of the Norwegian state. The next sections further discuss the two conceptualizations of sustainable reindeer husbandry and how they influence the state and Sámi reindeer herders' tools and practices for managing extreme events.

3.5 Conceptualizations of Sustainable Reindeer Husbandry – Different Ways of Knowing

The two conceptualisations of 'sustainable reindeer husbandry' build on different models for understanding of the human-animal-nature relation. The state' description of sustainable reindeer husbandry emphasizes practices that are based on nature's carrying capacity, ensures productivity and sufficient income for the herders. By setting fixed targets for reindeer numbers and carcass weights, the state does not only address the political objective of rational production; it also enhances the predictability and its control of reindeer husbandry. Another measure to ensure predictability is the requirement that each herding district makes land-use plans (Norwegian: *bruksregler*), that includes dates for moving from one seasonal pasture to the next (Reindriftsforvaltningen, 2009). A herding district is an administrative unit established by the state with the 1978 Reindeer Husbandry Act. In Finnmark, the herding districts typically include several *siidas* – the traditional management units of reindeer husbandry.

From a traditional reindeer herding perspective, however, the understanding of sustainable and rational reindeer husbandry does not include notions of predictability and stability. In an address to the World Environment Day in 2007, Secretary General of the Association of World Reindeer Herders Johan Mathis Turi stated that 'stability' is a strange word in Sámi reindeer herders' vocabulary (Turi, 2007). He explained that herders do not seek 'stability'; they rather seek becoming accustomed to changing conditions. The Sámi traditional reindeer herding knowledge about sound reindeer husbandry acknowledges the seasonal and spatial changes in nature and climate, and changes in the intensity of disturbances (for example from predators and human activities). From this perspective, sustainable and rational reindeer husbandry is facilitated through building resilience to changes and disturbances, including extreme events. The resilience is enhanced by maintaining flexibility in how the *siida* operates, as well as in the reindeer numbers, herd structure, grazing patterns, migration routes, etc. The Sámi traditional reindeer herding conceptualisation of sustainable reindeer husbandry, producing meat, and securing an income are important elements of sound herding practices. Yet, income generating activities are only part of a larger picture needed to reflect the complex role of reindeer husbandry as a livelihood, lifestyle, and culture.

A common representation of 'sustainable development' is three overlapping circles (Fig. 3.3). The circles symbolize ecology, economy and society, and sustainable development is the intersection of the circles. As discussed above, MAF's

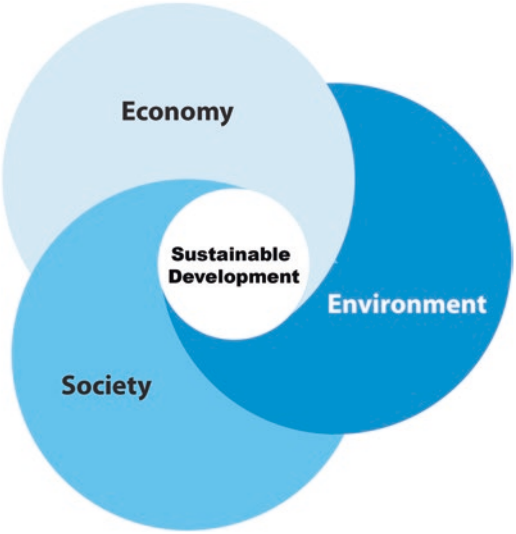

Fig. 3.3 An illustration of sustainable development closely associated with the definition used by the Brundtland Report

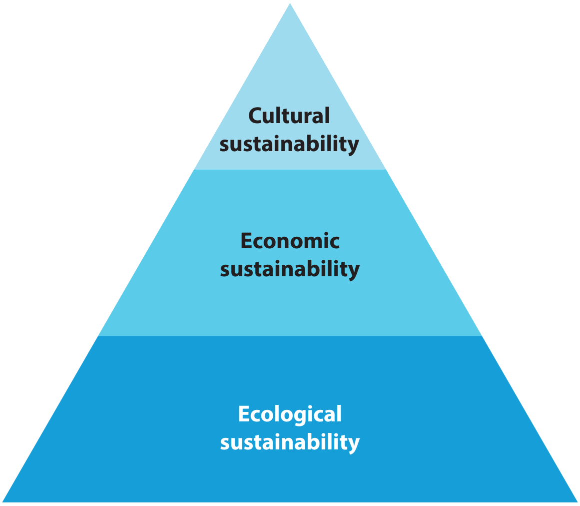

Fig. 3.4 A visual presentation of MAF's definition of sustainable reindeer husbandry

definition of sustainable reindeer husbandry differs in several ways; it is based on other components – that is, ecology, economy, and culture – with an internal hierarchy and a certain relationship of dependency: Ecological sustainability provides the basis for economic sustainability, and together ecological and economic sustainability provide an opportunity to safeguard and develop cultural sustainability. As such, MAF's conceptualization of sustainable reindeer husbandry could be illustrated as a pyramid where the bottom component forms a basis, and a precondition, for the components above (Fig. 3.4). A third conceptualisation of sustainable reindeer husbandry, as reflected in Sámi herding practices, was first illustrated by Eira et al. (2016) (Fig. 3.5).

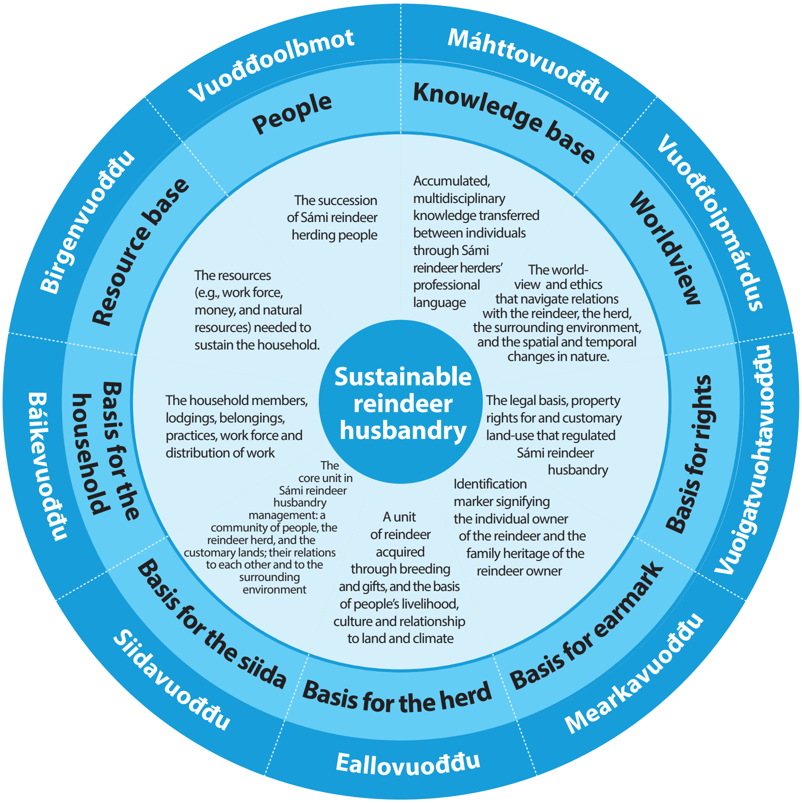

Fig. 3.5 A visual presentation of the Sámi traditional reindeer herding conceptualization of sustainable reindeer husbandry. The figure is based on an illustration first published by Eira et al. (2016)

The three illustrations of sustainability (Figs. 3.3, 3.4 and 3.5) are **models** that simplify reality to more easily communicate complex coupled human and nature systems (see e.g., Liu et al., 2007). The accuracy of a model reflects its ability to present reality; however, the more complex a system is, the more difficult it is to construct a model that mimics this reality (Barrow, 2014 [1995]). None of the figures reflect the full complexity of the 'real world'. Figures 3.4 and 3.5 are rather representations of the state's and the Sámi traditional reindeer herding's conceptualizations of sustainable reindeer husbandry, which inform these actors' planning and decision-making.

When comparing the two conceptualizations, it becomes apparent that they are based on different knowledge systems, and how different ways of regarding and dealing with threats to the sustainability of reindeer husbandry. For example, where the model based on traditional knowledge emphasises the relationship with the landscape and external factors that affect reindeer husbandry, MAF's focus on 'ecology' (that is, how many reindeer the pastures can support without being degraded) minimizes other environmental threats in the state-led attempts to secure sustainable reindeer husbandry. The all-consuming focus on reindeer numbers can be exemplified by a news item published by MAF late January 2020 where they announced that the conditions of the pastures in Finnmark are improving due to a reduction in reindeer numbers (LMD, 2020c). At the time of this announcement, herders in Finnmark were in the middle of a crisis caused by 'locked' pastures. Ten days later, MAF publicly confirmed the crisis. It described the crisis as climate related and not driven by reindeer numbers but it pointed to reindeer numbers as part of the solution: "Through a reindeer number customed to the pastures, the reindeer herders are now also better prepared when crises occur" (LMD, 2020b).

3.6 Mechanisms for Adapting to External Threats to Secure Sustainable Reindeer Husbandry

In the aftermath of the difficult grazing conditions during winter and spring 2017, an ad hoc working group of representatives of the herding community and the authorities reviewed the capacity within the reindeer husbandry to cope with 'locked' pastures and adapt to unpredictable and extreme events. The working group emphasized the importance of the herders being well prepared by having good plans for all eventualities to minimize the negative effects of a grazing crisis (Landbruksdirektoratet, 2017, p. 22):

> It is the person herding that is in charge and who makes decisions about where the herd should graze at any time based on weather, wind, and snow conditions. This is part of daily operations and can thus be regarded as a basic, preventive emergency response work. There is always a well thought out plan for how to use different pastures at different times of winter, as well as what alternative measures can be taken if unforeseen situations occur.

While acknowledging the adaptive capacity of reindeer herders, the working group also recognized that herders' ability to act upon 'locked' pastures is especially challenging; locked areas often reach far, and other land-use interests have occupied traditional grazing lands and limited the herd's access to alternative pastures. The working group listed the following coping mechanisms within reindeer husbandry:

- Use supplemental feed
- Reduce the size of the herd
- Move earlier between seasonal pastures
- Ensure that the herd rests (to avoid unnecessary use of energy within the herd)
- Transport animals from winter to summer pastures by trailer

In previous studies and dialogue with reindeer herders, we have found that Sámi traditional reindeer herding knowledge provides three key mechanisms for enhancing the resilience of reindeer husbandry. These mechanism form a basis for dealing with a reality of changing conditions and different type of disturbances, out of which poor grazing conditions is one: Maintaining a diversity within the herd (that is, keeping reindeer of different sex and age), maintaining mobility to make the best use of the landscape and its grazing resources, and keeping flexibility (Johnsen et al., 2017). The reindeer herders' notion of flexibility includes having 'buffers'; that is, to keep more reindeer than 'needed' as there will always be a loss of animals, to have access to alternative grazing areas in times when the regular pastures are unavailable because of the weather or disturbances, and to have access to labour (Johnsen et al., 2017). Today, this labour force typically consists of reindeer owners and family members who do not herd daily but who help in the more labour-intensive periods of reindeer husbandry; for example, migration, earmarking, and rounding up the animals for slaughter.

In spring 2020, we invited six reindeer herders to a workshop discussion about their experiences of *goavvi* events and more concrete approaches to minimize the negative effects of 'locked' pastures. The participants emphasised the importance of spatial and temporal mobility, and they pointed to the following measures that were not addressed by the ad hoc working group:

- Moving to other areas within the winter pastures
- Using seasonal pastures out of season
- Dividing the herd for a better distribution of the grazing resources/to attend to the weaker animals
- Herding around the clock
- Completely releasing control of the reindeer to let them search for available forage themselves

The workshop participants also pointed to the long-term measure of building and maintaining a resilient herd. This is done through the selection of animals for breeding and slaughter to ensure a diversity and structure adapted to the local landscape and climate conditions.

3.7 The State's Emergency Response

As a direct response to the grazing crisis in winter and spring 2017, MAF and the Norwegian Reindeer Herders' Association (NRL) agreed to establish a national emergency fund (Landbruksdirektoratet, 2017; LMD, 2020a). The coordination of emergency preparedness was delegated to the County Governor offices. And for each reindeer herding region, an Emergency Committee was established with the mandate to monitor the grazing conditions and advise the County Governor. In addition, each herding district was instructed to keep their own emergency savings.

As with the national emergency fund, these were savings for buying and transporting supplemental feed to the herd.

Today, if a herding district wishes to spend its savings, it must first get an approval from the County Governor. The County Governor also controls that the districts' emergency savings and grants are used according to its purpose (Landbruksdirektoratet, 2017). During periods with 'locked' pastures, the County Governor distributes national emergency grants for supplementary feed. The grants are distributed according to the severity of the crisis, the number of reindeer and the distance from the herd to the closest road – and in accordance with the following process (Landbruksdirektoratet, 2017; Eira, 2020):

- The herding districts report about poor grazing conditions.
- The County Governor's office gathers information to determine if there is a grazing crisis.
- The Emergency Committee is informed, evaluates the grazing conditions, verifies the grazing crisis and advises on what measures should be taken.
- The County Governor's office decides whether the herding districts can use their own emergency savings and/or apply for emergency grants.

The County Governor can further assist the herding districts by facilitating exemptions from the grazing regulations (that is, the land-use plans; *bruksreglene*) (Landbruksdirektoratet, 2017). All in all, it can seem that there are many types of mechanisms available that can support sustainable reindeer husbandry – also in a future with more unpredictable winters and 'locked' pastures. However, many herders experience that current regulations, decision-making processes, and the knowledge used to inform these processes, are obstacles for adapting to change and coping with a crisis. As the competition from other land-use interests (for example, mineral extraction, wind power production and cabin development) increases, the herders' ability to adapt to environmental change decreases.

In the following, we present the workshop participants' presentation of the *goavvi* event 2019/2020, their assessment of the emergency response provided by the state, and how the state's understanding of sustainable reindeer husbandry affects the herders' ability to adapt to extreme events.

3.8 Presentations of an Extreme Event – The *Goavvi* Winter 2019/2020

Having presented the state's organisation of emergency response for reindeer husbandry, we now present a synthesis of the participants' observations related to the *goavvi* event in inner Finnmark in 2019/2020 before we summaries the authority's assessment of the same winter (see also the herders' photo documentation in Fig. 3.6):

> While one herder described the autumn pastures as "good", another herder said that in his area, the mountain vegetation did not turn green and there were very little mushrooms.

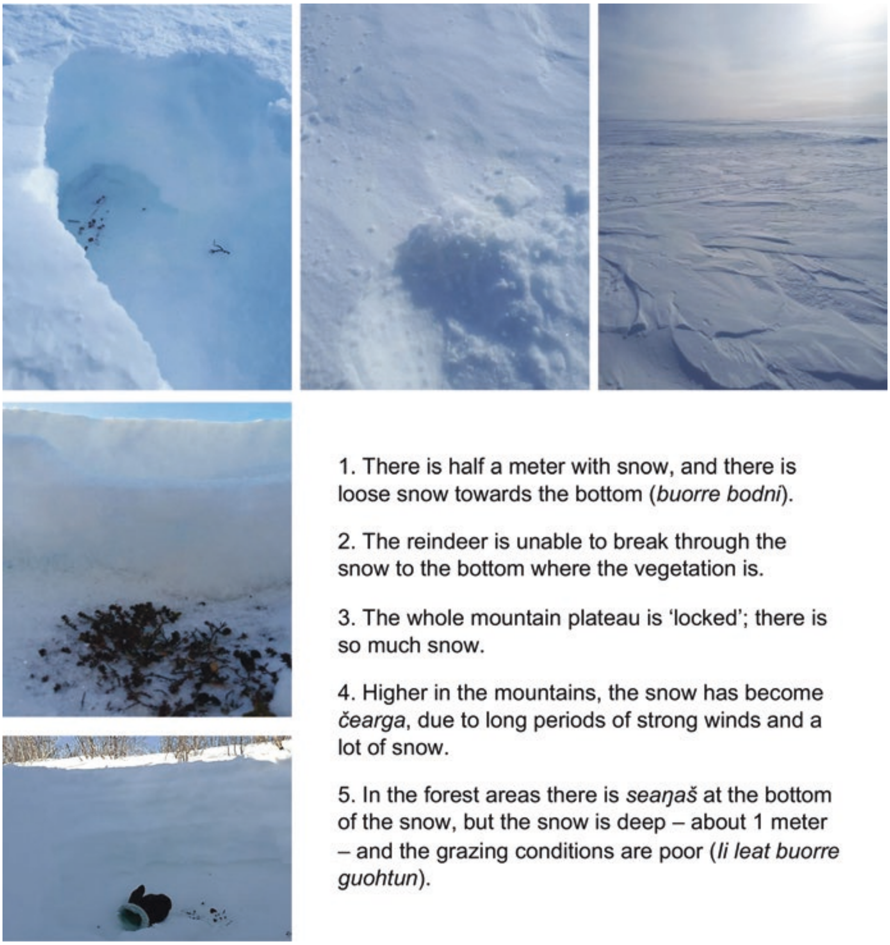

Fig. 3.6 Examples of text and photo documentation of snow conditions causing a *goavvi* during the winter of 2019/2020. The documentation was done by herders attending to the reindeer herds

Therefore, the herds from such areas were not in the best condition when winter started. The cold and snow came early, and there were few milder periods. Normally, the first snow disappears again, but this year it did not; instead, it turned into ice. Before Christmas, more snow (*vahca*) made access to the pastures difficult. Then, in late December the snow was wet (*gohpalat*; new wet snow that fastens immediately to things (Eira, 2012)), and it became difficult to move – for both reindeer and snowmobiles. And in January, the air temperature got colder, and there was a lot of wind, drifting snow and bad visibility (*guoldu*). The snow became very dense (*čearga* and *čiegar*; snow hardened by reindeer trampling (Eira, 2012)), and the reindeer could not dig through. The pastures were 'locked'. There were varying degrees of 'locked' pastures. In some forest the snow was loose (*seaŋaš*); in the mountains, it was *čearga* most places. In inner Finnmark, large parts of the pastures were inaccessible due to ice crust in spring-winter (*cuonju)*) and ice throughout winter.

Usually there are periods during winter with milder winds (*Hallemas-njáhcu* (Eira et al., this volume, Chap. 4)) that changes that snow structure and helps access to the ground

> vegetation, but these types of weather did not occur this year. Due to the poor grazing conditions, the reindeer did not rest in January; they were constantly on the move in search for better access to vegetation. The herders worked around the clock to keep the herd together and avoid intermingling with other herds. For some *siidas*, the work intensified already from late November. It required a lot of driving, wear on snowmobiles and equipment, and herders worked coordinated to control the herd. Still, it was not possible to avoid reindeer from moving out of the winter pastures. Some *siidas* decided to divide the herd and move into different locations within the winter pastures. Others moved the herd to the spring/autumn pastures earlier than scheduled. Some *siidas* did not feed their reindeer, but most used supplementary feed from February and onwards. However, the feeding caused intermingling of herds. The reindeer smell the feed from afar. They were attracted to the feeding areas, and the predators followed the reindeer.
>
> The winter was very long. Even in late April there were only small patches without snow at the spring/summer pastures. Some *siidas* organized trailer transport to spare the reindeer from the efforts of migration, and some had to continue with supplementary feeding until late May. Many reindeer died during the *goavvi*. In the beginning the herders recorded all the dead animals they found. But after a while, they stopped counting and checking the earmarks because of the mental strains.

The Norwegian Agriculture Agency agreed about the severity of the winter of 2020, which it referred to as a climatic 'crisis' and the most challenging winter in more than hundred years (Eira, 2020). The Agency explained that unusual amounts of snow and dense snow layers led to 'locked' pastures and difficult grazing conditions early in the winter in large parts of Sámi reindeer herding areas. "Reindriftsnytt" (a magazine about reindeer husbandry issues published by the Agency) reported that the grazing crisis of 2019/2020 affected 165,000 reindeer (Eira, 2020); that is, more than 75% of all semi-domesticated reindeer in Norway. The crisis, according to the Norwegian Agriculture Agency, was worst in Finnmark where many pastures were 'locked' from early January. All herding districts in West Finnmark received state emergency grants to buy and transport supplementary feed to their reindeer (letter from County Governor, dated 26. June 2020). The total allocation to reindeer herders in 2020 was NOK 42.7 million. In addition, the herding districts emergency savings totalled NOK 7 million at the beginning of the crisis (Eira, 2020, p. 10). The herders interviewed by "Reindriftsnytt" and the herders participating at our workshop all stated that the state grants were crucial for the survival of the reindeer during the *goavvi* event.

3.9 Obstacles for Adapting to Change and Coping with Crisis

2020 was the first *goavvi* event where the system with emergency funds was used in practice, and we invited the workshop participants to share their experiences with how it worked. The participants pointed to several issues that hindered efficient response to the critical situation on the ground. They said that the decision-making power to define when a crisis occurs, and the control of the emergency support, were distant from the individual herders responsible for the herds – and that this distance limited the herders' autonomy in attending their animals' well-being and created obstacles for using traditional knowledge to effectively adapt to environmental change and cope with the crisis.

The participants said the decision-making created a delay from when herders identified and reported on the crisis to when they got access to funds to purchase supplemental feed (see Table 3.1). Further, the allocation of grants depended on the Emergency Committee's assessment of the grazing conditions, and grants were distributed only when the Committee' evaluation confirmed that the herders' reports on 'locked' pastures were accurate. The workshop participants, however, questioned the competence with the Emergency Committee to interpret its observations of snow and ice, and they questioned why the Committee did not include local herders on their inspections.

The participants experienced the County Governor's office response to the herders' reports about 'locked' pastures as unpredictable. Some herding districts managed to convince the office to coordinate an inspection of the pastures rather quickly. Other herding districts felt dismissed; they were told the office was busy working with other herding areas in Finnmark. According to the workshop participants, the first reports about poor grazing conditions were sent from some herders to the County Governor's office already in November 2019. However, the County Governor did not approve use of the districts' emergency savings until 10th of February (Fylkesmannen i Troms og Finnmark, 2020), and the first emergency grants were not distributed before mid-March (Eira, 2020). The participants argued that the immediate possibility to act upon changing weather conditions and 'locked' pastures should lay with the herders, and that the time gap from when the herders reported about the crisis to when they received support from the authorities, affected the well-being of both animals and people.

The participants argued that the decision-making process made it difficult to attend to the needs of those herders with the most severe grazing conditions. The grants were distributed to the herding districts, but in reality the grazing conditions varied within the districts and therefore, not all herders had the same need for support. According to the participants, it would have been better if the emergency savings and grants should be distributed to and managed by the *siidas* independently, and not by the districts. They explained that the winter herding districts in West-Finnmark are very large and include many *siidas*, which might face different grazing conditions. This also affects how the winter districts assess the severity of a crisis, and how fast they act on expressed needs from individual *siidas*. Due to different interests and concerns, it can be challenging to reach consensus about the need for emergency grants and the internal distribution of these.

Yet another factor that the participants identified as limiting herders' autonomy in attending their animals, were the restrictions set on how the savings and grants should be spent. The herders furthest away from the road were offered helicopter transport, but a precondition was the use of concentrated feed to minimize the volumes. The herders could not decide themselves what feed to give the reindeer. Due to Covid19 travel restrictions, herders were prevented from purchasing cheaper concentrated feed in Finland, and thus, a large portion of the emergency funds went to helicopter companies (see also Eira, 2020, p. 10).

In addition to discussing the decision-making related to the emergency support, the workshop participants pointed to various elements in the state's model for understanding sustainable reindeer husbandry – and decision-making tools for facilitating sustainability – that become obstacles for the herders' ability to use traditional knowledge to adapt to a nature where 'locked' pastures and extreme events occur:

Firstly, the state regulation of reindeer pastures requires that each herding district has approved plans for the temporal and spatial land-use (Norwegian: *bruksregler*). The workshop participants argued that the fixed dates for moving from one seasonal pasture to the next removes some of the mobility and flexibility needed to adapt to disturbances and 'locked' pastures. The ad hoc working group that assessed the reindeer husbandry's capacity to cope with 'locked' pastures emphasized the importance of herders having good plans for all eventualities to minimize the negative effects of poor grazing conditions a grazing crisis (Landbruksdirektoratet, 2017, p. 7):

Both the fact that a crisis deviates from the normal and is an unexpected event are factors that make dealing with the crisis difficult if one is not well prepared and has developed good plans for all eventualities. Lack of control and time pressure to find a solution to the crisis reinforces and substantiates the need for good plans when a crisis arises.

The template for obligatory land-use plans, however, does not include plans for *goavvi*. Moreover, the land-use plans are defined as internal management plans for each herding district, and are not used to inform regional or national decision-making related to extreme events. Furthermore, because the grazing boundaries in Finnmark were set in 1933, they do not fit the current climate or grazing conditions. Thus, the participants argued for a more flexible and adaptive land-use system that takes environmental changes and unpredictable events into account.

Secondly, the increased competition for land has led to encroachment and fragmentation of reindeer pastures and limits the herds' access to alternative pastures when the grazing conditions are poor. The participants also pointed to the social stigma of having reindeer that grazes where it 'ought not to be', something that makes it challenging to move into alternative pastures. Thus, the herders said that lost pastures should be compensated by new grazing areas.

Thirdly, the state has allowed some herding districts to use part of Inner Finnmark as summer pastures. The consequence is a reduction in the size of important winter pastures, and – according to the workshop participants – this is not the best use of available pastures.

Fourthly, the state incentives for maximizing meat production (with an emphasis on calf production) affects the robustness of the herd. The participants argued that to slaughter young animals before they have been able to show their full capacity and potential makes strategic breeding challenging. Due to economic incentives offered by the state, the herds have few bulls and castrates that can dig through deep snow and ice crusts and thereby provide access to forage for the rest of the herd.

Fifthly, the participants addressed the state's emphasis on supplementary feeding to deal with poor grazing conditions. They explained that the focus on feeding undermined other adaptive measures. Not all herders want to use concentrated feed because it might alter the behaviour of the herd and make it more vulnerable to other threats, such as predators. Moreover, some reindeer will not eat the supplemental feed. The participants also explained that it is vital that the reindeer maintains its capacity to find forage on its own – also during winter.

The consequences of a *goavvi* are severe. A *goavvi* causes reindeer losses and fewer calves are born the following years. The negative effects on the herds' wellbeing make them less robust when faced with new occasions of unfavourable weather and poor grazing conditions. After the *goavvi* winter 2019/2020, the Agriculture Agency reported that there was a decrease in the number of calves. Less reindeer than normal were sent to the slaughter houses, which negatively affected the income of the *siidas* (Hætta, 2020).

While one can argue that there are institutions in place to ensure co-management between Sámi reindeer herders and various governmental levels (such as the Reindeer Husbandry Agreement and the Consultation Agreement), representation in decision-making has not lead to the inclusion of traditional knowledge in the state governance of reindeer husbandry (Heikkilä, 2006; Turi, 2016; Johnsen & Benjaminsen, 2017). Thus, the state governance becomes an additional burden as the indicators used to monitor sustainable and rational sustainable husbandry, challenge the traditional practices for strategic breeding and knowledge for rebuilding a resilient herd in the aftermath of a *goavvi*. Moreover, a year after the grazing crisis, the herding districts had to fight to keep the emergency grants which had been allocated to them. The County Governor had reclaimed grants which they argued had been spent outside the periods defined as 'crisis' by the Emergency Committee. The dispute about definition-power received attention in the press. In July 2021, the editorial of the regional Sámi newspaper *Ságat* stated that "the County Governor is creating a new crisis" (Ságat, 2021). It argued that there was a structural discrimination of reindeer herders and pointed to farmers who are automatically compensated if they experience a similar volume of crop failure due to climate conditions. The newspaper argued that favouritism had affected the herders' access to grants during the *goavvi*. The workshop participants shared the same observation.

3.10 Conclusion – Traditional Knowledge Left Behind

In this chapter, we present two different models for understanding sustainable reindeer husbandry – that of the Norwegian state and that of Sámi traditional reindeer herding knowledge. There are two key differences in the two models. Firstly, the model based on traditional knowledge presents a complex understanding of the interconnectedness of the components that jointly form the basis for sustainable reindeer husbandry, whereas the state model has a narrower and linear understanding of sustainability. Secondly, where the traditional knowledge model inheres notions of 'flexibility' and 'diversity' as measures for adapting to the surrounding environment and a changing reality, the state model is informed by notions of nature's 'carrying capacity', optimal herd structures, maximum reindeer numbers and fixed dates for when herds should move from one seasonal pasture to the next. Table 3.2 contrasts the differences between the Sámi traditional reindeer herding knowledge and the state's knowledge of reindeer husbandry. While the table presents the dichotomy between two knowledge systems, it is important to note these knowledge systems are neither static nor developed in vacuums. Sámi traditional

Table 3.2 The dichotomy between two models for the understanding of reindeer husbandry

Model for understanding…	…within reindeer husbandry based on traditional knowledge	…within the public management of reindeer husbandry
Sustainable reindeer husbandry	Complex, integrated, holistic, nomadic	Simplified, linear, reductionistic
Reindeer husbandry	A livelihood, way of life	An industry (Norwegian: *næring*)
The herd	Should be robust, functional, diverse	Should be productive, standardised, static
Reindeer-human relationship	Negotiated and built on compromises between the herder and reindeer	Reindeer fully controlled by humans
The surrounding environment	Always changing, both predictable and unpredictable	(External factors tend to be excluded in decision-making regarding reindeer husbandry)
Knowledgebase	Non-equilibrium thinking, traditional knowledgebase	Equilibrium thinking, knowledgebase from biology and ecology
Management	Adaptive, rule of thumb, living with uncertainty	Fixed targets, monitoring performance
Tools for decision-making	Qualitative, experience-based, observable (the reindeer's behaviour, muscle mass and building, hair quality, antlers, etc.)	Quantitative, theoretical, measurable (standardized indicators, norms and statistics about carcass weights, reindeer numbers, animal densities, etc.)
Mechanisms for coping with external threats, such as a *goavvi*	Contextual, flexible, and adaptive responses	Universal responses, based on rules of procedures

reindeer herding knowledge is constantly improved and informed by the herders' experiences and analysis, knowledge transferred from one generation to the next, science and technologies (Eira et al., this volume, Chap. 4).

In scientific literature and within science-policy platforms (such as the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, IPBES) a more plural approach to knowing and valuing nature is emerging. More attention is given to what and whose values and knowledge are reflected in public decision-making (Pascual et al., 2017; Díaz et al., 2018; Kenter, 2018; Jacobs et al., 2020; Pascual et al., 2021). For example, Pascual et al. (2021) explain that policymaking and knowledge production based on certain actors' conceptualization of nature can exclude other ways of defining, knowing and valuing it. These authors argue that a consequence of setting aside local and Indigenous understandings of non-human life and other human needs and worldviews is decisions that are preserved irrelevant locally. They point to the need for a more pluralistic perspective on conservation to ensure fairer decision-making and social equity. Thus, in pursuing a sustainable management of nature, Pascual et al. (2021) suggest a more inclusive and open-minded approach to defining policy goals and practical measures needed to achieve these goals.

The data on reindeer numbers and carcass weights which MAF uses to monitor sustainability assumes a predictable form of livestock production in stable conditions. However, standards and averages are not suited to inform pastoral production systems that operate in landscapes with temporal and spatial variations in distribution of forage (Krätli & Schareika, 2010). The assumption about stability, also diminishes the factors that herders understand as the greatest threats to their livelihood – encroachment, predators, and climate change – in the decision-making concerning reindeer husbandry. And while the Sámi traditional reindeer herding knowledge holds techniques for living with uncertainty, adapting to annual cycles and weather conditions, and protecting their reindeer from external threats, the regulations for 'sustainable reindeer husbandry' hinder an effective use of this knowledge. Moreover, the regulations enhance the state's control of Sámi pastoralism; the regulations provide tools for steering towards what the state sees as a 'rational reindeer husbandry', and they undermine the herders' possibility of self-governance.

The lack of recognition of traditional Sámi reindeer husbandry knowledge in policies and decision-making stands in contrast to Norway's action plan for sustainable development. With reference to the 1992 Rio Declaration, which defines principles for the relationship of states to each other and the relationship between states and their citizens in the field of environment and development, the action plan says (Norwegian government, 2004, p. 38):

> Indigenous people and their communities and other local communities have a vital role in environmental management and development because of their knowledge and traditional practices. (…) States should recognize and duly support their identity, culture and interests and enable their effective participation in the achievement of sustainable development

According to O'Brien et al. (2009), however, the Norwegian policies and public debate have tended to focus on Sámi rights and failed to address the factors and the knowledge that underlie the Sámi reindeer husbandry. While Norway's 2016 report on the follow up of the 2030 Agenda states: "The protection, restoration and sustainable use of ecosystems can also safeguard the basis for a sustainable Sami culture" (MFA, 2016), there are no targets for how much land should be preserved to ensure a sustainable reindeer husbandry today and in the future (Stortinget, 2020). Norwegian policies recognize reindeer pastures as the material basis for Sámi livelihoods and culture, but the focus is rather on protecting the land from 'too many reindeer' than for reindeer husbandry. Simultaneously, Sámi reindeer pastures are lost to recreational cabin areas, wind and hydropower development, mining activities and types of infrastructure and human use. (For an analysis on the loss of pastures, see van Rooij et al., this volume, Chap. 9).

The overall objective of the 2007 Reindeer Husbandry Act is an "ecologically, economically and culturally sustainable reindeer husbandry based on Sámi culture, tradition and custom" (Reindriftsloven, 2007). Yet, the state decision-making neglects the Sámi traditional reindeer herding knowledge about the socio-ecological system they are part of, and the herders' understanding of how to maintain the well-being of reindeer in times of crisis. Instead of facilitating Sámi tradition and customs, the state governance for a sustainable and rational reindeer husbandry, forces herders to practice a 'Norwegianized' type of pastoralism. A consequence is that the reindeer herders cannot use their own knowledge to adapt to a *goavvi* or other types of extreme events.

The Norwegian state governance of reindeer husbandry stands in contrast to the increasing recognition of traditional knowledge and practices by international research and policymaking. For example, the Intergovernmental Panel on Climate Change (IPCC) and IPBES emphasize the value of diverse knowledge systems, including indigenous peoples' knowledge, in developing fair, holistic and effective conservation and climate change adaptation strategies for the well-being of both nature and humans (IPCC, 2014; IPBES, 2018). While the IPCC, IPBES and the Brundtland Report points to an opportunity in learning from indigenous peoples' relations to complex forest, mountain, and dryland ecosystems, the Norwegian state governance has not included these aspects in its policies and regulations. Instead, the Sámi traditional reindeer herding knowledge and practices are left behind.

The winter of 2019/2020 was described as exceptional, but only two years later, reindeer herders in Finnmark experienced another *goavvi*. The 2017 White Paper on reindeer husbandry stated that a future with a warmer and more unstable climate will increase the need for an emergency response to avoid animal tragedies caused by lack of forage and water during extraordinary weather conditions (Meld. St. 32, 2016–2017, p. 21). In some years, there will be a need for emergency funds and additional feeding. But these are short-term there-and-then measures; and not all winters with difficult snow and ice conditions need to turn into extreme winters with large losses of animals. As a long-term strategy to ensure the well-being of reindeer and sustainable reindeer husbandry, the authorities should allow the herders to maintain their adaptive capacity. By having diversity in the herds, flexible grazing strategies and maintaining mobility, reindeer husbandry can utilize the changes in nature in line with the reindeer's natural behaviour. An important step towards a more inclusive and sustainable governance of reindeer husbandry is to include traditional knowledge and perspectives on nature-human relationships as legitimate, relevant, and valued contributions in policymaking. A broader recognition of Sámi traditional reindeer herding knowledge and practices would also help maintain the heritage of, as well as the adaptive capacity within, Sámi pastoralism.

3.11 Post-script

As this chapter was finalized early 2021, MFA had a public hearing of a report presenting suggestions for new criteria and indicators for monitoring the sustainability of reindeer husbandry. The report was put together by an ad hoc working group consisting of representatives of MFA, NRL and the Sámi parliament (Landbruksdirektoratet, 2020). MFA, however, specified the mandate of the working group as follows: Indicators identified should be in line with current reindeer husbandry policies and objectives (ecological, economic, and cultural sustainability); the indicators should be easy to measure and based on existing databases; and the existing criteria for ecological sustainable reindeer husbandry – such as, carcass weights, reindeer numbers and animal densities – should not be changed.

One of the new criteria for cultural sustainability suggested by the ad hoc working group was "the inclusion of traditional knowledge in public management" of reindeer husbandry. The group, however, was not very clear about what they meant by 'traditional knowledge'. They argued that this criterion is difficult to measure, and therefore, they did not suggest a quantitative indicator for the inclusion of traditional knowledge. Instead, they suggested that the Norwegian Agriculture Agency included a description of the importance of dialogue and consultations with reindeer herders in the annual reports on reindeer husbandry (Landbruksdirektoratet, 2020, p. 72).

In the public hearing about the suggested criteria and indicators for sustainable reindeer husbandry, both the national Reindeer Husbandry Board and the local association of herders in West Finnmark (*Guovdageainnu johttisápmelaččaid searvi*) emphasised that the inclusion of traditional knowledge is important for all management aspects of reindeer husbandry (LMD, 2021). The herders from West Finnmark also suggested that one way of measuring 'traditional knowledge' in the management would be to count the number of employees at the Norwegian Agriculture Agency with competence in Sámi traditional reindeer herding knowledge, as well as knowledge of the specialized Sámi language of reindeer husbandry. The Sámi Parliament responsed to the hearing by referring to the model of sustainable reindeer husbandry as reflected in Sámi traditional reindeer herding practices and first published by Eira et al. (2016) (and translated to English in this chapter). This model, the Sámi Parliament agued, should have been the starting point for developing new criteria and indicators for monitoring the sustainability of reindeer husbandry.

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Chapter 4
Sámi Traditional Reindeer Herding Knowledge Throughout a Year: Herding Periods on Snow-Covered Ground

Inger Marie Gaup Eira, Ellen Inga Turi, and Johan Mathis Turi

Abstract Sámi traditional reindeer herding knowledge is the basis decisions in time and space made by Sámi reindeer herders with emphasis on periods and cycles and related to reindeer husbandry on snow-covered land. This chapter outlines aspects of the Sámi traditional knowledge used by reindeer herders in Western Finnmark performing reindeer herding during periods with snow on the ground. We will highlight the periods from October till April, as these constitute the critical bottlenecks in the annual herding cycle. Using methods for communicating with herders and co-production of knowledge between reindeer herders and science, this chapter outlines traditional reindeer herding periods and cycles through the year focusing particularly on aspects of herding on snow-covered ground. Reindeer herding strategies and practices are highly complicated and systematic enterprises containing different types of knowledge on how the biological and gender-based behavioral aspects of reindeer and the movement of the reindeer in time and space are connected to climate, temperature, and snow metamorphism. This includes knowledge about the different seasons, cycles, and periods in a reindeer year. Reindeer herding periods and cycles contain different sub-cycles that are a part of a larger system based on the year, the lunar month and day/night, e.g., cycles related to the use of areas throughout the year; the biological cycles of reindeer, like rutting season, calving season, dropped or cast antlers and moulting fur; sexual behavioral cycles; cycles relative to climate and snow, the cycles of sexual maturity, cycles of extreme years and cycles that include reindeer herding periods throughout the year.

I. M. G. Eira (✉)
Sámi University of Applied Sciences, Guovdageaidnu, Norway
e-mail: ingermge@samas.no

E. I. Turi
International Centre for Reindeer Husbandry, Guovdageaidnu, Norway

Sámi University of Applied Sciences, Guovdageaidnu, Norway

J. M. Turi
International Centre for Reindeer Husbandry, Guovdageaidnu, Norway

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Keywords Sámi traditional reindeer herding knowledge · Herding periods · Seasonal cycles · Reindeer year · Co-production of knowledge · Snow-on-the-ground

4.1 Introduction

A saying among Sámi reindeer herders is that "reindeer are the easiest animals to understand" according to time and space. Naturally this presupposes a type of intimate knowledge among those who work with reindeer daily. The environment is based on the premises of nature, climate and determinations on how grazing areas can be used, setting the framework for reindeer husbandry.

Sámi reindeer herding is a livelihood and way of life, based on a versatile utilisation of various resources within an annual cycle. A part of the cycle is how to use land during the different seasons. The reindeer herd's annual cyclic route – like moving from summer to winter pasture areas – allows for utilising many types of natural resources (Benjaminsen et al., 2016). This is subject to certain rules and is mainly controlled by natural phenomena, but particularly based on the needs of the reindeer (Mathis Nilsen Eira in Finnmarkskommisjonen, 2019). However, this is a way of life and nutritional adaptation with roots far back in time, shared with several other reindeer herding groups in the Circumpolar North (Benjaminsen et al., 2016).

The variations of the seasons and the reindeer's learned behavior to migrate between and remain in the same areas at different times of the year is the ecological understanding of reindeer husbandry as a pastoral nomadic way of life (Eira et al., 2016; Sara, 2001: 81). Reindeer husbandry is based on an annual cycle that includes migrations between seasonal pastures where moving and migration are part of a basic principle for land use in reindeer husbandry, namely as part of the principle of alternation (see e.g., Reinert et al., 2009). Reindeer nomadism is therefore not a random act. As emphasised by Sara (2001), it is a carefully coordinated enterprise that requires consideration of several factors – grazing, climatic conditions, season, reindeer habits and annual cycle, presence of other reindeer herds and the like. Reindeer herders use knowledge related to the management of the individual animal as a resource and the relationship between animal herds and natural environments, and reindeer in combination with the exercise of control over separate herds throughout the annual cycle in different types of natural environments and under different weather and climatic conditions (Sara, 2001: 10–11). This knowledge forms the basis for reindeer herding world view which shapes and gives meaning to the observations and herding management. (Turi, 2016: 20).

A reindeer is controlled by its biological clock, time, landscape, and weather. Its movements and roaming are determined by pasturing (Eira, 2012) and avoiding threats at different times of the year. Reindeer graze in different areas throughout the year, going from one spring season to the next. The reindeer year is divided into eight seasons, and the seasons determine how reindeer herding is to be managed, how the herder or herding group makes tactical (short term) and strategic (longer term) decisions. This represents the core of the adaptive capacity of the system. (Oskal et al., 2009).

Reindeer herders have experience and knowledge of how the reindeer cope and adapt to different situations through the year (Tyler et al., 2007), as well as knowledge of how the reindeer evolved by nature to meet and utilise the different seasons in the best possible way (Turi, 1998). Indigenous researchers also in relation to studies on reindeer herding have in the recent past used the definition of traditional knowledge made by the permanent participants (i.e., indigenous organizations with special status) in the Arctic Council (2015):

> Traditional knowledge is a systematic way of thinking and knowing that has been developed and applied to phenomena across biological, physical, cultural and linguistic systems. Traditional knowledge is owned by the holders of this knowledge, often collectively, and is uniquely expressed and transmitted. Knowledge is generated through cultural practices, lived experiences, including comprehensive multigeneration observations, lessons, and skills, which have been developed and verified over millennia and are still undergoing development in a living process, including knowledge acquired today. and in the future, and it is passed down from generation to generation. (Arctic Council Permanent Participants, 2015)

This definition highlights the historical creation, holism, and current and future nature of such knowledge. In this paper this is the definition we will adhere to when we talk about reindeer herding knowledge. Sámi reindeer husbandry has also recently been defined by Norwegian supreme law as *Sámi reindeer herders' cultural practice* (NHR, 2021). This practice can thus be understood as an expression of the practice of the Sámi reindeer husbandry and the foundations that lie in the Sámi reindeer herders own understanding of what sustainable reindeer husbandry is (see Johnsen et al., this volume, Chap. 3).

However, we will use the term indigenous traditional knowledge (ITK) to denote such knowledge in general, and Sámi traditional reindeer herding knowledge to denote the knowledge in Sámi reindeer herding in particular. This choice is made to induce clarity of the concept of knowledge among indigenous livelihoods. The indigenous traditional knowledge in Sámi reindeer herding is expressed in different situations in time and space; it has to do with the year, variants of years, the day, the weather and other cycles that are important for herding. These cycles and time periods dictate work in reindeer husbandry. A cycle here is defined as a period in which phenomena are repeated in the same order, and is used in several disciplines (e.g., the *solar cycle* in astronomy as described by Aksnes, 2020). Yet there is limited work done to explain reindeer herding periods. This paper is a contribution to such work.

This chapter explores aspects of the Sámi traditional knowledge used by Sámi reindeer herders in Guovdageaidnu (Kautokeino) in Northern Norway throughout a year, with special emphasis on herding during periods on snow-covered ground in focusing on Sámi traditional knowledge the aim is not to travel backward in time but to understand indigenous traditional knowledge-based strategies and applying this to the current situation (Turi, 2016). Our goal is to investigate aspects of knowledge sectors that form the basis for decisions made in time and space by Sámi herders with emphasis on periods and cycles and related to reindeer husbandry on snow-covered land**.**

This study was done in Guovdageaidnu, a reindeer herding region in Western Finnmark, which is characterised by topographic diversity, tundra, and woodlands; it is the largest reindeer herding area in Norway. We applied a social-ecological framework (Berkes, 2012) connected to acquiring knowledge using reindeer herders' professional language (Eira, 2012). The area was selected based on its presence of Sámi traditional reindeer herding knowledge and potential relevance for other reindeer herding and nomadic communities. The study was conducted through participatory research, following a bottom-up approach focusing on locally defined categories and perspectives (see also Johnsen et al., 2017). The study team consisted of two scientists with background from Sámi reindeer herding families in West Finnmark and one expert Sámi traditional reindeer herding knowledge holder with long-term expertise in reindeer herding in Western Finnmark. All narratives are provided by elders, the communications and collaboration meetings of the study team were conducted in Northern Sámi language, which enabled the fluent use of reindeer herding terminology and concepts in its original language. This constellation enabled a co-productive approach to documentation of reindeer herding knowledge-base, thus developing knowledge, based on scientific methods and indigenous traditional knowledge. The constellation of authors enabled in-depth discussion on data and analysis that may have otherwise been difficult (see e.g., Turi, 2016), by enabling co-production in science and indigenous traditional knowledge.

Data collection was based on expert analysis by our indigenous knowledge holder, interview data and narratives are provided by 34 reindeer elder herders conducted between 2007 and 2009 (resulting in 800 pages of transcription) and literature and policy review. The focus has been on defining and analysing concepts that are used by reindeer herders themselves (Eira, 2012) and are based on the experience and developed indigenous traditional reindeer herding knowledge (see e.g., Meløe, 1997).

The chapter is organized as follows; The section below, 4.2, outlines our literature review on concepts of time in reindeer herding. Section 4.3 explains the Sámi traditional reindeer herding knowledge of herding periods through the year. Section 4.4 outlines 5 herding periods during the snow-covered parts of the year. Finally, Sect. 4.5. discusses and provides our conclusions of this study.

4.2 Concepts of Time in Sámi Traditional Reindeer Herding Knowledge

This section outlines the concepts of time in Sámi traditional reindeer herding knowledge, focusing on Guovdageaidnu, our area of study. The section is based on our literature review based on sources from earlier research and outlines understanding of time in reindeer herding.

4.2.1 Understanding of Time in Reindeer Herding in Guovdageaidnu

In reindeer herding, there is ambiguity in relation to seasons, and focus is on work activities and times these need to take place. The practical reindeer herding calendar is therefore not directly correspondent to the Gregorian calendar's time divisions such as months or weeks.[1]

The understanding and practise of the reindeer's life cycle is its basic need for access to food and water, space for rest and shelter and space for physical activity (Eira, 2012). This is a part of an annual cycle through a season and through day-night periods, and includes variations like grazing, resting, rutting, calving, snowfall, snowmelt, hot weather and the prevalence of predators and insects. There are also activities which derive from human needs for organizing herds, such as identifying animals, earmarking, slaughtering, castration, separation, moving herds and training animals for transportation and other needs (Magga et al., 2009).

The time calculations are often based on the working year and how nature changes throughout the year. When calculating time, the moon was used to calculate shorter periods and the sun was used to calculate longer periods. (Gaup, 1995; Granlund & Granlund, 1973). The old Sámi calendar contained 13 months (Wiklund, 1895) but was later adapted to 12 months to correspond to the Gregorian calendar (Gaup, 1995; Lid, 1945). As highlighted by Granlund and Granlund (1973: 97–98), the old Sámi calendar relates to reindeer herding by in part showing how the weeks and months in the calendar are based on migration times, calving (*guottet*) and rutting (*ragat*). The Sámi names of the months often describe natural phenomena and apparent characteristics (see e.g., Leem, 1756; Wiklund, 1895). For reindeer herding, time and reindeer biology are very important, such as the time when the calves are born, when moulting. Therefore, some names of the months in the Sámi calendar describe phenomena directly associated with reindeer herding. For example, May is *miessemánnu* in Sámi (reindeer calf month), in which calves are born (Lid, 1945). *Borgemánnu* (August), says something about how the reindeer's fur changes. Further, *golggotmánnu* (October) refers to *golggot*, i.e., exhausted male reindeer (during the rut) (Eira, 2011; Magga et al., 2001) and says something about a time when male reindeer have finished rutting and are exhausted afterwards (Sara, 1999). Other names for months say something about phenomena that are characteristic of the time in question, such as April (*cuoŋománnu*) describing snow conditions, translated to the month of dense snow/ice layer (Eira, 2012). Also, some weeks have names that refer to changes in nature throughout the year. In the summer months, reindeer husbandry uses names based on fur change that can be translated to thin fur cover, medium fur cover and thick fur cover (Sara, 1999). In other words, the understanding of time among reindeer herders in Guovdageaidnu contains

[1] The Sámi traditional reindeer herding knowledge based herding calendar also differs from the administrative or governmental reindeer herding year in Norway, which starts in the beginning of April and ends at the end of March the following year.

characteristics and descriptions of the old Sámi calendar, the seasons, the solar year, the summer and winter half-years and names of weeks (See Table 4.1).

Indigenous reindeer herding is based on the optimal use of different seasonal pastures (Turi, 2009). Reindeer herds often follow an annual cycle moving between winter, spring, summer, and autumn pastures (Eira, 2017). Seasonality is independent of geographical location and is somehow ubiquitous across the globe. In habitats in the temperate northern and southern hemisphere there have been categorised four seasons (spring, summer, autumn, winter); in tropical habitats there are only two (dry and wet) seasons (Chapman et al., 2014). In Sámi reindeer herding habitats

Table 4.1 Traditional understanding of time in Guovdageaidnu

Cycle	Time	Characteristic	Description	Sources
Ancient Sámi calendar	13 months	Names of months are named after reindeer husbandry, except Christmas month, New Year month and February	The first part of the word refers to important epochs in the year cycle Refers to changes in nature and life created by the year In a year with 12 months there are almost 13 new moons. Therefore, the Sámi year has 13 months	Leem (1756), Stockfleth (1852), Wiklund (1895: 96), Lid (1945: 130) and Grundström (1950: 51)
Seasons	8	The natural changes throughout the year	Compound names for parts of seasons such as *giđđadálvi* (spring-winter); *čakčageassi* (late summer)	Wiklund (1895: 96) and Sara (1999)
Solar year	4	Summer solstice, autumn equinox, winter solstice and spring equinox	When the sun is directly in the south at noon, in the west in the evening, in the north at midnight and directly in the east in the morning, both the compass direction and the division of the day into four is visible	Sara (1999)
Summer and winter half years	2	This division also gives the direction of movement in space throughout the year	North and South refer to topographical alternatives, i.e., the summer half-year-area and winter half-year-area	Gaup (1995) and Sara (1999)
Names of the weeks	52 21 in research area	In a Sámi understanding, all the weeks of the year have their own names. In Guovdageaidnu there are names for 21 weeks, starting from mid-summer lasting to Advent	Accounts of the yearly changes or events in nature one can expect and the week in normal years	Gaup (1995), Sara (1999), and Qvigstad (1888: 97)

Table 4.2 The reindeer herding seasonal cycle

Reindeer herding season	Approximate months	English translation
Dálvi	December–March	Winter
Giđđadálvi	March–April	Spring-Winter
Giđđa	April–May	Spring
Giđđageassi	May–June	Spring-Summer
Geassi	June–Aug	Summer
Čakčageassi	August–September	Autumn-Summer
Čakča	September–November	Autumn
Čakčadálvi	November–December	Autumn-Winter

or pasture areas, the reindeer herding year is divided into eight seasons (Eira, 2011; Manker, 1975) (see Table 4.2).

Autumn (*čakča*) and spring (*giđđa*) are defined *year by year* by changes that are normal for these periods. Both summer and winter are divided into 3 periods each: pre-winter/autumn-winter (*čakča-dálvi*), mid-winter/winter (*dálvi*), late winter/(*giđđa-dálvi*), pre-summer/spring-summer (*giđđa-geassi*), mid-summer/summer (*geassi*) and late summer/autumn-summer (*čakča-geassi*) (Manker, 1975). Each period affects reindeer behavior, as does the state of the natural surroundings, landscape, and weather. There are many changes to weather and the terrain throughout the year, and all operations must adapt to them accordingly. The rutting season and calving time have a natural biological connection with each other but are also dependent upon weather and snow conditions (Skjenneberg & Slagsvold, 1968).

4.2.2 Sámi Herder Knowledge of Grazing and Resting Cycles Throughout the Day/Night

Daily rhythms in movement and activity triggered by circadian cycles are the rule for many animals, but such movements require regular light/dark fluctuations and are lost when such stimuli disappear. For example, reindeer generally show circadian rhythms in movement and activity, but during periods of constant light (midnight sun) or constant darkness (mid-winter) they lose their rhythm (van Oort et al., 2005).

Reindeer have a regular daily activity pattern, and they move to satisfy their grazing needs while also finding time to calm down and rest. In this the basic cycle is *jánddur* (day and night, 24 h). *Jánddur* is divided into the cycles of *guohtut* (grazing) and *livvadit* (resting). The reindeer herd has a grazing pattern characterised by scattered groupings with regular grazing and resting periods throughout the day/night. The number of resting periods may vary according to the time of the year. There usually are fewer resting periods on snow-covered ground (*muohtan*) than on bare ground (*bievlan*). According to N.I. Eira (1984) the reindeer usually graze for 3 h and rest for 3 h at certain times of the day or night during very good grazing

Table 4.3 *Livat* – Resting cycle of reindeer

	Names of different rest times in English	Autumn/Autumn-winter	Winter
03:00–06:00	Morning rest	***Guovssolivat ~ beaive-badjánan-livat ~ iđit livat*****:** The reindeer's first morning rest in autumn	***Guovsso-livat*****:** The reindeer's morning rest in winter
09:00–13:00	Noon rest	***Gaskabeaiv-livat*****:** The reindeer's noon rest	***Beaivel-ivat*****:** The day rest, the reindeer's evening rest in winter
16:00–19:00	Afternoon rest	***Veaigelivat ~ eahkedis-beaivlivat ~ eahkesbeai-livat*****:** The reindeer's afternoon rest in autumn	
	Evening rest	***Guovssovuodjun-livat*****:** The reindeer's evening rest in autumn	–
22:00–01:00	Night rest	***Gaskaija-livat*****:** The reindeer's night rest in autumn	***Idja-livat*** – Night rest, the reindeer's evening rest in winter (ca 20:00–21:00)

Adapted from Nielsen (1979), Eira (1984)

conditions. Other times reindeer rest for approximately 2 h and graze for 4 h. There is, however, a difference in grazing and resting times between autumn and winter (Nielsen, 1979) which are expressed with different concepts (See Table 4.3).

The autumn/autumn-winter cycle usually has five resting periods: *Iđit-livat* (morning rest) (also called *guovsso-livat (daybreak rest), or beaivebadjanan-livat* (rest at daybreak)); *gaskabeai-livat* (rest at midday), *veaige-livat* (rest in the evening) (also called *eahkedis-beivlivat* or *eahkesbeailivat*); *guovssovuodjun-livat* (rest when dusk disappears) and *gaskija-livat* (rest at midnight). There usually are fewer resting periods on snow-covered ground (*muohtan* 'when there is snow') than on bare ground (*bievlan* 'when there is bare ground') (Eira, 1984; Nielsen, 1979). The cycle is determined by, i.e., *veaigi* (twilight or dawn) and *guovssu* (daybreak). Reindeer herders use four main terms for the times of day/night: midnight (*gaskaidja*), morning (*iđđesveaigi*), midday (*beaiveguovdil*) and evening (*eahkesveaigi*) that have consequences for herding (Eira, 2011). Reindeer herders know that the reindeer are most active at dawn, in the morning, at dusk, and in the evening. For example, *Eahkedisveaigi* (twilight) in Guovdageaidnu in January 2021 is at about 14:00 and *Iđđedisveaigi* (dawn) is at about 09:00.[2]

All these Sámi concepts of time form the background for reindeer herding periods through the year. In the following section the periods during snow-covered seasons as defined by Sámi traditional reindeer herding knowledge are outlined.

[2] See e.g., Time and Date (n.d.) Kautokeino, Norge: Soloppgang, solnedgang og dagens lengde, oktober 2021, online: https://www.timeanddate.no/astronomi/sol/norge/kautokeino (accessed 26.10.2021).

4.3 Sámi Traditional Reindeer Herding Knowledge of Herding Periods Through the Year

This section and Sect. 4.4 present the results of our study and is based on communication with reindeer herders, including knowledge from co-author J.M. Turi.

In Sámi traditional knowledge on reindeer herding in Guovdageaidnu, the periods in a reindeer year are understood as periods of built-in cycles that repeat from year to year, and where some basic elements are always present. Parts of the cycles are related to patterns on grazing, well-being, calving, rutting etc. The patterns are governed by environmental factors such as climate, nutritional needs, and cycles where each cycle is related to another. Some cycles are easily observable like rutting and calving (Skum et al., 2016), while others, like the resting cycle (*livat*) (see also Table 4.1), are more intricate and require knowledge and experience to be fully understood. The patterns are also influenced by environmental factors, where flexibility and change are prerequisites for survival reindeer. Both traditional holistic knowledge and a herder's physical observations of snow play key roles in herd management (Eira et al., 2018).

According to Sámi reindeer herders, an important factor is always to have an overview of the herd and the animals that are away from the herd. There are also five key factors that characterise snow cover and snow type: (1) access to water, food, and space, (2) physical activity, shelter, and rest, (3) mobility for reindeer and herders, (4) visibility of tracks in the snow, and (5) visibility of animals and environment (See also Eira et al., 2010, 2018).

One tool that reindeer herders use is to anticipate situations. Herders anticipate conditions regarding climate, snow conditions, environment and use these to constantly adapt to new situations by knowing the nature of reindeer (in Sámi: *bohcco luondu*), its reflexes, moving patterns, reactions to external stimuli, typical behavior in relation to other reindeer, natural surroundings, and seasons. But even if reindeer herders use the predicting as a tool, one must remember that the natural environment is at one hand extremely predictable and repetitive, while at the other extreme, unpredictable, and shifting. In pastoralist thinking, the principle of flexibility or mental preparation for change is prominent and it must be adjusted to daily evaluations and decisions in relation to short-term and long-term pasture strategies. The environments related to herding and *siida* systems are open-ended. All this creates a kind of predictable unpredictability. But by using the reindeer herder's knowledge and the ongoing practice and changes in the socio-ecological system, herders can form and maintain the reindeer herd according to their own plan and pasture areas. The ability to anticipate is also used in different situations like the well-being of the reindeer, and this can best be understood in terms of cycles that are based on indigenous traditional knowledge of reindeer herding. Annual cycles in herding include a round of years or a recurring period and are displayed with seasons, months, weeks, time of day/night to be understood. According to Hyndman (2011), seasonal patterns are series that are influenced by seasonal factors like the quarter of the year, the month, or day of the week.

The development and behavior of reindeer follow a pattern that is determined by how the reindeer as a species is equipped to respond to its surroundings and the environment, i.e., the landscape, the vegetation, the varying food supply, and the varying climatic conditions throughout the individual parts of the year. It follows that there is a significant coincidence in development and behavior patterns of reindeer in the different geographical areas at different times of the year, but also some significant differences that relate to the combination of landscape, vegetation, nutrient supply, and climatic conditions in individual areas (e.g., snow conditions).

Although the year is divided into eight seasons, the herding season is a gender and behavior related division, which means that female reindeer have more and different periods than male reindeer. A reindeer year is thus divided into nine periods for female reindeer and eight periods for male reindeer. The one period that applies to females is period 5, the calving period. Simultaneously the males continue to follow 4. period, the spring period. As shown in Table 4.4 the periods are divided into weeks and in relation to approximate time.

Focus aspects of the reindeer herding knowledge and practices are dealing with the sustainability of nomadic husbandry and herding. These include issues like herd management, relationship to local landscape and natural environment (Ruong, 1964), knowhow and adaptation to varying climatic conditions, and knowledge processes, ethical considerations and decision making (Eira, 2012; Sara, 2013). Furthermore, as described by M.N Sara (2013), reindeer herding is a highly complicated enterprise. Control is never complete or guaranteed because the animals are self-sufficient and in continuous movement within a vast and complex landscape (Bull et al., 2001).

Summarized, a reindeer cycle and a period can contain week names, seasonal grazing areas – topographical sections, light/dark – moon, climate – weather and snow conditions, temperatures, the behavior of a single reindeer and the herd, herding systems, biological factors, age, gender, antlers, and other significant tasks, as outlined in Table 4.5.

Table 4.4 The reindeer herding periods of a year

Period	Name of the period	Approximate time
1	*Vuosttaš muohta ja njáhcu* (First Snow and thaw period)	Weeks 41–44
2	*Skábma* (dark time period)	Weeks 45/46 till week 2
3	*Dálvi* (winter period)	Week 50 till beginning of February
4	*Dálveguovdil* (mid-winter period)	Beginning of February till end of march
5	*Giđđa* (spring period)	Beginning of April till end of May
6	*Guottet* (calving period)	End of April till *Jonssot* (June 24th)- end of June
7	*Geassi* (summer period)	End of June till middle of august
8	*Čakča-geassi* (Autumn summer period)	Middle of august till middle of September
9	*Rágat* (Rutting period)	Middle of September till *dálvevahkku* (from approx. October 14th)

Table 4.5 Contents of a reindeer herding cycle

Week Names – Sámi Month Names	Seasonal Grazing Areas	Topographical Sections	Reindeer Behavior
Antlers	Age – Gender	Grazing and Resting	Biological
Light – Dark	Climate – Weather	Significant Tasks – Moon	Snow Conditions
	Temperatures		

4.4 Five Herding Periods During the Snow-Covered Parts of the Year

This section provides examples of the fundamental understanding of Sámi reindeer herd management during the snow-covered parts of the year. We have divided the reindeer herding year into 9 periods as described by reindeer herders (see Table 4.4), and out of these we will cover the 5 periods which are snow-covered. These are: *vuosttaš muohta ja njáhcu* (first snow and thaw period), *skábma* (dark time period), *dálvi* (winter period), *dálveguovdil* (mid-winter period) and *giđđa* (spring period).

These periods form the basis for decisions made by herders in time and space on snow-covered ground. We will give examples of content for these periods. These cycles are described in narratives provided by elders from the herder communities on annual seasons and periods. They express the relationship between using Sámi reindeer herding technical concepts connected to seasonal cycles and the sequence of periods corresponding to land use, snow, reindeer biology and behavior.

The patterns in a *reindeer year* set the external framework for the Sámi reindeer herding which is conducted in the traditional way in certain geographical areas. Throughout the year, the seasonal grazing areas and the topographical sections strongly affect reindeer handling in a period. Periods in each cycle are related and dependent on each other.

In periods reindeer patterns are influenced by environmental factors that require continuous adjustments to maintain the best possible situation for reindeer. The cycles in reindeer herding change depending on area, environment, climate, sex and age of individual animals and the experience of individual animals and the herd as a whole. Reindeer are standing in and using different types of terrain and landscapes, during the day, in different weather conditions. This requires reindeer herders to be able to read the terrain and weather to predict the different responses to the animals related to gender and age. This knowledge is used, for example, to find probable areas for reindeer that are temporarily missing, also described by Paine (1972). This shows the depth of knowledge displayed with the reindeer herders' technical language that is required for this activity. Reindeer herders use, i.e., several key concepts that are crucial to the understanding of how principles of interdependence between reindeer herd, personnel and pasture are managed. The concepts are derived from Sámi traditional reindeer herding knowledge and are organized chronologically from autumn-winter to spring-winter. An outline of key understanding shown by concepts is displayed in Table 4.6.

The herders play a crucial role in evaluating and observing the situation regularly during the day, every day during winter. This is about reindeer behavior on the snow, survival, sustainability, and the well-being of reindeer. Thus, knowledge of the annual biological and behavioral cycles of reindeer, land use, climatic conditions, snow, herding systems, and the relationship between these forms the basis of nomadic work with reindeer. Table 4.6 represents knowledge of grazing patterns during different seasons and topographies and weather conditions; wind and different snow conditions are particularly crucial for herd control (Eira, 2022; Paine, 1972). Snow physics, as shown in Table 4.6, have a significant impact on herding and grazing ability (Eira et al., 2018). On average there are 228 days a year with snow on the ground in Guovdageaidnu (Vikhamar-Schuler et al., 2010).

The knowledge of snow physics is part of the herder knowledge system for snow and ice. They articulate a comprehensive knowledge concerning snow physics that contains different snow characteristics like hardness, density, stratigraphy, layer thickness, snow depth, snow water equivalent and physical processes of snow that affect these (Eira et al., 2013). So, the denser the snow is, the harder it is for reindeer to dig holes in the snow and reach the grass/lichen, etc. below the snow (Eira, 2012) (see Fig. 4.1).

In the annual cycles of snow on ground, the snowpack presents a picture of the weather event from the time of first snow and consists of snow embedded in layers with different characteristics like order and thickness of layers within the snowpack. These are also highly significant for reindeer herders as they affect reindeer survival, sustainability and well-being, and human working conditions.

Throughout the winter in a winter grazing area, a *siida* may use more than 20 different topographic areas (Eira, 2012), affecting how the snow settles on different types of terrain/different landscapes and thus influences the reindeer in different ways (Eira, 2022).

The daily work with reindeer on snow-covered areas comprises many different types of activity – especially related to the herd, the herder and the *siida* – like "ecology, herding strategies, coordination of herding tasks and in relation to surrounding *siida* units" (Sara, 2009: 158). A part of the herding strategies during winter is to find food for the herd with the lowest possible energy expenditure for digging and movement, while controlling the herd. The herding strategy also

Table 4.6 Key concepts used by Sámi reindeer herders on weather and snow conditions and herding

Key concepts used by Sámi reindeer herders on weather and snow conditions and herding
Bievla: Condition with snow-free ground in early autumn and late spring
Vuosttaš muohta: The first snow deposited in the autumn that builds up the snow cover on the ground
Dálvvi vuođđu: The basis of winter. The snow on the ground in the autumn, variability of snow, weather, winds, temperatures and precipitation, melt/ freeze cycles, ice causes for how winter will be. The ideal situation in the autumn will be if soil is frozen before snow accumulates on the ground surface. The snow can thus thaw because the soil is frozen before the snow cover develops. Conversely, snow on warm soil can lead to the most critical grazing variables for reindeer
Bodneskárta: A result of a melt and freeze cycle occurring in late autumn/early winter when snow melts and the water freezes to form a hard coating of ice on the ground and plants. This condition will have a great negative impact on grazing possibilities in winter because it is almost impossible for the reindeer to penetrate the ice layer and thus reach the pasture (food)
Golggu-njázut: Slushy snow (*njáhcu muohta*), a combination of snow and liquid water occurring in connection with All Saints Day. This condition occurs because of alternating snow, higher temperatures and subsequent thawing. One can expect that it will become a bad winter with snow and subsequent rain in combination with large temperature fluctuations from minus to plus, and then colder temperatures. This will form ice layers (*geardni*) and at worst produce *bodneskárta* conditions
Seaŋáš: Granulated snow with lose snow structure that forms at the bottom of the snowpack. This snow can provide good snow conditions for the reindeer and improve dense snow and thus better grazing conditions. When the herders know that the snowpack contains *seaŋáš*, they know that it is easy for the reindeer to dig through *seaŋáš* to the pasture plants beneath. Seaŋáš develops in shallow snowpacks, usually at the beginning of the winter season when the temperature gradient is > −10 °C/100 cm snow depth
Seakŋut: The *seaŋáš*-process that forms of because of large temperature gradients within the snow pack. This can change the dense snow consistency to *seaŋáš* in very cold temperatures
Oppas: Snow condition in an untouched or untrodden area in winter. In this condition, the entire snowpack from the surface to the bottom includes loose snow, snow types like *vahca, luotkkomuohta, seaŋáš* and thus have not been touched by reindeer when grazing
Čiegar: Snow condition with very dense snow in an area in winter. Such conditions occur because reindeer have been grazing in the area leaving cold grazing holes (*suovdnji*) in the snow. The process that makes *čiegar* is that the reindeer by grazing is destroying the snow crystal structure, so that the snow change, sintering process goes much faster
Čearga: Dense surface snow layer that can be from 5 cm to 1 m deep made by winds depositing hard-packed snow later of blown snow from January to April. The wind is transporting the snow, resulting in broken snow particles, and thus forming a strong and dense snowpack that can be so hard that neither reindeer nor people can dig through the snow
Skávva: Thin ice-layer at the surface formed by the freezing of sun melted surface snow. This occurs in spring-winter and spring. This is a part of the melt and freeze cycle, the stage before *cuoŋu* (strong crust on snow). The crust has strength enough to support the weight of people and reindeer. For migrating in spring, *skávva* can bring good travelling conditions
Cuoŋu: Ice layer which results from melt starting in mid-morning or early afternoon making *njáhcu* and freezing starting when the sun goes down. This belongs to the *cuoŋu*-cycle, i.e., melting followed by refreezing in spring-winter. This makes a hardened snowpack that obstructs reindeer in getting through the layer to the lichen but can bear both people and animals

(continued)

Table 4.6 (continued)

Key concepts used by Sámi reindeer herders on weather and snow conditions and herding
Ruovdecuoŋu: A very dense layer of ice that occurs when the snow has been softened up and then frozen during the night. It is a part of the *cuoŋu*-cycle
Moarri: A thin crust on the surface formed because of alternative thawing and refreezing. It is almost hard enough to support the weight of the reindeer, but not quite hard enough to support the weight of people. The crust is very sharp, and the reindeer avoids going into *moarri* because it cuts the legs/hooves when one breaks through. If the herders are trying to move the herd in *moarri* conditions, it becomes very difficult to do so because it is hard for the reindeer to move through this type of snowpack
Goavvi: Disaster event connected to snow conditions that cause starvation and death of reindeer, negative calf production (*miesehis jagit*) and less nutrition – which in turn affects the herders' livelihood, economy, and psychosocial well-being. This appears during extreme weather events caused by a combination of different ice formations, amount of snow, dense and hard snow that is too hard for a reindeer to penetrate like ice (*jiekŋa*) layers on the surface or in the snowpack, ice frozen into the vegetation (*bodneskárta*), deep snow (*gassa muohta*), and wind-packed snowdrifts (*čearga*). These conditions can cause impenetrable pastures – often referred to as 'locked' pastures

Fig. 4.1 Reindeer grazing and making grazing pits in the snow (*suovdnji*). (Photo: I.M.G. Eira)

includes observing and monitoring snow conditions and the behavior and reaction of reindeer to different types of snow and ice on the ground, and snow in the air. This comprises the nature of the snowpack with different layers with unique characteristics in terms of density based on diverse snow crystals, amount of drifting, and the temperature in the snowpack, and influenced by snow metamorphism or the change of snow crystals over time (Eira, 2012, 2022).

A basic concept used in connection with herding on snow-covered land is *guođohit*, which is closely linked to *guohtun*, which describes grazing conditions and access to food through the snowpack: how easy or difficult it is for the reindeer to gain access to food by digging in the snow (see Fig. 4.2).

In winter, the snow conditions also are of importance for grazing and resting. When grazing conditions in snow are good (*buorre guohtun*) (Eira, 2012), these are more fixed in relation to the time of day than when grazing conditions are worse.

Fig. 4.2 Reindeer herder evaluating *guohtun* in the snowpack. (Photo: I.M.G. Eira)

Both grazing and resting times (see Table 4.3) and synchronization of the herd can change with the weather, reindeer-specific conditions, and the seasons. Grazing and resting times are nevertheless something that can be easily manipulated by the herders without creating significant problems. Here, however, it should be said that it is not always wise to manipulate these activity cycles. Manipulation of grazing and rest times often takes place during practical herding, for example when moving over long distances, or when the reindeer are corralled inside fences.

The approach and considerations necessary vary from year to year. There is a saying in reindeer herding that *Jahki ii leat jagi viellja*, 1 year is not another year's brother. This highlights the experience of variance between years, and that 1 year's climatic conditions do not follow the previous year (see also Tyler et al., 2007). The ecological seasons vary and therefore also the herding periods vary. It is necessary to take into consideration both variations through the year, and variations from year to year. Herding periods also overlap, as is especially evident between *skábma* and *dálvi* (Sects. 4.3 and 4.4). In addition, it is not possible to place these periods in exact week numbers. We have, however, included approximate week numbers and time frames for the periods.

4.4.1 Vuosttaš muohta and njáhcu *(The First Snow and Thaw Period)*

Vuosttaš muohta and njáhcu period (first snow and thaw period) begins after the end of *ragat*, the breeding season in the middle of October. A day of significance is the 14th of October, called *Dálveidja/dálvebeaivi* (winter-night/winter-day). The week of this date marks the beginning of the period. *Vuosttaš muohta* (See Fig. 4.3 below) *and Njáhcu* last from the middle of October to the middle of November.

As mentioned before, this period begins with the first snow, often appearing around the middle of October. The period is characterised by changing from *bievla*

Fig. 4.3 *Vuosttaš muohta* – The first snow. (Photo: I.M.G. Eira)

(snow-free ground) to *muohta* (snow), that is of great importance for the rest of the winter. The first snow often melts again, but sometimes this snow stays and makes the snow cover on the ground. During this period the basis of winter is formed. The snow on the ground in the autumn, variability of snow, weather, winds, temperatures and precipitation, melt/freeze cycles, ice will make the basis for how the rest of the winter will be. The ideal situation in the autumn will be if soil is frozen before snow accumulates on the ground surface. The snow can thus thaw because the soil is frozen before the snow cover develops. Conversely, snow on warm soil can lead to the most critical grazing variables for reindeer.

In this period, reindeer herders anticipate a significant week *dálvevahkku* (winter week) October 8–14. Herders know that after this week, the climate will change with colder air and snow. Furthermore, herders also know that the behavior of the reindeer herd will change from hectic times to calmer conditions.

The period also includes weather characterized as *njáhcu. Njáhcu* is thawing weather, and occurs both in autumn and spring, and *njáhcu muohta,* wet slushy snow, that occurs as a result of alternating snows and thaws. This condition occurs because of alternating snow, higher temperatures and subsequent thawing and subsequently freezing.

Herders anticipate that snow and subsequent rain in combination with large temperature fluctuations from minus to plus will result in a bad winter. This rain and freezing will form ice layers (*geardni*) and at worst produce *bodneskárta* conditions (see Table 4.6 above). If the first snow has thawed and then frozen again it will turn (metamorphic) to ice. This will affect *guohtun*, as the lichen is frozen under the snow, sometimes throughout the whole winter until spring.

This period is divided into three subsequent weeks called; *Golggu-njázut, Simonvahkku-njázut and Hállemas-njázut. These are* around week 42–45. *Golggu-njáhcu*, denoted from the term *golgu,* refers to the time the male reindeer is exhausted after the rutting season. This normally occurs during weeks 42–43. Then follows *Simonvahkku-njázut* at the end of October. Finally, *Hállemas-njázut,* (derived from the Sámi word for All Saints Day on 1 November) comes on appr. week 44.

Reindeer herders have through generations been told that if the thaw does not occur in early November, it will be a bad winter and thus bad grazing conditions for reindeer. The prediction or anticipation for the winter is that no thaw in November can cause mild weather (with plus degrees) and periods of rain on snow. Such weather conditions cause ice layers in the snowpack and possibly the ground will be icing, which makes it difficult for reindeer to reach lichen under snow and ice. For example, In the beginning of November 2019, there was no thaw around the time of *Hállemas-njázut*. This caused hard pasture conditions already in the early winter of 2020 and these snow conditions were preventing reindeer to reach lichen. (See Johnsen et al., this volume, Chap. 3) Earlier the *Hállemas-njázut* corresponded with the calendar, occurring from 1 November. In recent years, however, this seems to have changed, as there has been no such thaw in November for several years due to climate conditions.

The weather in autumn to winter, especially in snow/ice types that occur in the autumn (like *bodneskárta*), has major consequences for *guohtun*. This condition will greatly impact grazing possibilities negatively in winter because it is almost impossible for the reindeer to penetrate the ice layer and thus reach the pasture/food. In 1910, Johan Turi (1931) described the transition from bare ground to snow-covered ground using some snow concepts and how these occur.

> At that time, when the bulls are worn out, then it generally thaws, and that thaw is called golggonjacco (the debility thaw). And then you generally lose the herds because it is very bad weather, fog and rain, and when it thaws much there is bare ground in some places, and in other places the snow is left lying, and when it freezes, then that snow is turned to ice or, as it is called, bodneskardan (bottom crust), and it remains all through the winter just as it is at the time when the last thawing stop and the cold comes. But if the thaws do not spoil the snow, then it will be a good winter, unless there comes very deep snow, for the reindeer can get to the mosses even if the snow is fairly deep, if only there is a clean bottom, that is, no ice on the bottom. And it is at this time that the Lapps are afraid (wondering) what the winter will be. (Turi, 1931: 53–54)

During this period, the reindeer move more out of instinct (see also Eira, 2011: 44) and the reindeer herders know that reindeer generally move to areas that are in topographical sections like lowlands in this period, where dense vegetation is found. With this knowledge, the herder can predict how the reindeer will move in the terrain. Reindeer also tend to start moving fast after one other in a long line (*ruvgalit)* (Eira, 2011), and this makes it in general more difficult to herd and requires more from the reindeer herder. But whether the reindeer is calm or moves a lot will of course vary from year to year.

In this period, most of the *siidas* will migrate from the autumn pasture areas to winter pasture areas (Eira, 2011: 46). During the migration, the herders follow the reindeer rest cycles that include five resting periods. It is worth noting, however, that administrative rules on reindeer herding dictate when herders can move from one seasonal pasture to another. *Siidas* cannot move from autumn pasture areas to winter pasture areas before 1 November.

4.4.2 Skábma *(Period of Polar Nights)*

Skábma, the period of polar nights, follows from the middle or first half of November to sometime in the earlier part of January, around 45/46 till week 2. This period is characterised by snow on the ground (usually) and dark time (polar night) when darkness lasts for more than 24 h.

During this period, the reindeer are often found in boglands and low areas and dense forest terrains. This period usually has cold weather and no wind, so the forest will often have snow and ice on the trees (*rinádat*). *Ritni* is steam that freezes to ice-crystals on the ground. This happens when the temperature on the ground falls below the dew-point-temperature.[3] *Ritni* was more common in earlier years when this period had longer periods *buolaš* (very low temperatures, i.e., below −10 °C) (see Fig. 4.4).

In the last part of this period, due to climatic conditions, especially low temperatures, the herders will find granulated snow at the bottom of the snowpack (*seaŋáš*) that can last right until the beginning of April, possibly a period of almost 4 months with good grazing conditions. But the availability of pastures under the snow cover constitutes a critical bottleneck in the annual herding cycle. From around the end of November to the beginning of December the reindeer herd began to change behavior towards a *dálveeallu* (winter herd).

Fig. 4.4 *Ritni* – steam that freezes to ice-crystals on the ground. (Photo: I.M.G. Eira)

[3] Dew-point temperature is the temperature below which the water vapor in a volume of air at a constant pressure will condense into liquid water. It is the temperature at which the air is saturated with moisture (see Jones MB (1985) Plant Microclimate. In: Coombs J, Hall DO, Long SP, Scurlock JMOBT (eds) Techniques in Bioproductivity and Photosynthesis, 2nd edn. Pergamon, pp. 26–40).

4.4.3 **Dálvi** *(Winter Period)*

The winter period begins in the middle/end of December, around week 50, and lasts till the beginning of February. In January the sun will be shining again in the north and the time of darkness is over.

These areas have been in permanent darkness for a few months when the sun remains below the horizon. The period is usually characterised with very cold, low air temperatures and snow. The coldest air temperature measured in Guovdageaidnu was −57 °C (not officially recorded in the meteorological station) in January of 1999 (Eira, 2012). Cold temperatures are a prerequisite for the creation of loose snow, called depth hoar (*seaŋáš)* that is close to the ground which reindeer can easily dig through to access food (Eira et al., 2013) (see Fig. 4.5).

If the bottom of the snowpack is good (if there are loose snow types), then the reindeer easily can reach the vegetation underneath. But if there is ice at the bottom, this has a negative effect on their ability to graze. It is therefore important to check snow conditions at the bottom of the snowpack.

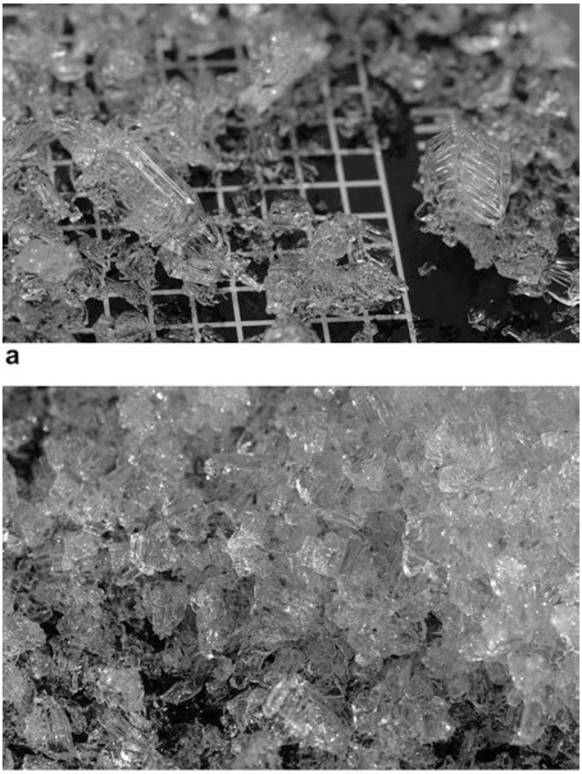

Fig. 4.5 (**a**) *Seaŋáš* – depth hoar. (Photo: I.M.G. Eira). (**b**) *Seaŋáš* – depth hoar. (Photo: I.M.G. Eira)

Examples from January and the beginning of February show herding decisions on winter pasture areas due to different snow conditions. Different topographical sections of the winter pasture are used, like *vuopmi* (woodland), *roavvi* (long, not very high wooded mountain), *čearru* (rather flat, usually wide tracts high up in the mountains with little vegetation and long stretches of nothing but gravel and stones) and *jeaggi* (marshes). In winter pasture areas reindeer herders also encounter terrains that are dangerous for both people and animals called *opmu* (miry holes) (see Fig. 4.6). Herders with local knowledge will know the location of these and be able to avoid them. Reindeer, however, may seek these as there are fresh herbs, *gorddehat* (Equisetum fluviatile) and calcium available here.

From around December to April, the herders emphasise whether the snow is loose or hard in their evaluation and characterisation of winter pastures, deciding how the herd has grazed (Eira & Mathiesen, 2021). If there is *oppas* (see Table 4.6 for English translation and explanation of Sámi snow terms) then it is good, but if there is *čiegar* then the herd has to be moved to other parts of the grazing area. They use their knowledge of *oppas* and *čiegar* which are determining factors in explaining an evaluation of the survival and sustainability of reindeer (Eira et al., 2010). *Oppas* designates an untouched or untrodden area in winter where reindeer have not been grazing (Nielsen, 1979:178; Eira, 2012) and *čiegar* designates areas in winter where reindeer have been grazing intensively and where the snow is hard (Nielsen, 1979 I: 382; Eira, 2012). This implies that grazing snow conditions are good because the entire snowpack from the surface to the bottom includes snow types like *vahca, luotkkomuohta* and *seaŋáš* (Eira et al., 2013). The main strategy in winter is to use *oppas* in an economical way to preserve and save it as a kind of food-capital through the winter, which can contribute to the survival of reindeer during the winter (Eira,

Fig. 4.6 *Opmu* – some kind of miry holes. (Photo: Aslak Anders I. Gaup, Guovdageaidnu, 2019)

Fig. 4.7 *Čiegar and Oppas.* (Photo: I.M.G. Eira, 2012)

2012). The ideal image in each winter *siida* area mostly contains *oppas* and somewhat less *čiegar* (see Fig. 4.7).

During the winter period, the herders must know how reindeer or herds affect the snow cover and how this in turn affects areas where reindeer are to graze. The herding strategy in winter is often that the herder drives around the herd and monitors how the herd is grazing. The reindeer herd is subject to controlled spreading (*lávdat*) within a forest area, at the same time as one is aware of not driving the scooter in the area. It is important to keep the area as untouched as possible regarding tracks etc. *Lávdat* is perhaps the only way to utilise the pastures sensibly (Eira & Mathiesen, 2021). If the herd is grazing quietly and keeping together, the herder will be looking for tracks of straying reindeer. If there are tracks crossing the circling tracks of the herder's snowmobile, the herder must find out where the reindeer have gone and bring them back to the herd; and if the herder observes that the herd is not grazing quietly and has escaped from the core winter grazing area, he must find the reason for this behavior (Eira, 2012). This has to do with the knowledge of *guohtun*, on how reindeer access food through the snowpack. The perfect *guohtun* contains loose snow (*luotkko muohta*) and granulated, loose snow (*seaŋáš*).

Including *seaŋáš* process that can improve snow conditions, weather and wind can both improve snow conditions, or worsen them (Eira, 2012). A lot of snow and wind can cause *čearga*. This snow condition does not usually create big problems for the reindeer to dig in the snow, but it can cause poorer grazing conditions. *Čearga* conditions affect the mobility of both reindeer and humans as it is easy to travel on this type of snow. Consequently, the herders need to be very careful not to lose individual reindeer to neighbouring herds.

Weather, wind, and snow conditions from autumn–winter 2019 to spring 2020 made a *goavvi* (hazard) year for reindeer and herders (see Johnsen et al., this volume, Chap. 3). According to meteorological data (Fig. 4.10), there was a combination of much precipitation in the form of snow combined with strong winds, and the snow was transformed into round crystals that make snow denser and harder and led to much *čearga*. The snowpack became very hard, with ice layers on the surface, and below that there were hard, thick layers of snow (*čearga*), and under this were an ice layer 2–4 cm thick (*geardni*). At the bottom of the snowpack, there were almost no *seaŋáš*. Many *siidas* also reported ice frozen in soil and vegetation (*bodneskárta*). There was a very late snowmelt this spring.

A lot of rain, snow, and strong winds from December 2019 to January 2020 increased the hardness of the snowpack throughout winter and until the snow started melting. The highest wind speed in Guovdageaidnu was 12.3 m/s on December 28th and January 4th (see the Fig. 4.10 below) and this led to a lot of thick *čearga*. The snow depth from base to snow surface (*gassa muohta*) was also 97 cm in March. In a normal year, the snow depth is approximately 60 cm (see Fig. 4.8).

4.4.4 Dalveguovdil *(Mid-Winter Period)*

Dálveguovdil period (mid-winter period) is the period from the beginning of February till the end of March/beginning of April. For reindeer herders, this period will usually be a very stable herding period.

The period starts with *dálveguovdelvahkku* (mid-winter week). A day of significance in this period is *Gintalbeaivi* (candle day) on February 2, and the associated week (*Gintalvahkku*). There is a saying in reindeer herding that *gintalbeaivi* marks the middle of the winter, or that on *gintalbeaivi* “the back of the winter breaks”. This

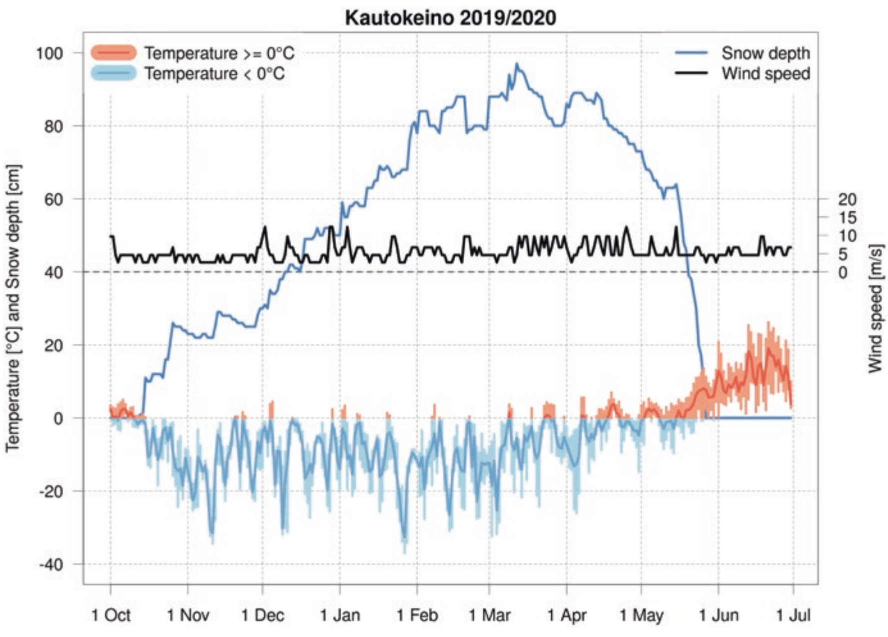

Fig. 4.8 Temperature, snow depth, and wind speed in Kautokeino from 1st October 2019 to 1st June 2020. (Julia Lutz, Meteorological Institute 2021)

means that from this day the weather begins to turn towards spring. Other days of significance are *Máhtebeaivi* (Mathis day) February 24th and *Márjjábeaivi* (Maria day) on March 25th. Reindeer herders have experienced that from *Máhtebeaivi* there will usually be more and more snow. This snow is often called *borgafásttut (snow drift in time of fasting)*. *Fásttut* (time of fasting) follows Easter and will always fall on a Sunday 49 days (7 weeks) before the 1st day of Easter.

At the end of this period in normal years, the climate, higher temperatures, precipitation, and snow conditions will have a major impact on the reindeer and herding, and grazing conditions will be worse in the forest areas (*vuopmi*). The reindeer herd will thus move to higher topographical sections of the winter pasture, to tundra (*duottar*). This is the first time in the winter that the reindeer are moving. Thus, there is an alternation between two landscape or ecotype landscapes in relation to the snow (amount of snow, depth, hardness); *vuopmi* and *duottar* are two landscape types that are used in alternation.

If *guohtun* conditions earlier in the winter period have been good, and it has been possible to save area units where there is the least snow, e.g., larger openings in forests and marsh areas with low tufts, then the herd will still be able to stay in low forest areas (*vuopmi*). Thus, in the last part of this period, the reindeer herd will move to higher topographical sections of the winter pasture from woodland (*vuopmi*) to tundra (*duottar).* The weather type and snow conditions (amount of snow, depth, hardness) affect the alternation between the two landscapes.

4.4.5 **Giđđa** *Period (Spring Period)*

The *Giđđa* period lasts from the beginning of April to the end of May. In this period, the herd as a unit will change. At this time of year, the females will naturally separate from the males, but as a strategy it has been common for most *siidas* to make an orderly separation of males and yearlings that do not follow their mothers, to establish this part of the herd as a separate unit under supervision. After this, two different herds have been established – a female herd (*čoavjjet eallu*) and a male herd (*luovas eallu*) – to be herded. In this period, the herders must use knowledge and skills to know which animals there are or not in the herd unit by getting an overview of the animals that have not been observed. This is a simplification, and a number of strategic animals are used to notice if these are present in the herd. Strategic animals often have special characteristics or special appearance (Eira, 1984).

The weather will change this period with increasing temperatures and melt and freeze cycles will appear, and the snow conditions and snowpack will change drastically (Maynard et al., 2011). In the period the temperatures will rise above freezing with melting snow or rain followed by refreezing (rain-on-snow conditions) form very dense ice layers in the snow. The strength in the snow layer increases with the number of melt-freeze cycles (*geardni, cuoŋu*). Weather conditions during the period of intense solar radiation make for warm days and thus the snow will become wet and thaw (*njáhcu)*, followed by strong refreezing during the cold nights. Refreezing of wet snow creates a melt-freeze crust on the surface (*cuoŋu)*. The density and strength of the crust increases with the number of melt-freeze cycles. This is the *cuoŋu*-cycle (Eira & Mathiesen, 2021) (see Fig. 4.9).

In Guovdageaidnu, the temperature and snow conditions make this a challenging time, herds are grazing close to each other, so it is important to avoid mixing with the other herds. So, when herders say the situation is *cuoŋu*, the other herders immediately know that the snow is so hard that – in such conditions – the reindeer move quickly over great distances, and the herd must be managed tightly to avoid it running off or breaking up and scattering (Eira, 2011). (See Fig. 4.10).

When the situation becomes *cuoŋu*, the reindeer can enter the forest because they are no longer able to graze. The forest is important for the reindeer because they can find brown beard lichen (*lahpuid*) on the trees (Holand et al., 2000: 10; Eira, 2011).

While reindeer feed on many kinds of plant species on an annual basis, the main source of nutrition in the winter is various species of lichen (*jeagil*), but other plants like heather (*daŋas*) and grass (*sitnu*) are included in the menu. Access depends on snow quality and snow layers. Water intake is in the form of loose snow (*vahca*).

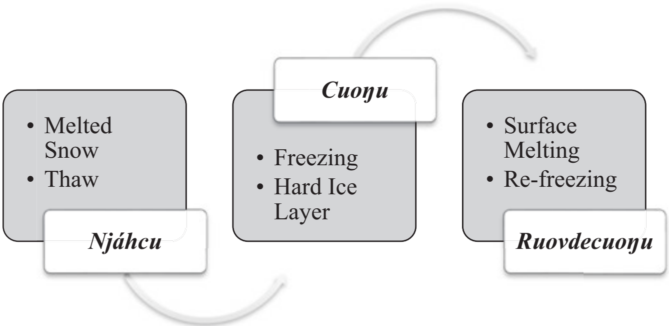

Fig. 4.9 *Cuoŋu* cycle

Fig. 4.10 Reindeer herders moving the herd. (Photo: I.M.G. Eira)

Space for physical activity (*lihkadeapmi*) is essential. A reindeer is always on the move when it is not resting. Wind and landscape have a direct impact on the movements of a herd and its individual animals. Uphill and against the wind are the preferred directions for the movement of reindeer. Resting places (*livvasadji*) must be undisturbed and have shelter (*suodji*) when needed. Longer transfers for reindeer take place along a migration route (*johtolat*). Mobility for reindeer and herders (*siivu* 'going') depends on snow quantity and quality and on existing tracks on the snow, which in turn depend on wind conditions. There is a wide variety of terms designating different kinds of tracks. Observation of tracks is key to monitoring, controlling, and protecting a herd (*vuohttit* 'find tracks of'), *(vuohtádat* 'the kind of snow (surface) on which animal's tracks are easily seen') (Nielsen, 1979 III: 828), *(časkilit* 'look for tracks of animals'). Visibility (*oaidnin*) depends on daylight/moonlight, snow in the air, wind and snow conditions on the ground and rime on the trees, *ritni* ('(thick) rime on trees') (Nielsen, 1979 III: 276).

4.5 Discussion and Conclusions

This chapter has shown examples of which kind of knowledge the herders have about many aspects of their environment and their herds, and how they apply that knowledge throughout the snow-covered periods of the reindeer year. Our goal has been to outline reindeer herders' own interpretation, perspective, and analysis of how herding happens throughout the year especially during the snow-covered parts of the year.

Our main findings show that there are many aspects of knowledge sectors Sámi herders are using as the basis for planning and decision making related to reindeer herding on snow-covered land**.** These are reindeer herders understanding and using multidisciplinary knowledge in a holistic approach to make decisions based on the reindeer's needs and behavior in time and space. Reindeer herders' indigenous knowledge is a prerequisite for working with reindeer and contains systematic, multidisciplinary, complex, holistic knowledge based in reindeer herding cosmology and professional language. The planning, decision-making and practices of herders are based on Sámi traditional reindeer herding knowledge. This includes knowledge about the different seasons, cycles, and periods in a *reindeer year*. As we have shown, this knowledge is complex, containing 8 seasons, diversity of daily or weekly cyclises and even longer periods, and 9 herding periods.

Reindeer herding periods and cycles contain different sub-cycles that are a part of a larger system based on the year, the lunar month and day/night. In reindeer husbandry you will find, e.g., cycles related to the use of areas throughout the year; the biological cycles of reindeer, like rutting season (see also Skum et al., 2016), calving season, dropped or cast antlers and moulting fur (see also Collinder, 1984; Eira, 2011); sexual behavioral cycles; cycles relative to climate and snow, the cycles of sexual maturity, cycles of extreme years (*goavvi*) (see Eira, 2012) and cycles that include reindeer herding periods throughout the year.

It is crucial to have knowledge to be able to anticipate situations for reindeer based on weather conditions related to special weeks and days of the year that can provide information about what to expect. Herders' planning and decisions, and the practices of herding are based on the ability to anticipate situations and developments in near and more distant futures. The ability to anticipate or predict is based partly on a herder's experience and thus the knowledge and ability to observe (read nature) and calculate within a framework of the traditional knowledge foundations. Three factors are important for anticipating and adapting reindeer husbandry to changing environments. That is, the natural traits of reindeer, reindeer's utilisation of grazing (how grazing areas utilised throughout the day/night and any changes in grazing utilisation) and how climate change can conceivably impact changes in grazing plants, degree of utilisation etc. (Oskal et al., 2009).

Siida members' joint planning and decision-making is thus based on the ability to anticipate situations and developments in the near and slightly distant future. This ability to prognosticate is based on experience, knowledge, and the ability to observe (read nature) and calculate how to manage the herd within the framework of a traditional knowledge base. All these aspects of herding in winter include traditional observation and mental monitoring of variability and changes in time and space in the use of grazing land and grazing conditions (Eira et al., 2010). This can help herders anticipate reindeer movement by watching their natural behavior associated with the season, the pasture, and the area (Eira, 2011) in the annual cycle. The herds move between units of areas, which represent the best or only alternative in different seasonal sections. The major seasonal changes require predictability and rapid adaptation responses in reindeer husbandry (Paine, 1972). Furthermore, this includes knowing that herds have regular periods (over weeks), like typical gathering times and periods that are typical spreading times. The herder must anticipate situations and make plans and decisions according to the necessity of the reindeer and the herd.

Reindeer herders' multidisciplinary knowledge encompasses knowledge of individual animals, plants, landscapes, weather, people, and – not least – various kinds of interactions between them. Understanding the field of reindeer herding relies on various categories of thought, namely knowledge of reindeer, environment, landscape, weather, and specific knowledge of the mutual relations in these subjects, and characteristics, i.e., specific differences in reindeer, snow, and weather, and on landscapes. The core of reindeer herding traditional knowledge is centered on identifying and describing physical and biological characteristics and phenomena, considering the magnitude of the observed phenomena, considering the relationship between such phenomena, and predicting possible consequences. This knowledge is articulated and structured linguistically with categories that are passed on to future generations. and it includes subsystems linked to different types of science and knowledge such as hydrology, meteorology, biology, topography, animal welfare, land management, adaptation strategies to climatic conditions, etc. (Eira, 2022).

Reindeer herding knowledge is understood and structured holistically on domesticated reindeer and their relationship to humans, the relationship between animals and human beings, and the natural environment related to time and space.

The holistic way of knowing about reindeer herding requires comprehension of the parts: reindeer, environment, landscape, and weather are intimately interconnected and are explicable only by reference to the whole. In other words, everything is connected to something else, making it difficult to define something without referring to something else.

As we have seen, reindeer herding strategies and practices are highly complicated and systematic enterprises containing different types of knowledge on how the biological and gender-based behavioral aspects of reindeer and their movement in time and space are connected to climate, temperature, and snow metamorphism. According to traditional ways of understanding reindeer herding, often underlined by herders, herding strategies consist of continuous observation, judgment, and a combination of relevant factors in every situation. The ecological understanding of reindeer herding as a pastoral means of subsistence includes the variations of the seasons and the learned behavior by reindeer of migrating between and remaining in the same areas at different times of the year (Sara, 2001: 81; Eira et al., 2016). This is especially evident in the behavior patterns of individual animals and the herd, which can best be understood in terms of annual cycles, lunar months, and the day-and-night cycle.

However, the value of the knowledge varies according to the season of the year. At times, it is of little practical value and at others it is indispensable; in certain seasons, it is relatively difficult to regain lost knowledge (Paine, 1972). Based upon the traditional Indigenous knowledge of the land and land use over generations (and their practice of traditional reindeer husbandry) reindeer herders have developed important local adaptation strategies to live with uncertainties in their Arctic environment (Mathiesen et al., 2018). Without an understanding and knowledge of how the *reindeer year* breaks down, sustainable reindeer husbandry will be almost impossible to maintain in various areas as we know it from ancient times.

To enable the description of the complex understanding of herding periods based on Sámi traditional reindeer herding knowledge, the constellation of authors was important. This was facilitated by the constellation of the author team, with the expert reindeer herder and scientists. Without this it would not have been possible to collect and analyse concepts and terminology in reindeer herding needed to understand the herding periods. Reindeer herding narratives and language-based knowledge about themselves, and their tasks have been important inputs here to gain an understanding of their own reality of herding on snow-covered ground. As noted by Meløe (1997), we must experience something ourselves if we are to be able to understand the knowledge. What we understand the knowledge by are words, language or concepts that belong to the business. If you do not know the concepts of reindeer husbandry, then you do not know what the business contains.

Reindeer herding knowledge, like other types of traditional knowledge, has been given little attention by researchers and in environmental management. Most reindeer research has focused on biological aspects and measurable facts of individual animals like weights, blood values, parasites, metabolism etc. as mentioned before the reindeer herding knowledge represents a complexity of the system, as a holistic reindeer herding system. It is rare to see this complex knowledge in governmental documents. Rather they try to simplify this complexity by making the complex "readable". The complex applies to, for example, land use, business considerations, language, and concepts (Eira et al., 2016; Scott, 1998). Nevertheless, the knowledge and experience of the reindeer herders themselves is still the foundation for everyday management of herds, and this knowledge has not been replaced or superseded by research-based knowledge. Failure to incorporate Sámi reindeer herding knowledge in governance efforts will hinder adaptation to forthcoming challenges (see e.g., Turi, 2016).

With increasing climate change and land-use changes traditional reindeer herding knowledge is essential for forming reindeer herders' adaptation strategies and building social ecological resilience. The preservation and use of such knowledge is therefore crucial for future sustainability of reindeer herding. Further research on indigenous reindeer herding knowledge on cycles and processes for herding and animal behavior can contribute to supporting reindeer herders' adaptation strategies and highlighting opportunities and obstacles available. Further development and use of methodologies where indigenous traditional knowledge holders and scientists co-produce knowledge could be an important step towards this development.

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Chapter 5
Learning by Herding – Transmission of Sámi Reindeer Herding Knowledge and Skills

Mathis Persen Bongo and Inger Marie Gaup Eira

Abstract The chapter addresses the issues of disseminating the knowledge and skills of the Sámi reindeer herders: frameworks, methodologies, and ways of knowledge transmission in reindeer husbandry. The chapter overviews existing teaching practices, learning levels, and learning arenas, comparing traditional knowledge transmission and academic curriculum. The authors discuss lifelong learning, systematic learning methods, and responsibilities. The chapter findings are based on the interviews with the Sámi reindeer herders from Guovdageaidnu/Kautokeino, a literature review, and author's reindeer herding experiences.

Keywords Sámi reindeer herding knowledge · Knowledge transmission · Indigenous knowledge

5.1 Introduction

> For though the Laplanders have never learned the science of the stars, yet they know the various stars and their situation and designate them by certain names (Leem, 1808: 411).

Reindeer herders have developed extensive knowledge of reindeer herding and reindeer husbandry and the environment sound surroundings. A quote from the early 1700s explains that the knowledge transmission among Sámi people does not depend on the formal school education but traditional knowledge which provides learning in many disciplines in line with science, e.g., glaciology, knowledge about snow that Sámi reindeer herders possess which they combine with reindeer herding strategies on snow-covered ground (Eira et al., this volume, Chap. 4; Eira & Mathiesen, 2021).

M. P. Bongo (✉)
Sámi High School and Reindeer Husbandry School, Kautokeino, Norway

I. M. G. Eira
Sámi University of Applied Sciences, Guovdageaidnu, Norway

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Reindeer herders as Indigenous people have unique ways of transmitting traditional knowledge compared with learning in formal schools (Bongo, 2005). Transmission can be defined as getting to know something from someone else, as when someone else who knows (Greco, 2020) tells one. Transmission can also refer to the process of transferring cultural items, such as skills, from one individual to another (Ohmagari & Berkes, 1997). The term *reindeer herding skills* refers to the expertise and competencies involved in being self-reliant and making a livelihood off the reindeer herding (Bongo, 2005).

According to Berkes et al. (2008), the transmission of traditional knowledge (TK) has improved livelihoods in turbulent times and changes in many Indigenous communities. The learning process of children from Reindeer herding families and the adults' transmission of different types of knowledge has always been significant in reindeer husbandry. For the reindeer herding families, it is important to teach children to become skilled reindeer herders (Bergland, 1998). Furthermore, it is important to avoid loss of traditional knowledge in reindeer husbandry society, as is the case in many other Indigenous societies (Paniagua-Zambrana et al., 2016).

Reindeer husbandry parents organize and facilitate learning strategies for how the children are to best achieve reindeer husbandry competence. Reindeer herding competence is complex and deals with many different subject areas, which together constitute the body of knowledge necessary to function as a skilled reindeer herder (Bergland, 1998). Competence is the ability of an individual to do a job properly and includes a combination of knowledge, skills and behavior used to improve performance; or as the state or quality of being adequately or well qualified, having the ability to perform a specific role (Wenger-Trayner et al., 2014).

Sámi reindeer herding has always taught children traditional knowledge that is practically linked to traditional Sámi trade (Hoëm, 1996). Cajete and Bear (2000: 97) states that Indigenous teachers understood that people learn in many ways and that each person perceives, thinks, and then acts in individual ways.

The Sámi reindeer herder parents still raise their children to function within the special environment and culture of reindeer herding. The learning process of reindeer herders traditionally and historically largely takes place in the field while working with the *family* and operating *siida*'s. The term *siida* is one of the most important terms in Sámi reindeer husbandry (Sara, 2013). A Sámi reindeer herding *siida* is a unit that organizes joint work with reindeer herders who for generations have adapted to the reindeer, grazing areas, climate, and ecological conditions (Sara, 2013). *Siida* is an old form of organization with families, reindeer herds, grazing areas, migration sites, infrastructure as the most important elements (Hågvar, 2006; Sara, 1983). According to Mikkel Nils Sara, the *siida* is the original Sámi self-governing local community, where people have moved between different settlements within the *siida* area, depending on the resources sought during the year.

In this chapter, We will provide an overview of what transmission of traditional reindeer herding knowledge contains based on the issue on what are the characteristics of transmission of reindeer herding knowledge and skills to children in reindeer husbandry in Guovdageaidnu/Kautokeino, Northern Norway.

- What characteristics are found in the transmission of Indigenous/traditional knowledge in reindeer husbandry in Guovdageaidnu.
- What kind of methods and what content do reindeer husbandry parents use when they teach reindeer husbandry knowledge and skills to children in reindeer husbandry.

This chapter is based on studies and methodological framework from the *Rievdan* and *Ealát* projects. Collection of data to this study is also based on conversations and interviews in North Sámi language with four Sámi reindeer herders (two women and two men) who are between 65 and 80 years old. All of these have worked all their lives and still are working with reindeer in Guovdageaidnu. They also have experience of transmitting reindeer herding knowledge to younger generations. The interviews were conducted from 2017 to 2020. There have also been used written sources: Leem, 1767, Nielsen, 1979 (1932–1962) and Eira (2011, 1984). The authors of the chapter are themself also reindeer herders from this area and have become acquainted with reindeer husbandry knowledge through their own upbringing and many years of practice. The subsequent presentation must therefore also be considered a result of extensive participatory observations of their own culture, and in contrast to researchers from outside. The authors have acquired the knowledge through the Sámi language, which is the reindeer husbandry professional language. The analysis of the material and explanation of the characteristics of reindeer husbandry knowledge transmission will be done within the framework of the Sámi understanding of sustainable reindeer herding (Eira et al., 2016).

In this chapter, We will give an overview of what the dissemination of traditional reindeer herding knowledge contains. We will present only a few selected examples that concretize different parts of the process. Reindeer husbandry knowledge, competence and skills contains much more than what We had the opportunity to present here. The findings led to an opinion on different paths in the development of knowledge for reindeer herding children/youngsters, the reindeer husbandry method for teaching, learning by herding and a small comparison to the academic way of approaching teaching and learning.

5.2 Reindeer Herding Knowledge: An Overview

Long before the development of academic science, Indigenous peoples have developed their ways of knowing how to survive and ideas about meanings, purposes, and values (Magga, 2005: 2). Indigenous people have observed and experimented to understand how the world worked, and to apply what was learned. (Cajete & Bear, 2000: 44) Reindeer herding has accumulated knowledge from generation to generation; this knowledge has been and still is the basis for survival and further development of the livelihood (Oskal et al., 2009). According to Cajete and Bear (2000) the accumulated knowledge of the Indigenous people represents an ancient body of thought, experience, and action of environmental wisdom, that can form the basis for evolving the kind of needed cosmological reorientation. This knowledge is presented in “high contexts”, in which many levels of information are shared at many levels of communication.

New generations are introduced to reindeer herding since childhood, and in this way, they already have early knowledge of the various elements and tasks. The transmission of knowledge thus includes these knowledge bases passed from one generation to the next. In each generation, individuals make observations, compare their experiences with what their teachers have told them, perform experiments to test their knowledge’s reliability, and exchange findings with others. What is characteristic with traditional knowledge is not its age, but how it is acquired and used (Balto 2003; Battiste & Henderson, 2000).

Sámi traditional knowledge is often linked to practical tasks in utilizing nature and engaging in traditional Sámi industries such as reindeer husbandry (Hoëm, 1996; Lund, 2001). Thus, reindeer herders’ knowledge represents traditional knowledge (TK)/Indigenous knowledge (IK). TK is *“a cumulative body of knowledge, practice and belief, evolving by adaptive processes and handed down through generations by cultural transmission*” (Berkes, 2012: 7) like oral history, stories, myths, songs, lessons and more recently exists in written form. Traditional knowledge is dynamic; it is modified by its holder to reflect changes in the environment as each new generation incorporates its own empirical knowledge or local observation (Nichols et al., 2004: 69). TK is holistic knowledge produced and further developed through daily work, most often in practical situations within a constantly recurring annual cycle (Bergland, 1998: 42). According to Jan Henry Keskitalo (2009), TK is based on certain similar conditions where the relationship between human and nature is a construction that can be seen as a social process. Traditional Knowledge exists through people and their work and practice and is in oral form. Keskitalo argues that knowledge can be seen as a process, something that changes over time and has different levels and different parties (Keskitalo, 2009).

Reindeer herding knowledge base represents a whole knowledge system that includes a set of networks representing different knowledge with corresponding subsystems (Eira, 2022). This include, e.g., topography and characteristics of terrain and landscape, place names, weather, snow and climatic conditions, evaluating access to forage beneath snowpack (*guohtun)* and tracking, adaptation strategies to climate conditions and how to live with uncertainties in this environment. Furthermore this include land management, biology, physiology, behavior of reindeer, animal welfare, botany, navigation, astrology, mathematics, economics, management, strategic thinking and planning, etc., of Sámi reindeer husbandry with knowledge processes, insights, cosmology, and values related to individual reindeer, business adaptation, reindeer herds, reindeer owners, households, and *siida work* (Benjaminsen et al., 2016). This knowledge base contains multidisciplinary knowledge (Eira, 2022) and reindeer herding specialist language (Eira, 1984, 2012).

Reindeer herding represents a *way of life* (Oskal et al., 2009) that is professionally challenging and rewarding, and thus represents a meaningful life for people (Turi, 2008). The reindeer husbandry way of life includes, according to Keskitalo (1998: 338) “knowledge, skills on and intimate relationship with the animals and the landscape"; special closeness to the reindeer, knowledge of its biology and living habits, and its relationship to nature; special proximity to the landscape, weather and traveling conditions; traditional knowledge of animals, nature and farming methods acquired through childhood, adolescence, and adulthood. Thus, reindeer herders need an extensive array of skills when managing a herd. It is, e.g., important to be able to distinguish between the different animals in their own herd and in herds that belong to others. If a herder is asked to give a description of a reindeer, they must be able to recognize individual animals, identify the earmarking of the reindeer and connect it to the owner (Sara, 2001).

This also includes knowledge and skills about maintaining good social conditions in reindeer husbandry; social proximity in the *siida* is centered on the reindeer and working with these animals, on nature and weather conditions, grazing conditions, strong family ties, kinship, loyalty, and positive external relations to other *siidas* – with interpolation through operational and social considerations.

It is also important to mention something about the gender distribution in Sámi reindeer husbandry. Reindeer husbandry is gender-neutral and does not formally differentiate between women and men (Reindeer Husbandry Act of 2007). As early as A.D. 550 there are narratives about how women are regularly on the hunt with men, and thus women and men are doing everything in cooperation and in the same way engage in hunting and other activities. This is confirmed by the historian Procopius' writings about a people called the Scrithiphini (referring to the Sámi) whose sustenance came from reindeer (Dewing, 1919 Procopius, English translation vol. III. New York). Other academics like Leem (1767), Pirak (1933), Demant-Hatt (1931), Sara (2002), Joks (2007) and Utsi (2010) have confirmed that the traditional division of labor in reindeer husbandry from earlier times until today presupposes that both women and men can be mobilized for all types of work, such as herding, marking, migrating, slaughtering, etc. According to Joks (2007) and Utsi (2010), there has, to some extent, been a gender division of labor, but this is not constant because this depends on a *siida's* size, number of members, and gender division (Joks, 2007). Women must be able to perform work that is defined as male work and what is defined as female work, and which men do not perform (NOU, 2001: 35) presented as a two-way relationship, namely a knowledge and skills basis for being able to perform general and gender-specific tasks in households and *siida* and a material basis for establishing business or livelihood. Therefore, it is necessary that knowledge transfer is gender-neutral and that both girls and boys learn the various work tasks that are part of the daily operation.

Reindeer herding families emphasize that children must from early childhood be given an opportunity to participate and contribute to the family's work with reindeer and at the same time acquire skills and knowledge. Everyone in the family from several generations can be a teacher[1] or reindeer herding tutors. This way of raising

[1] We use the word *teacher* about those who transfer knowledge in a reindeer husbandry perspective. This must not be confused with the concept of teacher in a formal education system. *Learner* is used for all those who are gaining reindeer herding knowledge and skills.

children can help both younger and older family members develop a natural relationship with each other (Bergland, 1998).

Tutorial given by Indigenous peoples is based on the nature and quality of communicating at all levels of being. Indigenous teachers practice the art of communicating through language, relationships with social and natural environments, art, play (Cajete, 1994). This can be shown by the extensive terminology both in terms of the animal itself, herding and grazing, snow, weather conditions, landscape, and food culture etc. (Eira, 1984, 2011, 2012; Sara, 2003; Sara & Eira, 2021).

5.3 Learning by Herding

The aim of this chapter is to show different paths in the development of knowledge for reindeer herding children, the reindeer husbandry method for teaching, learning for herding. We have used *learning by herding* as a metaphor to *learning by doing* (Dewey, 1916) to show how reindeer herders aims to bring reindeer herding to the real world in learning situations using different learning methods for different learning levels, feedback methods and methods of how to assess reindeer herding children's acquiring of knowledge.

The learning process of reindeer herding practices includes most of the element's indicative of traditional knowledge systems like being informal, intuitive, oral, practical, experimental, inclusive, and holistic (Sara, 2011: 140). This competence is developed and managed through the reindeer herding and embodied in language and communication methods, clothing, working methods, work tools, manners, and social norms (Bergland, 1998). Learning the reindeer husbandry's professional or technical language and using correct and relevant concepts related to context, work tasks, and activities are necessary to become a suitable reindeer herder.

5.3.1 Learning Levels

Learning by herding and the process of transferring reindeer husbandry knowledge is a lifelong process. The development of transmission of knowledge and skills starts already at an early age and that learning continues throughout life, which shows a lifelong apprenticeship.

According to our informants there are age-related levels in the knowledge process. Already as the child is a baby, at approximately 6–12 months, the parents start the first level of learning, by socializing their children to reindeer husbandry.

In the Sámi carrying cradle, *gietka* (Nielsen, 1979), the children follow the parents and observe their working and communicating. They follow the parents for example when the reindeer are brought into the fence and inside the fence when the marking is carried out. Even if the child at this stage only observes the activities, e.g., listening to the grunting, *ruovgat*, of the reindeer, they experience the smell of reindeer, the activities will still be remembered for a long time.

From the children are approximately 1–2 years, they are allowed to participate in different types of activities adapted to their age. Now the process of socialization continues with the *siida*, reindeer and reindeer husbandry and gradually they gain an understanding and interest in reindeer husbandry. At this level, parents begin to use various methods to encourage their children to engage in reindeer husbandry. Children will, e.g., be introduced to important and necessary reindeer husbandry artifacts such as a belt with a knife, lasso etc. that the children can use in play activities. They start by training to use a lasso to catch toy reindeer. They are playing by marking an ear tag on a calf with a knife (see Fig. 5.1).

The parents use different methods to get the children interested in reindeer and reindeer herding by letting them train and play with reindeer toys. This shows that to do, and play are integral parts of reindeer husbandry learning; apprenticeship is a form of activity-based learning. The playing and freedom to participate in real work tasks preparing the child into the reindeer husbandry profession (Hoëm, 1996).

When children are from ages before they start at public school, they can be present to learn, observe and work, e.g., within the enclosure, for instance “helping” parents earmarking calves (more about marking calves, see section *Learning earmarks by herding* in this chapter). At this level, they begin to participate more actively with the assistance of an adult by trying to catch the calf, feel the calf’s ears with their fingers, hold the calf’s head when the parents earmark the calf, and participate in the conversations.

They will also be introduced for various work in reindeer herding, e.g., get to know the landscape and communicate properly together with those who know this.

Fig. 5.1 1–2 years old reindeer herder child playing earmarking a calf. (Photo: Inga BM Triumf)

From the age of 8–10, the children are introduced to herding reindeer, among other things. The purpose of this is to learn to herd the reindeer to avoid the reindeer getting away from the herd. At the same time, it is also necessary to learn and know the behavior of reindeer, find a grazing area where the reindeer finds food and graze calmly. This task belongs to the foundation of *siida* (*siidavuođđu*) (Eira et al., 2016). Reindeer are habitual animals that instinctively return to their usual grazing areas at different times (see Eira et al., 2022, Chap. 4). Therefore, it is important to teach the children knowledge about the reindeer's behavior. The informants say that it is important to teach children "to think like a reindeer", so that they learn to understand where the reindeer can go or how they will behave. This means that during herding, if a reindeer has left the herd, they can find the lost reindeer by thinking like a reindeer in relation to its behavior on the landscape.

The first herding assignments the children receive are most often the herding of a herd of male reindeer (*luovas eallu*). Most *siidas* separate males from the main herd to establish a separate unit to be herded. It is easiest to herd male reindeer in the spring because they no longer strive for spring grazing areas as pregnant female reindeer (*čoavjjehat*) do (Eira et al., 2022, Chap. 4).

One of the informants says that when he teaches children how to herd reindeer, he first takes the child to the herd to explain how the herding should be done and which direction the reindeer must not be allowed to go. This is a part of the herding training. Furthermore, herding assignment content herding with supervision. The child can be left alone by one edge of the herd (*dien rávddas*) to herd. However, the adult makes sure that at this edge it is easiest to look after the reindeer. The adult himself/herself withdraws a little, to another edge of the herd, but no further away than he can have an overview of how the child is doing. This is reassuring for the child who sees that the adult is not that far away and can help if any reindeer runs away. This is an example of teaching and learning strategies for solving the task of herding.

During the herding exercise in dark time (polar night) when darkness lasts for more than 24 h (Eira et al., 2022, Chap. 4) the adult can give the children guidance and knowledge how to use the moon for light and stars for knowing the time and direction (orientation). An elder reindeer herder said that the stars like *gállá bártnit* (orion's belt) also as *čuoiggaheaddji* (who chase on the ski) are the three stars that form a belt constellation in line by and appear in the night sky at the proper times. In the area of Guovdageaidnu, when *gállá bártnit* appears in the south, then the time is approximately 7:00 pm. These observations can be used to guide in an astronomical way.

As the children get older, they get more difficult herding work, in relation herding the celestial direction at the edge of the herd that the reindeer are moving towards. In this way, they expand their herding skills and get a sense of mastery of the work that has been done in a good way. The learners must also acquire knowledge of how to develop and maintain a robust and functional herd adjusted to local landscape and climate (Benjaminsen et al., 2016; Sara, 2001). The herding achievement can also be a topic of conversation at home about how the child has managed alone as a reindeer herder.

5.3.2 Competences and Skills

Reindeer herder teachers facilitate learning by using multiple learning methods and content in the transmission of reindeer herding knowledge (see Fig. 5.2) and involve the learner to participate in processes that take place throughout the reindeer herding annual operating cycle (Eira et al., forthcoming, Chap. 4). Facilitating learning of herding is often linked to work tasks that are also useful for reindeer husbandry in collaboration with adults, *teachers,* and *supervisors* (Balto, 1997, 2005; Hoëm, 1996; Sara, 2002).

These processes allow herding knowledge, skills, and professional/specialized language to gradually develop until one finally emerges as a fully trained professional reindeer herder (Fig. 5.3).

The objectives are based on the core values of reindeer herding: children must receive knowledge and practices based on herding values and specialized language and reindeer herding societal life. Every reindeer herder is expected to have knowledge of and skills in it (Eira, 1984).

Teachers must also prepare children to understand and use nature to provide optimal resources for covering the necessities to make a living from reindeer husbandry and protect it for future generations. The parents want the younger generations to become competent reindeer herders who have accumulated enough knowledge, skills, and experience to perform and evaluate various actions and work alternatives related to reindeer husbandry (Bongo, 2005).

Our informants emphasize that parents must teach children to gain self-confidence to believe in what they do, and to become independent, while at the same time learning to work individually and collectively. Parents want to teach children to master different work types, such as herding, knowing how to describe the

Fig. 5.2 6–7 years old reindeer herder girl "helping" grandfather earmarking calves. (Photo: BEA Bals)

Fig. 5.3 Learning methods in Sámi reindeer husbandry (Adapted from Bongo, 2005)

reindeer and the herd, different weather conditions, snow types, landscapes, navigation, marking, slaughtering, etc.

In reindeer herding, there is a need for both individual and collective knowledge and skills. Knowledge transmission is organized so that learners acquire knowledge and skills that (1) they, individually, need and (2) they need in *siida* or the household. An individual reindeer herder according to our informants must acquire individual skills and knowledge based on the need for *siida's* reindeer husbandry and self-oriented interests over time. They must thus have individual and household-specific knowledge, local *siida* knowledge, and more general knowledge exchanged in *siida* communication and relationship (Benjaminsen et al., 2016). This is the private level that deals with the household business income, called *birgejupmi*, *as a* «form and degree of self-salvage» (Nielsen, 1979 I: 179). This does not directly concern the *siida* but includes business adaptation comprehending reindeer and other resource utilization belonging to the household economy, including the meat-producing economy (Sara, 2013: 10–11).

Furthermore, the collective part of reindeer herding is made visible in connection with *siiddastallan* (Sara, 2013) so there is a need for knowledge and skills that contribute to being able to cooperate and collaborate with other *siida* members, different parts of the *siida* unit and between other *siidas*. In reindeer husbandry, everyone must learn to cooperate and contribute to sharing with others in activities related to daily operations and other reindeer husbandry-related activities to become a part of the working community (Sara, 2001). They have to learn *siiddastallan*, the part of the reindeer husbandry practice that the traditional Sámi *siidas* have been responsible for meaning keeping/running a *siida*, working with reindeer and a reindeer herd (Sara, 2011, 2013).

According to our informants, about the reindeer's behavior, there is no point in moving the herd to other areas because the reindeer are habitual animals that instinctively return to their usual grazing areas. Herders follow the reindeer rather than seek complete control over the reindeer or the landscape (Benjaminsen et al., 2016). So, in this knowledge process, children witness and learn how experienced herders facilitate the animal's natural behavior, its adaptation to the natural environment and the annual cycles and weather conditions, and how they protect the reindeer from external threats.

Children learn and experience that reindeer permeate all life in the *siida* and therefore the reindeer need full attention regardless of the season. That is why reindeer must be protected, herded, and sometimes assisted with relocation or when there is not enough food for it. This is at the core of social, cultural, and economic life (Liégeois et al., 2019). It is important to come to terms with reindeer. In a metaphoric sense, the reindeer herders are "negotiating" with their reindeer (Sara, 2013) and with nature on their *siida's* behalf. They negotiate with the climate and environment to ensure the survival of reindeer. This comprises learning how reindeer are a free-range animal, for the most part, in their natural surroundings (Sara, 2001) and that the reindeer grazing area or land is constituted through the herders and reindeer activities in it.

Parents teach their children that having *reindeer luck* means if your reindeer survives, the herd prospers, the cows calve and the herd is healthy, well provided for, and beautiful. (Oskal, 2000) This luck presupposes ethics and morals for everyone and everything, both animals, humans, and the environment. This ethics is thus about being honest, fair, and getting along with the animals, the reindeer grazing land, and people (Oskal, 1995). According to Oskal (1995), it is important for reindeer herders to come to terms with nature, be reconciled with it, and manage it conscientiously to the best of their ability and care. In this understanding all animals including insects are necessary for the ecological functioning of the survival of all living things, e.g., some Sámi myths also say spiders have an important function as protectors.

Transmitting the knowledge of a worldview or cosmologies and ethics that encompass the holistic relationship with reindeer and the herd is important

(Benjaminsen et al., 2016; Oskal, 1995). Cosmologies are deep-rooted, symbolically expressed understandings of "humanness" (Cajete & Bear, 2000: 52).

Our informants tell us that it is important to transmit the reindeer herding knowledge by adapting various methods and content to give children competence and skills to understand and work with the reindeer, landscape, seasons, and climate. Further, they state they are strongly influenced by their relationship with the reindeer, which is a part of a larger socio-ecological system that is simultaneously predictable and unpredictable, repetitive, and changing (Oskal et al., 2009). Reindeer herder parents make their children ready to use knowledge and understanding from both the past and the present to prepare them as reindeer herders for a sustainable future. This approach can be compared with eco-education, as Cajete & Bear (2000: 63) call it.

5.3.3 Transmission of Traditional Knowledge and Sustainable Development

The traditional knowledge to be transferred is based on the foundations – or *vuođđu,* used both as the first or last part of compounds meaning fundamental, main, or chief part of the word (Nielsen, 1979).

Vuođđu constructs the basic principles of the Sámi reindeer herding traditions and customary customs. This is bound to different sides and at the same time, it once binds Sámi reindeer husbandry, and the way of life. (Eira et al., 2016).

This understanding of the foundation applies to both knowledge and action with a view to being a good reindeer herder and having *reindeer luck*. According to Cajete and Bear (2000: 267–268) foundation is "the metaphorical truth that one works through to express one's life—reflects the evolution of ways of "coming to know and of living based on a life-sustaining cosmology".

The basis for the reindeer husbandry's worldview is both about the reindeer, human as well as nature, which presupposes a responsibility to take care of, maintain and respect other living beings, plants, animals, own and others grazing land and the places you live. Our informants mention that children must also learn to maintain this indefinitely to maximize the well-being and safety of reindeer and humans. In this understanding, there are nine foundations for versatile utilization of various resources within the annual cycle, which is an attempt to continue the reindeer herding style for the sustainability of reindeer husbandry (see Eira et al., this volume, Chap. 3).

The different *vuođđu* represent the sustainability of reindeer husbandry (Eira et al., 2016). Figure 5.4 shows these nine foundations:

1. the knowledge base (*máhttovuođđu*) with different types of knowledge related to the other *vuođđu*,
2. the *herder,*
3. the *siida* (*siidavuođđu*),

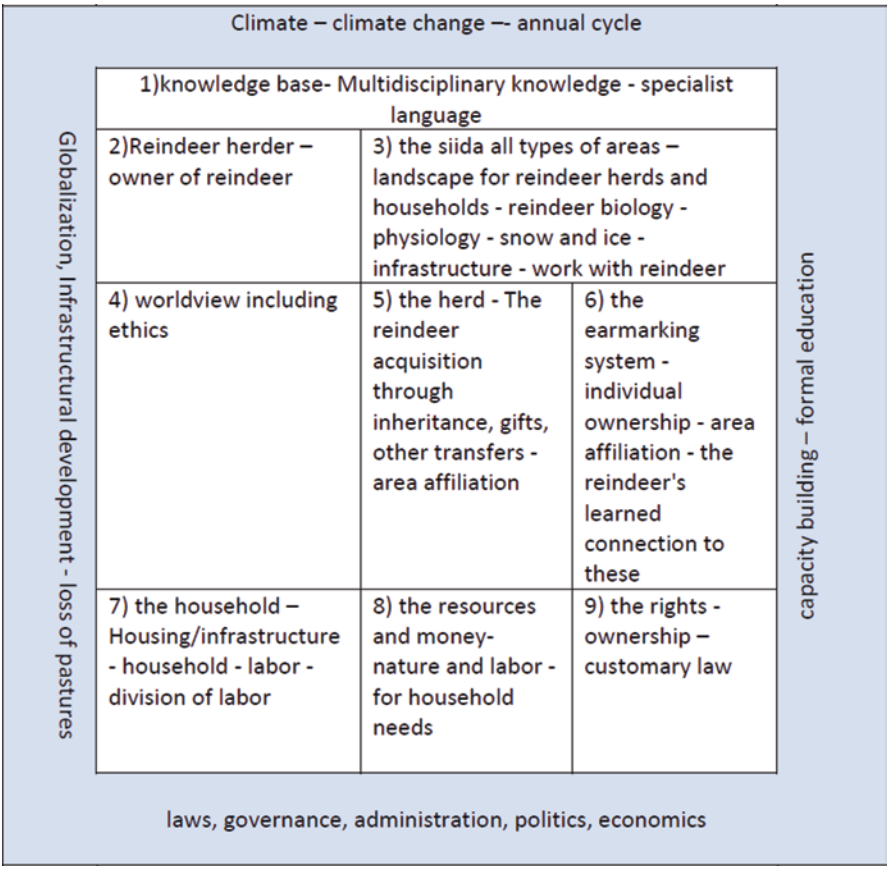

Fig. 5.4 The content framework for what herding children must learn in order to gain a Sámi understanding of sustainable reindeer husbandry. (Adapted from Eira et al., 2016)

4. the worldview including ethics (*vuođđoipmárdus*),
5. the herd (*eallovuođđu*),
6. the earmarking system (*mearkavuođđu*),
7. the household (*báikevuođđu*),
8. the resources, nature, and labor (*birgenvuođđu*).
9. the rights (*vuoigatvuohtavuođđu*) (Eira et al., 2016; Johnsen, 2018).

All of this includes knowledge and skills about a range of tasks, decisions, and actions, from the part related to the performance of annual recurring tasks that prepare for action in confusing and not previously experienced situations (Sara, 2001: 10–11). The blue border represents external influences affected by local, national, and international politics and economic processes regarding globalization, land use, laws, regulations, economics, prices, and subsidies that have affected traditional reindeer husbandry (Sara, 1978). These are expected to be known by reindeer owners to protect and develop the industry and culture for future generations.

Reindeer herding practice-based knowledge contains elements that must be present to achieve sustainable reindeer husbandry. Thus, this approach to nature and management is very similar to the idea of sustainable development (World Commission on Environment and Development, 1987: 43). In traditional Sámi reindeer husbandry, the whole family is still involved in herding, although this is changing since the women have work outside the reindeer husbandry and the children are in compulsory school (Utsi, 2010).

The future herders must also learn how external factors can affect reindeer herding, including laws, regulations, prices, plans prepared by the authorities and political decisions and objectives on land use, and resource allocation in the reindeer grazing areas which affect reindeer husbandry (Sara, 1983).

5.3.4 Learning Earmarks by Herding

In this section, we will show an example of a specific task of transmission knowledge, how children gain knowledge about marking the ear of a calf, as a part of the earmarking system (*mearkavuođđu*) in the model of sustainability of reindeer husbandry (Eira et al., 2016).

The earmarking system is an ancient system that is the core principle in Sámi reindeer husbandry (Eira et al., 2016), and thus transmission of knowledge and skills on how to mark reindeer is one of the core elements for those who want to become reindeer herders. The system provides a great opportunity to identify reindeer quickly and efficiently, even if the animals are far away. We will use earmarking as an example in this chapter and describe this in learning levels to explain knowledge transmission in reindeer herding (Nystad & Eira, 2005, Ruddle & Chesterfield, 1977; see Fig. 5.1).

The description of Sámi reindeer herders labeling their reindeer is given by Leem and others (1767, 1808) as early as the seventeenth century: "*The Laplanders impress a mark on the ears of their reindeer that each may be enabled by it to distinguish his own*" (Leem, 1808: 403). The reindeer earmarking system is one of the customary legal schemes for reindeer husbandry (Norwegian Reindeer Act of 1933) implemented by oral agreements and agreements within the relevant *siidas* (NOU, 2001: 34). The right to a reindeer mark is closely linked to a person's identity. A reindeer mark that has been in the family's possession for generations not only provides a cohesion within the family through all the marks that are derived from the main mark, but it is also used as an external identification for other families, *siidas* and districts. (NOU, 2001: 34). The earmark system is a visual language in which notches and cuts are the words (Uhre, 2020), but it is also a knowledge system with concepts like *njávkat* (to feel with your fingers), *rievdadus* (a change made to the original main cut), *gáhččanbeallji* (not an ordinary cut made due to a mark that was cut too deep), *šearus* (as a perfect cut), according to the informants.

Over the years children learn to become proficient in earmarking. The goal is to give children the knowledge to become familiar with this complex system. The learning methods used are closely linked to real working tasks (Aikio, 2010; Balto, 2005; Bongo, 2005; Hætta, 1993; Keskitalo, 2009) to *eallovuođđu* (Eira et al., 2016) and other tasks in Sámi reindeer herding. Parents introduce children to earmarking from an early age: at the beginning children observe and learn.

In the following levels (see Table 5.1), they gradually participate themselves and learn to feel with fingers (Sámi language *njávkat)* how the several cuts of reindeer's earmarks are composed, i.e., the various cuts in the child's earmark using specialist language of earmarking. This is repeated several times, and the children gradually begin to participate in the whole process of the adults cutting the ear tags.

The next level on the learning ladder is to mark the calf itself with detailed guidance from the adult, first just by making incisions in the earlobe – *luddestat* – to get a feeling of cutting in the ear and then the whole earmark with the family's main cut – *Oalli* – and the child's sub-cut – *rievdadus* (informants). It is appropriate here to talk about the importance of creating a nice and easily identifiable earmark (*šearus)*. It is also appropriate to start talking about the reindeer's gender and appearance, hair color, antlers, and whether the reindeer has special characteristics that make it easily recognizable (Eira, 1984; Leem, 1767, 1808).

At level six, the student is ready to move on and complete the entire earmarking process solely, but still with an adult who holds the calf's head and provides expert guidance. This involves reflecting on the result and identifying any potential for improvement in the future (Balto, 2005; Triumf, 2011). Both the child and adult are responsible for the result as equal partners. In this connection, it is also appropriate to talk about *gáhččanbealji*, a bent ear caused by too deep cuts in the ear (Eira, 2011).

In the seventh level, the student begins to earmark independently, without significant help from an adult. Depending on the skill's complexity, the student first began to perform part of the skill complex, and finally, the entire skill complex (Ohmagari & Berkes, 1997).

After years of practice, the learner in the eighth level appears as a knowledgeable person with their own earmark signature. The work process is now automated, and the learner has gained a more integrated knowledge for how things must be done, without always being able to explain it (Eira, 1984).

5.3.5 Traditional Knowledge Transmission

Transmission of traditional knowledge and skills has its own learning models (Nystad & Eira, 2005; Ohmagari & Berkes, 1997; Ruddle & Chesterfield, 1977). Studies by Ruddle and Chesterfield (1977) and Nystad and Eira (2005) show that the learning process with traditional knowledge and skills is level-based and emphasizes learning by doing repeated practices over time instead of by passive watching and copying. So, instructions are not only sequential but additive so with each succeeding level, tasks learned earlier are repeated.

The goal of both models is to make the learner independent and competent in solving a certain type of task. In the Sámi model, this level is called *ieš* (by him/

herself), in the sense of being able to solve the work on their own with personal solutions and methods. This level is in the model by Ruddle and Chesterfield (1977) described as becoming a peer (or equal partner) to the teacher. Although the two models have different levels, the transmission process, and the goal of it are similar (Table 5.1).

In the Sámi sense of education and knowledge transmission, it is important to let learners make decisions on their own, e.g., when they participate in herding, slaughtering etc.

Our informants tell us if the learners do something that is not entirely correct, the teacher provides feedback by not directly saying what to do but leads the learner to make their choices. The teacher can say this: “It may be a good idea to patch the *pesk*[2] slightly on the side, to prevent it becoming too wide; or perhaps it is best to rip up this seam, to prevent it becoming a little bit skewed” (Bongo, 2005: 30). By this, the teacher does not give instructions but rather gives the opportunity to decide and gradually discover themselves that perhaps it is appropriate to do so as the teacher says (Balto, 1997).

These models are at the same time similar to and different from the western academic teaching models (Bongo, 2005). The transmission of knowledge in reindeer herding takes place holistically and often through daily work (Bergland, 1998). The foundations utilize various resources within a constantly recurring annual cycle, whose conditions are related to *birgejupmi*, which is part of the foundations of the household and the resources *(báikevuođđu and birgenvuođđu)*. This forms the basis for knowledge transfer, which most often occurs in the interaction between humans,

Table 5.1 Indigenous learning process of traditional knowledge and skills in levels

Nystad and Eira (2005)		Ruddle and Chesterfield (1977)	
6	IEŠ – Peer – Competent use his/her own initiative and method for solving a task	8	Becoming a peer (or equal partner) to the teacher
5	Can solve the task independently	7	Independent performance of the skill complex by the apprentice and ability to experiment with the task; and
4	The IEŠ – “Teacher”, IEŠ is leading the work with the assistance of a teacher	6	Becoming an assistant or apprentice to the instructor
3	Teacher – IEŠ, teacher is leading the work with the assistance of the learner	5	Performing the skill complex under supervision
2	The teacher gives guidance, response to the learner, who is making self-testing by repeating the practice	4	Helping with the entire skill complex
1	Learner is doing observation, is included in the work, and contributing according to own ability	3	Helping with simple steps
		2	Observation of the teacher performing the skill
		1	Familiarization or the identification of the skill to be learned

[2] Jacket made of reindeer hives.

animals, pastures, and the various reindeer husbandry situations that often involve the whole family.

Learners are gradually lifted to a level of knowledge where they can make independent decisions and find their own ways of working and learning (cf. Informants). In this way, the knowledge is made available to others in the household and the *siida*. The levels of the transmission process are adapted to the learner's level of knowledge, and assessment on how much he or she can absorb learning content, mentioned as Indigenous learning models (Nystad & Eira, 2005; Ohmagari & Berkes, 1997; Ruddle & Chesterfield, 1977).

The teacher uses communication methods, talking and chatting to explain, narrate, communicate, show, and demonstrate. Furthermore, as in *cuoigut* (a method to make a mental note of something; Eira, 1984) by pointing is often used in the process of how to distinguish a reindeer from others through language (Eira, 1984), articulating and describing partly without language and word descriptions (*cuoigut)*, that can be compared with Harris' (1990: 13) statement that we understand what words mean by having the objects they stand for pointed out to us. In addition, distinguishing can be in talking reindeer herding talk, *boazoságat* (explained below), and using the professional reindeer herding language.

Teaching identifying a reindeer, can be characterized as a complex teaching, and learning system. This traditional knowledge transmission process is called *bagadallan*, which means to explain in detail to a person. In this process the reindeer are described in detail regardless of whether they are visible or not. The learning system of distinguishing reindeer is based on a mathematical approach, *garžžideapmi*; that means reducing the number of possible animals. Step №1 of the process is to identify the earmarks of the reindeer, then №2 state the gender, then №3 describe the color and, №4 describe the antlers. Also, in step №5 the herder must recognize which reindeer are not present in the herd. These factors are used to limit (exclude) the number of possible reindeer to only a few animals.

In all the task examples we have mentioned in this chapter, the reindeer herding language is significant for learners' outcome. Through the whole knowledge transmission process, the reindeer herder tutors use specialized or professional language with a high level of precision for descriptions and vocabulary of reindeer herding. Language thus plays a key role in structuring knowledge and knowledge sharing (Eira, 2022; Von Krogh et al., 2000), and it is through language that traditional knowledge is available. (Eira, 2012; ICR, 2006). The reindeer herding concept systems, like herding system, earmark system, etc., have evolved under the conditions of systematic working cooperation between the learner and those who have the responsibility to transmit knowledge. The use of language or acquisition of knowledge is based on various phenomena and how they are named and seen in the light of the traditional reindeer herding knowledge (Eira & Mathiesen, 2021).

The specialized language is used in communication, the process of assigning and conveying meaning to create shared understanding (Eira, 2012; Sara & Eira, 2021). Language is also significant for the participants of the reindeer herding in their communication. They need to use and know how prominent specialized terminology in Sámi language is used in different situations (Sara, 2013). If there is a breach of the language structure, there is also a breach of the knowledge transfer (Meløe, 1988; Sara, 1978). According to Eira (1984), when communicating reindeer herding issues (as in *boazoságat),* knowing the specialized language of reindeer herding is a prerequisite. *Boazoságat* or reindeer talk is characterized as the Sámi reindeer herding internal communication and conversation method, for example, used in connection with herding shifts or when the reindeer herder comes from the herd/*siida*. With reindeer talk, herders communicate with the people who are not present at the herd about the herd situation and how they did manage herding the herd.

In our opinion *boazoságat*, is not only the *siida* communication, but also a learning method which, together with actions, among other methods creates in-depth knowledge that can be both local or global notions that impact reindeer husbandry such as climate, mining, etc. The learner naturally has less knowledge and understanding of what deals with the conversations and work tasks but are still seen as a full-fledged participant at the individual's level or age level. This process can be called in-depth learning (Sawyer, 2006). It is expected that herders know the subject content of concepts in detail and by this can relate and use them in the proper context. By participating in *boazoságat,* the learners become active listeners of the issues discussed and can intervene in the conversations, ask questions, and suggest solutions (Eira & Mathiesen, 2021).

An important part of the learning process is learning not only to articulate knowledge through words. The basis of the Sámi oral traditions it is also customary to use stories, sayings, experience, *joik* and *diiddat* in learning. The telling of stories is a part of communication and learning. Story is one of the most basic ways the human brain structures and relates experience (Cajete, 1994).

Joik is the traditional Sámi form of music. It is a way of communicating with other people, between animals and humans, and between people and nature (Jernsletten, 1978; Skaltje & Utsi, 2005). The *joik* is closely linked to nature, and people often get the yoik from nature, the wind, the sound of the river, the formation of the mountains, the sounds and rhythm of the reindeer, and the sound of other animals and birds (Utsi, 2011). Turi (1910) writes the *joik* (*luohti*) about a reindeer that springs out like a ray of sunshine and about grunting (*ruovga*) to reindeer calves. There are *joiks* about animals, insects, birds, fish, nature, pastures, mountains, fishing lakes, etc. People can communicate directly with these via the *joik* (Skaltje & Utsi, 2005; Utsi, 2011). A good example is the *joik* of mosquitoes that come to midsummer every year and help the herders to gather the reindeer herd up from the valleys (Utsi, 2011). These are important transmission methods in reindeer husbandry (Bongo, 2005). By learning these, the learners will be aware that, e.g., *joik* can be part of the herding situation and can be used during reindeer herding in the darkness to communicate through *joik* with other herders and other *siidas*.

Using Diiddat have also been important in teaching. Our informants explain that *diida* is a rule of thumb that is *Sámi guidance sentences that each individual must interpret and consider whether to follow*. Here is an example of a story presented that is adapted to different age groups. Parents remind the children after having eaten reindeer meat, where there are bones left, that: "The one who goes out with the bones out of the *lávvu*, herding cabin or house will get many reindeer". The children have been told that while throwing the bones back to land they should say “let me get many reindeer”. Often this activity makes a sort of competition among the smallest children because everyone wants to receive many reindeer. At the same time, the children perform useful work (Bongo, 2005).

5.3.6 Feedback and Assessment from the Tutors

Reindeer herding tutors or teachers use feedback and assessment in the learning process to encourage and motivate the children to trial and error for their further development. Based on the goals, the teachers are continuously using different methods to assess how the learners understand the task and how they master task-solving. One method is to assess whether the learner is *fitmat*, which means one who has a keen faculty of recognition that finds it easy to notice and remember (Nielsen, 1979). In reindeer herding it is common to give feedback to the child that he/she when you see that the child can remember reindeer marks and special reindeer. One who is *fitmat* has easy to notice and remember earmarks and has the capability to make mental notes of reindeer and easily discovers those reindeer in the herd (Eira, 1984). It is common to give feedback to the child that he/she is fit.

Also, in reindeer herding, teachers are assessing how the children are learning. In Sámi language there are some concepts used to expressly characterize how a person carries out the work they are doing, e.g., *hága* and *searra*. These concepts are a part of the learning process of response. These describe how learners have implemented work using their knowledge, skills, and behavior. It is the teacher or someone who observes the student and who gives feedback on how the learners have solved. The student naturally has less knowledge and understanding of the core of the conversations and tasks because they have a lower level of knowledge, but they are still seen as a full-fledged participant in their own level of knowledge and age and completed the individual or the collective work. One who is characterized *searra* is someone, who is good at all kinds of work and has the skill (Nielsen, 1979, p. 625 Volume III). *Hága* is used to describe someone who is strong and skilled to solve tasks or work (Nielsen, 1979, p. 287 Volume II). In some areas in Guovdageaidnu, the concepts are synonyms and used for both female and males, but in other areas the concepts are related to gender, where *searra* is linked to a male reindeer herder’s competence and *hága* to female (information retrieved from the informants). It is precisely through such encouragement that learners are motivated to actively participate in the working and learning process. In this way, the knowledge is made available to others in the household and the *siida*.

Both feedback and assessment of learning in traditional reindeer herding can be called unique ways of learning. With these methods, the unique qualities of each child as a learner are naturally accepted and honored (Cajete & Bear, 2000: 97).

5.3.7 Reindeer Herding Teachers, Tutors and Learning Arenas

Knowledge transfer from generation to generation takes place by different generations participating in and collaborating on different work tasks within different fields (Benjaminsen et al., 2016). The responsibility for knowledge transmission belongs foremost to the parents, siblings, grandparents, and relatives or other people in *siida* (Benjaminsen et al., 2016).

Elder reindeer herders are important in the learning process (Bongo, 2005) because they are relied upon as the keepers of essential knowledge. Elders provide guidance and facilitate learning, often through story along with artifacts and manifestations of traditions (Cajete & Bear, 2000). In a study by Ohmagari and Berkes (1997) many elders pointed out that expertise and competencies involved in being self-reliant and making a livelihood of the land were not taught by formal education, but their way was learning by doing through apprenticeship. This can also be characteristic of the ideology in reindeer herding knowledge transmission (Bongo, 2005). This shows that there is substantial agreement between the Indigenous peoples' way to transfer knowledge (Ohmagari & Berkes, 1997).

It is assumed that reindeer herding is reindeer herding children's way of life (Eira et al., 2016: 45; Bongo, 2005; Sara, 2003). Reyes-Garcıa et al. (2010) indicate that the transmission of traditional knowledge occurs through:

- transfer from parents to children which assumes individual variations.
- transmission between individuals of the same generation results in the rapid spread of new knowledge.

5.4 Transmission of Knowledge from Older to Younger Generations Involving Knowledge Transferrers and Receivers

Ways of knowledge transmission take place in the different arenas related to the different *vuođđu*, following the reindeer herding annual cycle. In the time of the first Sámi author to publish a secular work in a Sámi language, Johan Turi (1854–1933) deduced (Demant-Hatt, 1931) that nature is affecting the herders' way of thinking. The best arena for thinking is outside, in the tundra or in the mountains:

> The reason for this is that when a Lapp gets into a room his brains go round … they're no good unless the wind's blowing in his nose. He can't think quickly between four walls. Nor is it good for him to be among the thick forest when it is warm. But when a Lapp is out on the high fells, then his brain is quite clear, and if there was a meeting-place on some fell or other, then a Lapp could state his case quite well (Demant-Hatt, 1931: 19).

The arenas are at the level of family and household, *siida*, and meeting points between different *siidas* and with the rest of society (Eira et al., 2016: 38).

According to informants, parents use different concretization methods found in natural arenas of the reindeer husbandry, e.g., they use reindeer skin that is in the *lávvu* to show/teach children how to describe a reindeer in detail and talk about reindeer earmarking knowledge and fur colors, while antlers description can be done practicing lasso throwing. Continuation of learning this can be done close to the reindeer and herd, e.g., in connection with work in the fence (*gárddástallan*), but also in connection with *boazoságat* (Eira, 1984, 2011). According to Eira (1984, 2011) one can observe the reindeer with all senses be done in the herd, while in the home arena, you must use other methods.

Another example is the household as an arena for learning of economic decisions and these types of knowledge and skills (Utsi, 2010). Arenas are out in nature where learners are trained in the interpretation of natural conditions and sustainable adaptation to the natural environment (Balto, 2005; Benjaminsen et al., 2016; Keskitalo et al., 2017; Triumf, 2011).

5.4.1 Traditional Knowledge vs. Academic Curriculum

According to Cajete and Bear (2000: 44) both Western science and Indigenous science use research and data gathering because people need to discover, or rediscover, their own creative abilities.

In the perspective of Sámi traditional knowledge, it also practically links to traditional Sámi reindeer husbandry (Hoëm, 1996). The transmission of knowledge is informal and has been carried out through Indigenous learning system; a system that is closely related to nature and essential daily tasks. On the other hand, school and education is mandatory for children between the ages of 6 and 16 (Thune et al., 2019). Educational programs provide important human development tools, but they can also compromise the transfer of Indigenous peoples' knowledge all around the (Sub)arctic circumpolar area (UNESCO, 2020). Regarding children from reindeer herding societies, the school system isolated them from the reindeer herding environment, thus nothing in the academic curriculum reflected reindeer culture (Lund et al., 2007).

The association between formal school and the reindeer herder's knowledge seem to have two diverging views, based on how the formal school system with organization and content that is regulated by law (Lund et al., 2007) have precedence over the informal learning system in reindeer herding with lack of this subject in school (Lund et al., 2005).

The formal school argument is if the children do not attend school, but are instead herding, they lose important school knowledge (Bongo, 2005), like mathematics and other subjects. However, children lose important reindeer herding knowledge if they cannot participate in work with reindeer (Marakatt, 2020). This also shows a dimension in the historical, social, and cultural contexts, the experience of the relationship between the state and the minority population (Keskitalo, 1993).

Sámi reindeer society experiences that reindeer herding children cannot learn the knowledge system for herding at school. It means that the school does not contribute knowledge that is useful and relevant to reindeer husbandry (Marakatt, 2020;

NRK, 1978). This view is also expressed by Johan Turi (1910), written by Demant-Hatt (1931: 39) at the beginning of the twentieth century:

> But for all that, school spoils Lapp children, they get a good education, but they learn a lot of useless things too, and they get a peasant's nature … and they are away from the Lapps during their best learning years, and they only learn about peasant life and nothing at all about Lapp life. And their nature is changed too, their Lapp nature is lost, and they get a peasant nature instead. And many of the children in the schools get consumption; and when there are no schools in the Lapps' own tents, then they have to go to where there are schools, even if it is not altogether good.

Table 5.2 is a simple schematic comparative representation of knowledge transmission from two ways of knowing.

Compared with reindeer herding knowledge and Indigenous knowledge, the Western School system has a great impact on reindeer herding knowledge and skills. There is a gap between what is emphasized by content, methods, and guidance between the Sámi reindeer herding world and the world of public education. While formal education is based on the western ways of understanding, the schools in Sámi areas have occasional projects dealing with reindeer husbandry, which are not included in curricula (Bongo, 2005). This shows the status of how the western knowledge prevails in the school system for reindeer herding children where there ought to be two ways of knowing.

The public school systems omit knowledge about reindeer herding that is necessary for those who are going to work with reindeer, and omits traditional knowledge related to belief systems, spirituality, and cosmology, which are a natural part of the knowledge transfer of the Indigenous people themselves (Ohmagari & Berkes, 1997). However, some schools allow reindeer herding parents to take their children out of school for periods to work with reindeer herding, and they gradually can build up the knowledge necessary to become a skilled reindeer herder (Hætta, 1993).

The reason being that it is difficult to learn reindeer husbandry, i.e., the knowledge needed to become professional reindeer herders, through the public education systems (Hoëm, 1996). Today, the reindeer children in primary school Sámi areas have neither reindeer husbandry as a subject nor as part of the curricula (UDIR,

Table 5.2 Formal education knowledge vs traditional knowledge compared with reindeer herding knowledge

Western school knowledge transmission	Reindeer herding knowledge transmission
Formalized education	The prerequisite for reindeer herders, but not formalized learning
Educational/school-based learning	Learning through work and collaboration
Surface level-processing combined as factual knowledge and including deep level-processing,	Deep level-processing, as with in-depth learning, understand and be able to use the knowledge in new situations
Based on written transmission	Based on oral transmission
Special languages related to themes	Learning is rooted in specialized language related to tasks
Themed	Holistic

2022). On the other hand, some schools offer sporadic projects that deal with reindeer husbandry. At high school level there is only one school in Norway, reindeer husbandry school in Guovdageaidnu that offers comprehensive reindeer herding education to both reindeer herders' youngsters and others that are interested in this subject (SVSRS, 2022). This shows that the knowledge, values, skills, and interests that Indigenous students possess are largely ignored in favor of strategies aimed at enticing them to conform to mainstream education (Cajete, 1994).

5.5 Discussion

The characteristics of reindeer husbandry parents' transmission of reindeer herding knowledge and skills to children in reindeer husbandry is that they are using different methods and different content in time and space. Findings represent learning levels, competence and skills, transmission of traditional knowledge and sustainability, learning earmarks by herding, teachers, and arenas.

5.5.1 Lifelong Learning

The findings show that knowledge transfer in reindeer husbandry takes place in the same way as it has been done for generations, as a lifelong learning process. The transmission of knowledge starts already in childhood through knowledgeable guidance from a more competent person. In adolescence, learners appear as people with good beginner skills who can complete many work tasks, still with support from an experienced reindeer herder who can evaluate work performed. The goal is to develop advanced knowledge that makes learners independent and self-confident and throughout life.

According to Cajete and Bear (2000: 76) The Indigenous universe can be illustrated as a circle of learning, life, and relationship that is inclusive of all-important information needed to make life decisions.

The knowledge transmission focuses on learners' personal development, initiated by parents, but also self-initiated. This training is best done through daily chores in the *siida* with trial and errors, and this takes place outside the formal educational institutions. With herder's solid specific knowledge and skills of reindeer husbandry and experience through life make them outstanding reindeer husbandry professionals, who act wisely, handle the *siida* safely all year round, and pass on knowledge to new generations.

5.5.2 Systematic Learning Methods and Content

Reindeer herding knowledge transmission proves to be a systematic teaching and learning process in relation to content, age, space, and time. Reindeer herding parents use different methods and different content based on children's age and throughout the reindeer herding year. Learning methods reflect the nature of reindeer husbandry: both individual skills and working mode, and collective knowledge and skills. One learns individually how to be a reindeer herder, to handle animals, people and nature while maintaining reindeer herding. At the same time, learning is a part of collective settings: participation in conversations, work, and gaining the ability to collaborate and cooperate. The systematic learning process plays a key role in developing children's path to becoming reindeer herders. Knowledge among Indigenous peoples is acquired in a completely different way than in the formal school, but still extremely systematic. (Cajete & Bear, 2000: 80) Learning processes and learning methods are based on learning through inductive and action-oriented working principles (Bongo, 2005). This includes innovation and learning through repeated practices that emphasize practical application of knowledge in authentic work situations (Bongo, 2005).

These findings support a study conducted by Bongo (2005) where it is emphasized that reindeer herding teachers choose teaching methods to ensure that learners first and foremost learn what they are supposed to, but also to let them gain knowledge about what they need to know about reindeer husbandry. Thus, this is both Indigenous (Hoëm, 1996; Keskitalo, 2009) and hybrid knowledge (Berkes, 2012). This includes knowledge and skills about a range of tasks, decisions, and actions, from parts related to the performance of annual recurring tasks to the parts that prepare for action in confusing and unknown situations (Sara, 2001: 10–11).

The content is based on the framework of reindeer herders' understanding of sustainable husbandry, multidisciplinary content, and multiple ways of knowing. Learning contributes to the learners' development of important adaptation strategies and skills in living with the uncertainties in the Arctic environment to adverse climate conditions and managing to create sustainable livelihood systems (Eira, 2022; Mathiesen et al., 2018).

Learning the reindeer husbandry's worldview and ethics is important from a reindeer husbandry perspective, which deals with teaching children to take responsibility for both humans, animals, and nature. Children have to learn to be honest, fair, and get along with everything that includes reindeer husbandry (Oskal, 1995). According to (Cajete, 1994) morals and ethics are modeled by the family and community and embrace respect for the elderly, honesty, proper behavior, and proper treatment and respect for all living beings.

The findings state that the reindeer herding learning system contains a holistic approach, as an understanding of the reindeer husbandry as whole and that all the parts of it are closely interconnected and explainable only by reference to the whole.

The holistic way of thinking is common in Indigenous people's lives (Berkes, 2012) and in the philosophy of learning in a Sámi context (Balto, 2005).

In the learning process and in communication, the reindeer herding language is prerequisite for obtaining this special knowledge. Learners hear words repeatedly used in their proper places in various working situations, and thus they gradually learn to understand the significance of processes and objects. Throughout the learning processes, learners participate closely in work (Bongo, 2005) and acquire concretizations of concepts related to subject contents and processes and discover the symbolic function of words (Eira, 2012). According to Wittgenstein (1997), this method provides learning the special language effectively because of the short distance between the work, learning goals, the learning content, and the professional language. Learners learn through understanding and using the Sámi reindeer husbandry language developed and with words that are older than proto-Sámi (Lehtiranta, 1989), i.e., words that are older than about 2000 years (Sara & Eira, 2021).

To encourage and motivate the children to perform the tasks in the best possible way and to develop their own competence and skills, reindeer herding tutors or teachers continuously using different methods for feedback and assessment in the learning process. The feedback is meant to get the learners to understand the master task-solving. In this process teachers use specific Sámi concepts – *fitmat, hága, searra* – that aim to highlight the learners' strengths and achievements. This can be compared to feedback and assessment in a formal education (UDIR, 2022).

5.5.3 Responsibility for Learning and Learning Arenas

The findings indicated that the responsibility for learning in reindeer husbandry is added to the family, *siida* members and other reindeer herders. These represent an extended view of who the child must relate to. This means that children early learn the significance of family, responsibility, respect, and the foundations of relationship and kinship, as mentioned by Cajete and Bear (2000). In our opinion this makes the teaching both flexible and robust because the learning is addressed to many tutors. Furthermore, this optimizes learners' knowledge: the learners receive different knowledges since there are so many responsible for the teaching. This kind of responsibility to teach children has its basis in interacting with other people. What children do with an adult today, they can do alone tomorrow.

The process of transmission of knowledge turns out to include the performance of functions and activity in reindeer herding and is related to which learning arenas are used at different times. Reindeer herding learning arenas include different herding areas, landscapes, *siida*, *lávvu*, fence etc. These arenas are important and useful because these are where the authentic reindeer herding work tasks are carried out.

5.6 Conclusion

In this chapter, we have presented an overview of the characteristics of how transmission of reindeer herding knowledge and skills to children in reindeer husbandry in Guovdageaidnu are done.

Reindeer herders need a comprehensive range of knowledge and skills to manage a reindeer herd on different landscapes in different times of year. A repetition of the activities that are done on purpose (competence management) is the success criterion for a strong learning culture for the reindeer herding population. Here, knowledge is transformed into competence in practical reindeer husbandry work through concrete and planned activities and learning processes.

The reindeer herding teachers use multiple methods, thought processes, philosophies, concepts, and experiences in their teaching of reindeer herding children for they need to achieve and apply knowledge about reindeer herding and the natural world. Through examples, We have illustrated several main points that characterize the Sámi reindeer husbandry education system, e.g., learning by doing different tasks; learning by example; cooperative and collaborative learning; the role of repetition; learning from own mistakes; the relationship between learner and teacher; manage motivation through appropriate praise and guidance; etc.

The children learn through practical and authentic reindeer husbandry activity and work and communicating reindeer herding specialized language in interaction with others. Teaching through a real situation expands the realm of learning beyond speculation and allows the students to judge the truth of a teaching for themselves (Cajete, 1994). The student makes observations that are included in the work and contributes to the work according to his own ability at the same time as the teacher makes observations of the learner who performs the skill. Teachers facilitate learning by using different methods to involve the child in the participation in the work tasks that are often related to different work processes that take place throughout the annual operating cycle. Through these processes, reindeer husbandry knowledge and skills are gradually developed until you finally emerge as a fully trained professional.

Obligations and responsibilities related to knowledge transfer are assigned to both parents or close family members, the household and the *siida*, depending on how work tasks are generally divided between them. The learning arenas are often outside, in nature, at the places where the various works take place, in *lávvu*, in houses etc.

The development of detailed practical reindeer herding knowledge and the accumulation of the learner's personal wisdom are crucial to ensure sustainability and resilience in reindeer herding and reindeer husbandry. To learn what a reindeer herder must learn, one needs the methods that reindeer husbandry teachers use in the learning process. On the other hand, there is a catch to this. Knowledge transfer that previously took place through long-term and natural surroundings in the *siida*, today takes place through short periods where pupils and students can participate and acquire the traditional reindeer husbandry knowledge.

Although educational programs provide important human development tools, no reindeer husbandry education program and curriculum have been developed based on the methods and content of reindeer husbandry. Because the school system isolates children from their reindeer herding environment, that can then compromise the transfer of knowledge to future reindeer husbandry generations. There is a great need for a professional curriculum for reindeer husbandry that teaches reindeer owners to cope with external influences such as globalization, infrastructure development, loss of pastureland, laws, governance, administration, politics, economics, capacity building etc.

There is a need for a formal education program for reindeer herders in all levels in the educational system based on reindeer herding understanding and knowledge base and combined with western knowledge which is relevant to reindeer husbandry. Because of the nature of reindeer husbandry, the program must be developed as a flexible learning model in relation to content, time, and space to combine the schoolwork with daily work in reindeer husbandry.

With a changed view of educational programs and curricula to offer reindeer owners customized teaching programs by gaining reindeer herding knowledge, understanding and creative thinking from past and present to prepare reindeer husbandry for a sustainable future.

Appendix 5.1: Glossary of Sámi Terms

Sámi concept	Definition
báikevuođđu	household foundation
bagadallan	to explain in detail to a person
birgejupmi	a form and degree of self-salvage
birgenvuođđu	resource foundation
boazoságat	"Reindeer talk" characterized as the Sámi reindeer herding internal communication and conversation method, for example used in connection with herding shifts or when the reindeer herder comes from the herd/*siida*
cuoigut	a method to make a mental note of something by pointing is often used in the process of how to distinguish a reindeer from others through language, articulating and describing partly without language and word descriptions
čoavjjehat	pregnant female reindeer
čuoiggaheaddji	one who chase on the ski
dien rávddas	on that edge of the herd
diiddat	a rule of thumb that is Sámi guidance sentences that each individual must interpret and consider whether to follow
duodji	Sámi handicraft
ealát	pasturage, food
eallovuođđu	*eallu* foundation
eallu	reindeer herd
fearánat	occurrence, event; experience

(continued)

Sámi concept	Definition
fitmat	a person who has a keen faculty of recognition that finds it easy to notice and remember; is good at imitating (Nielsen, 1979: 779)
gahččanbeallji	not an ordinary cut made due to a mark that was cut too deep
gállá bártnit	the stars in Orion's belt
gárddástallan	working with reindeer in the fence
gáržžideapmi	reducing the number of possible animals
giđđajođidettiin	during the spring migration with reindeer
gietka	Lapp cradle (in which the child can be carried)
goahti	tent (with two pairs of tent-poles curved at the top, where they are joined by a transverse pole: ef. *lávvu*).
guohtun	assessing how easily reindeer can access by digging through snow to the food
hága	description of someone who is strong and skilled to solve tasks or work
ieš	my self, themself, himself, herself etc.
luddestat	(made) fissure, crack; as a part of earmark: narrow cut lengthwise in the ear
luohti	Sámi song method, with the tune belonging to it; about a particular person, animals, or things.
luovvasat	the male reindeer herd (when they are kept separate from the herd of females during the calving time in spring).
máhttovuođđu	knowledge base
mearkavuođđu	earmark foundation
muitalusat	narratives
niibeboagán	belt with a knife
njávkat	feel with your hand or fingers the ear of the reindeer to confirm owners of the reindeer
Oalli	the main earmark of the family
orohat	pasture area
pesk	jacket made of reindeer skins
rievdadus	a change made to the original main cut
ruovgat	grunt: the noise is made by the female reindeer and reindeer calf when they have got separated
searra	someone who is good at all kinds of work and has the skills
šearus	as a perfect cut in the ear
siida	the original Sámi self-governing local community, where people have moved between different settlements within the *siida* area, depending on the resources sought during the year
siidavuođđu	*siida* base
siiddastallan	the part of the reindeer husbandry practice that the traditional Sámi *siidas* have been responsible for meaning keeping/running a *siida*, working with reindeer and a reindeer herd
suohpan	lasso
vuođđoipmárdus	worldview
vuođđu	foundation or base
vuoigatvuohtavuođđu	base for rights
báikevuođđu	household foundation

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Chapter 6
Ethics of Knowledge Production in Times of Environmental Change

Michaela Stith, Robert W. Corell, Rosa-Máren Magga, Matthias Kaiser, Anders Oskal, and Svein Disch Mathiesen

Abstract This chapter includes transdisciplinary analysis, ethical considerations, and guidelines about co-producing research across science and Indigenous peoples' traditional knowledge systems, particularly in the Arctic region in times of environmental and climatic change. The authors intend to reach out to many readers with different backgrounds and interests. The study employs inter- and transdisciplinary framing of the knowledge systems. This includes an implicit criticism of the typical narrowing of study to disciplinary siloes. It is claimed that traditional academic research misses the importance and positive contributions of different knowledge traditions and thought styles, and it is further claimed that inclusivity of these traditions is an ethical component of responsible research. In this sense, it is hoped that the following chapter inspires researchers to transcend institutionalized knowledge framings and opt for co-production of knowledge that is ethically responsive to rich cultural traditions in the Arctic. Any type of research done in communities should not exploit the Indigenous communities and knowledge holders.

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M. Stith (✉)
Native Movement, Dgheyhey Kaq' / Anchorage, Alaska, USA

R. W. Corell
International Centre for Reindeer Husbandry, Guovdageaidnu, Norway

University of Miami, Coral Gables, FL, USA

Global Environment and Technology Foundation, Arlington, VA, USA

R.-M. Magga · A. Oskal
International Centre for Reindeer Husbandry, Guovdageaidnu, Norway

M. Kaiser
Centre for the Study of the Sciences and Humanities, University of Bergen, Bergen, Norway

S. D. Mathiesen
International Centre for Reindeer Husbandry, Guovdageaidnu, Norway

Sámi University of Applied Sciences, Guovdageaidnu, Norway

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6.1 Introduction

Arctic Indigenous peoples face transformative changes that are impacting family-based nomadic traditions. Indigenous reindeer herders encounter vegetation changes in and around pastures where land use such as forestry, strictly protected areas, and tourism have been introduced without their free, prior and informed consent. Added to these impacts are climatic changes that will create challenges for reindeer herding in the future (Magga et al., 2020).

> …Remember, it is not us reindeer herders who have been the cause of climate change. The reindeer know what paths to take. Many people have lost their connection with nature, but the animals maintain this connection and that is why we follow the reindeer.

Senior reindeer herder Vassily Vassilievich Nomchaivyn of brigade № 4 in Kanchalan, Chukotka (Magga et al., 2020).

From the herders' perspective, it is important to increase cooperation between reindeer herders and researchers. Several studies of traditional Sámi knowledge have examined the role of traditional knowledge in Sámi reindeer husbandry and found it important for observation of snow cover (Eira et al., 2013, 2016), herding organization (Sara, 2009), reindeer governance (Johnsen et al., 2017; Turi, 2016), nomadic slaughtering and reindeer meat quality assessment (Sara et al., 2022; Sara & Eira, 2021) and smoking of reindeer meat (Krarup-Hansen et al., 2022). Traditional knowledge is based on experience that is accumulated in people's memory and actions over multiple generations (Magga et al., 2020). Article 26 of the Declaration on Science and the Use of Scientific Knowledge (UNESCO, 1999) states that:

> traditional and local knowledge systems, as dynamic expressions of perceiving and understanding the world, can make, and historically have made, a valuable contribution to science and technology, and that there is a need to preserve, protect, research and promote this cultural heritage and empirical knowledge.

Moreover, the Intergovernmental Panel on Climate Change concluded in the Special Report on the Ocean and Cryosphere in a Changing Climate:

> Institutional arrangements that provide for strong multiscale linkages with Arctic local communities can benefit from including indigenous knowledge and local knowledge in the formulation of adaptation strategies (high confidence). The tightly coupled relationship of northern local communities and their environment provide an opportunity to better understand climate change and its effects, support adaptation, and limit unintended consequences. (IPCC, 2019)

The mainstream scientific community and governmental institutions have today begun to demand the implementation of traditional knowledge. The term "Indigenous knowledge" recognizes that Indigenous Peoples constantly produce and reform what they know (Johnson et al., 2016: 7). This chapter aims to discuss Indigenous knowledge and the ethics of knowledge production in times of environmental change. The findings of this Chapter are based on the INTERACT II D9.1 – Guide for Local Adaptation to Environmental Change Project (Magga et al., 2020).

6.2 Philosophical Approach to Scientific Knowledge and Indigenous Knowledge Systems

We shall here introduce philosophical aspects of defining and delineating different knowledge systems. Philosophers always start with the classics. The classical definition of knowledge is knowledge as *justified true belief.*[1] This goes back to Plato (cf. Plato's Theaetitus) but gained importance in the philosophical discussions since the twentieth century. Now, reflect for a minute on each term! Truth in knowledge systems is always assumed to be the case, though it remains a tentative hypothesis. If you find out something is not true, we don't call it knowledge anymore. We are fallible, yes, but when we credit something as knowledge, we assume its truth. Furthermore, if we know something, then we obviously also believe it. The opposite is not true: not all that we believe we would classify as knowledge.

And now secondly**: justified** true belief. This is the more problematic issue about justification, and that is where different knowledge systems differentiate. Obviously, scientific knowledge is based upon a very specific way of justification, and that includes two crucial elements. On the one hand, there is a whole range of scientific methods that produce certain results, the methods that link the theoretical part with the empirical part of our conceptualizations of reality. On the other hand, it includes the social element of validation, the element of peer review, and organized skepticism (as discussed by Merton, 1938, 1973). That is, scientific knowledge is validated through the process of criticisms from your peers within the scientific communities, and we call this the peer review which can take various forms. This is the basic justification of knowledge in science.

How is it for Indigenous knowledge systems as a contrast? Well, they are also justified beliefs and they are justified through – more or less – place-based or regional, social traditions, very often accompanied by personal experiences and narratives about them. They can change over time as experiences accumulate and errors are erased. And finally, the transmission of trusted elders in the community (rather than peer review) is the bridge from the past to the present, and from the individual to the community. These are the reasons why one would give credit to Indigenous knowledge systems as they have emerged in various locations.

Now, the important observation here is that those justifications are completely rational. Rational in the sense that they give us relatively good reasons to believe in them. But the reasons are different. In that sense, they are rational systems where the difference lies with the accredited value of the sources. People actually value the sources differently. In science, tradition does not count for much, whereas it counts for quite a bit in traditional systems of Indigenous knowledge.

The challenge in modern society is to align these two knowledge systems and not to end up with the intellectual hubris that only values scientific knowledge. We need

[1] This is the so-called JTB condition of knowledge. We shall here not engage in the further development of JTB by Gettier-style examples, but simply refer to current textbooks for further discussions (cf. e.g., Lehrer, 2018).

Fig. 6.1 Sámi scientist meeting Nenets reindeer herders in Yamal, Russia (2009). (Photo: S.D. Mathiesen)

to overcome the belief that scientific knowledge is superior in all walks of life. As we have experienced time and again, it is not; often science has created the problems in the first place which then science is called upon to repair (e.g., the use of pesticides during the Green Revolution). In any case, the conflict between knowledge systems is not a matter of fact or the reality out there, but it is a matter of whose values count the most (Funtowicz & Ravetz, 1993). Our approach and view are that we have to align these two knowledge systems and that we have to interact with both of them (Fig. 6.1).

6.3 Defining Indigenous Peoples' Traditional Knowledge in the Context of the Arctic Council

The multitude of terms and definitions related to Indigenous and traditional knowledge causes confusion about the meaning behind the words. For the purposes of this chapter, it is important to highlight as stated by Magga et al. (2020) that Indigenous knowledge is (1) inherited, owned, and generated by the holders of that knowledge and (2) place-based, varying depending on the setting (Magga et al., 2020).

The only official definition developed in an international, intercultural Arctic context is in the *Ottawa Principles on Traditional Knowledge*, developed by the six Permanent Participant organizations that represent Indigenous Peoples in the Arctic Council:

> Traditional Knowledge is a systematic way of thinking and knowing that is elaborated and applied to phenomena across biological, physical, cultural and linguistic systems. Traditional Knowledge is owned by the holders of that knowledge, often collectively, and is uniquely expressed and transmitted through Indigenous languages. It is a body of knowledge generated through cultural practices, lived experiences including extensive and multigenerational observations, lessons, and skills. It has been developed and verified over millennia and is still developing in a living process, including knowledge acquired today and in the future, and it is passed on from generation to generation. (Arctic Council Indigenous Peoples' Secretariat, 2015)

Since 2015, many Permanent Participants have taken an institutional standpoint preferring the term “Indigenous Knowledge” to “Traditional Knowledge” (Magga et al., 2020). This change seems to have begun in 2013 when the Arctic Council used the term “traditional and local knowledge (TLK)” in a Ministerial Declaration for the first time since its founding in 1996 (Arctic Council, 2013, 2017). The Arctic Council began to use “TLK” as its default term to “Support the use of consistent terminology regarding traditional and local knowledge throughout the work of the Arctic Council” – a recommendation suggested by the Arctic Council’s Sustainable Development Working Group (2015).

One may notice that terms like “traditional and local knowledge” or “local and Indigenous knowledge” equate Indigenous Peoples’ knowledge to knowledge that is held by locals who can refer to old traditions which include segments of knowledge (Magga et al., 2020). For terminological reasons, it may be wise to adopt the phrase given by the Arctic Council in 2019, traditional knowledge and local knowledge (TKLK), which distinguishes local knowledge systems from indigenous knowledge systems.

Many Permanent Participants define Indigenous Knowledge with the same wording agreed in the Ottawa Traditional Knowledge Principles; the terminology has shifted primarily to emphasize Indigenous Peoples’ ownership of their own knowledge systems (Magga et al., 2020). Yet different Indigenous institutions retain varying positions on the definitions and terminology. In its report “Application of Indigenous Knowledge in the Arctic Council,” the Inuit Circumpolar Council offered this expanded definition:

> [Indigenous knowledge] has developed over millennia and is still developing in a living process, including knowledge acquired today and in the future, and it is passed on from generation to generation. Under this definition, IK goes beyond observations and ecological knowledge, offering a unique ‘way of knowing’ to identify and apply to research needs which will ultimately inform decision-makers. (ICC, 2016, n.d.)

Indigenous Peoples retain the ability to coin their knowledge systems: for example, the Sámi Council prefers to use their own language to describe their way of knowing: “*Árbediehtu*” (Guttorm, 2011). The International Centre for Reindeer Husbandry (2006) uses the terminology *árbevirolaš máhttu ja dieđalaš máhttu* for traditional knowledge. The herders’ knowledge of assessing lávvu-smoking is not only *diehtu* - theoretical knowledge about the practice - but also embodied skills, *máhttu.* (International Centre for Reindeer Husbandry, 2006; Krarup-Hansen et al., 2022). Inuit Circumpolar Council Alaska (2016) specifically notes that the Inuit, for example, can sometimes refer to their knowledge as “Indigenous Knowledge”, “Inuit Knowledge” or “Traditional Knowledge”.

Arctic Peoples agree on the following stances in the definition of Indigenous Knowledge:

- Indigenous knowledge is a systematic way of knowing.
- Indigenous knowledge is paramount to Indigenous world views; it emphasizes ways Indigenous peoples relate to other people and the environment.
- Indigenous knowledge is passed down through generations and relies on communication with elders.

- Indigenous knowledge is not static; Indigenous peoples are constantly producing and reforming Indigenous knowledge systems.
- Indigenous knowledge is place-based and varies depending on the setting.
- Indigenous knowledge holders experience a common fight to bring their world views and understanding back to their peoples.
- Indigenous knowledge is rooted in the use of land but opposes the conquest of the land.
- The Permanent Participants referred to the holistic definition of traditional knowledge – which is integral to Indigenous knowledge – in the Ottawa Traditional Knowledge Principles.

(Arctic Council Indigenous Peoples' Secretariat, 2018)

The difficulty in assigning one definition or term is that Indigenous knowledge systems constantly evolve around the location where that knowledge is held (Magga et al., 2020). One should consider that over 500,000 Indigenous people live in the Arctic, comprising many different ethnicities and communicating in up to 90 languages – depending on the methods used to classify languages and dialects – each of which is inherently linked to its own Indigenous knowledge system (Arctic Council Indigenous Peoples' Secretariat, n.d.). Indigenous Peoples are non-monolithic with varying perspectives on how their knowledge systems should be used, shared, and communicated. Therefore, working directly with Indigenous Peoples and institutions of a particular study area is essential to co-producing knowledge across science and Indigenous knowledge systems.

6.4 Science for Policy in Complex Reality

Many people, especially in academia, tend to separate the descriptive parts of our language use from the normative parts. As a consequence, many scientists would hold that science is about facts of the world, and that values have no role in science since we seem unable to "discover" them from our empirical observations. However, this traditional view has since the 1950s been criticized even from within the philosophy of science (Rudner, 1953; Douglas, 2009), and nowadays many would agree that facts and values are in fact intertwined, even in the best of our sciences.

This is even more obvious when one moves to science-for-policy, i.e., the move to transform knowledge into practice. In most cases, one discovers that reality is rather complex, and allows for different lenses on how to account for this reality (Saltelli et al., 2020). In these cases, we typically accumulate the inherent uncertainties at the same time as the stakes of getting it wrong get higher. This is basically the situation of post-normal science (PNS) as described by Silvio Funtowicz and Jerome Ravetz (1993). The "mantra" of PNS is this: (i) facts are uncertain, (ii) values are in dispute, (iii) stakes are high, and (iv) decisions are urgent (Gluckman et al., 2020). In PNS values and facts are intertwined. This challenges traditional conceptions of relevant expertise. If values are at stake in PNS, then obviously we cannot simply rely on scientific peer review as quality assurance. Therefore, PNS includes a call for "extended peer review", where affected parties and civil society are included.

This is also an ethical consequence if one takes the call for Responsible Research and Innovation (RRI) seriously. PNS becomes a condition not only of our sciences but of society at large. With this background, we quickly see how this leads to a call for the co-production of knowledge and transdisciplinarity.

6.5 Co-production of Knowledge and Transdisciplinarity

All science-for-policy, and all efforts to bring knowledge to specific uses starts always with the problem formulation. It is therefore important to realize that this is the first hurdle: Who defines what the problem is? Are all actors and parties agreed on what the problem is? Is there one or many problems to deal with? Often, we will face what was called "wicked problems": "problem understanding and problem resolution are concomitant to each other" (Rittel & Webber, 1973).

A "co-production of knowledge" approach brings together different knowledge- and value- systems while building collaborative partnerships from 'different ways of knowing' (Magga et al., 2020). The peoples in the Arctic are also experiencing rapid changes, and those who will experience the most extreme changes will need to access the knowledge gathered about and around them so that they can adapt to the rapid changes (Eira, 2012). According to ICC Alaska (2022), "*Bringing together multiple knowledge systems, specifically Indigenous Peoples' knowledge systems, and science, can lead to more equitable, inclusive, and useful outcomes*" (Yua et al., 2022) (Fig. 6.2).

Research that is relevant to local communities and benefits them needs to involve the communities. This can be done through the co-production of knowledge between the local communities and the scientific community (Eira et al., 2013, 2018; Näkkäläjärvi & Juntunen, 2022). The parties or actors produce new knowledge together, on equal terms:

Fig. 6.2 Community-based workshop in Yamal tundra. (Photo: S.D. Mathiesen)

> We propose that co-production should be viewed as an exploratory space that brings together different values and social relations and a generative process that produces new interactions and forms of knowledge and that can lead in turn to meaningful ways of shaping and taking part in health care. (Filipe et al., 2017)

Co-production of knowledge is the production of knowledge happening in the sphere where academic knowledge and other knowledge systems meet (Pohl et al., 2010). Co-production of knowledge is now also integrated into the widely used concept of transdisciplinarity (Kaiser et al., 2020; OECD, 2020) which extends interdisciplinary science by opening up for other epistemic traditions as an ongoing dialogue with, among others, Indigenous knowledge systems and other stakeholders. Transdisciplinarity is characterized by: (i) *Ab initio* commitment to the framing of the question by integrating different domains and disciplines of knowledge, even when this means working across different theoretical perspectives and methodological practices; (ii) a focus on real-world problems, where context and complexity are recognized and confronted as part of the methodology (Gluckman et al., 2020).

Another definition of co-production of knowledge is "simultaneous production of knowledge and social order" (Guston, 2001: 401). Knowledge co-production processes need to address methodology, theory, and use of the co-produced knowledge in practice (Magga et al., 2020).

According to Pohl et al., "Sustainable development requires the production of knowledge that strikes a balance between scientific and other forms of knowledge" (2010: 267). Co-production of knowledge supports sustainable development by balancing the extraction and use of natural resources with Indigenous knowledge about the integrity and stability of the natural system. According to Eira (2012), co-production of knowledge can benefit local communities and the scientific community, and the end product is sustainable science.

Co-production of knowledge is also a way to produce the best available knowledge because local communities are involved, can influence the research process, and make it more relevant for themselves. Another relevant factor is that co-production can provide different angles to approach issues and phenomena that contribute to robust results (Saltelli et al., 2020).

Some of the Arctic Council projects have actively involved Indigenous knowledge in Indigenous-led projects, such as: 'Indigenous youth, food knowledge and Arctic change' (EALLU) managed by the Association of World Reindeer Herders and 'Circumpolar Wildland Fire' and the Arctic Wildland Fire Ecology mapping and monitoring project (ArcticFire) lead by the Gwich'in Council International to advance work on wildland fires at the Arctic Council. Some of the projects have focused on bringing together traditional knowledge holders, scientists and resource agencies to assess freshwater river systems, identifying actions that are taken by the Permanent Participants in recent years that build resilience, or deploying traditional and local knowledge through the creation of a knowledge exchange program and establishing professional networks related to energy resources for remote Arctic communities. In addition, the Permanent Participants have provided their expertise in Indigenous languages and traditional knowledge for the language map on Arctic Indigenous languages produced by the UiT University Library and the Arctic

Council Indigenous Peoples' Secretariat (2019) that is further developed as an online educational resource.

According to Wheeler et al. (2020), attention to the role of Indigenous knowledge in environmental monitoring, research, and decision-making is likely to attract new people to advance this field of work.

Co-management builds adaptive capacity at multiple levels by fostering shared understanding, increased dialogue, and interaction. Co-management provides emerging networks that give rise to new social practices and interactions, allowing greater ability to cope with variability and building longer-term adaptive responses that minimize risk and uncertainty (Armitage et al., 2011).

6.6 Current Principles and International Ethical Guidelines to Cooperate with Indigenous Peoples

Calling on different groups and sectors of society to work together towards a common goal will always involve potential conflicts arising from social hierarchy and differential power relations. Therefore, ethical issues will arise and need to be clarified. The International Centre for Reindeer Husbandry (ICR) has developed its own Ethical Guidelines. According to the guidelines, traditional knowledge has equal value to scientific knowledge and has essential practical value for the carriers of such knowledge in their day-to-day activities and subsistence. Guidelines also note the need to develop additional guidelines tailored to each partnership:

> TK is more than a source of empire for researchers. TK carriers shall play a central part in shaping projects and shall be involved as equal partners in consultation and decision-making.

This guideline supports the need to create such guidelines where the scientific community and local community meet, their knowledge plays an equal role and their cooperation can be developed.

When working with Indigenous issues, on Indigenous land, and with Indigenous peoples, then cultural sensitivity plays an important role. The ICR Ethical Guidelines (2006) recognize Indigenous Peoples' ownership of the knowledge and the use of the knowledge, and underline that "*all researchers working in the North have an ethical responsibility toward the people of the North, their cultures and the environment. Traditional knowledge is of equal value as scientific knowledge and when traditional knowledge holders' knowledge is used, they have a right to determine how it should be used. Traditional knowledge carriers shall play a central part in shaping projects and shall be involved as equal partners in consultation and decision-making*" (International Centre for Reindeer Husbandry, 2006).

The guidelines also discuss the role and the importance of capacity building benefitting the communities and how all relevant projects shall include capacity building as a separate project goal (ICR Ethical Guidelines):

- "Capacity building means empowering Indigenous peoples as minorities through increased knowledge, in order to make them able to become truly equal partners in processes with mainstream society. The capacity building thus includes building knowledge in the Indigenous societies themselves, their people, their own institutions, and organizations.
- All relevant projects shall include capacity building as a separate project goal. As far as practically possible, the projects should involve some form of evaluation of effects on capacity building. The projects should preferably be designed so that any results of capacity building are made measurable".

Considering the further development of the Arctic Science Cooperation Agreement (2017) and the outcome of the 2nd Arctic Science Ministerial Meeting (2018),[2] there is a strong need for new guidelines outlining (1) how researchers should operate in Indigenous peoples' territories and (2) how cooperation between researchers and local communities can be developed.

Various other guidelines include The Global Environment Facility, "Principles and Guidelines for Engagement with Indigenous peoples" (2012); United Nations Development Group, "Guidelines on Indigenous Peoples' Issues" (2009); CARE Principles for Indigenous Data Governance; UNESCO, "UNESCO Policy on Engaging with Indigenous Peoples" and "UNESCO's Engagement with Indigenous Peoples" (2018). The Akwé: Kon Voluntary Guidelines provide a collaborative framework ensuring the full involvement of Indigenous and local communities in assessing the cultural, environmental, and social impacts of proposed developments on sacred sites, lands, and waters traditionally occupied by Indigenous peoples and local communities (Secretariat of the Convention on Biological Diversity, 2004).

Common among these guidelines in that research activity must be based on free, prior, and informed consent (FPIC). It is a principle protected by international human rights standards that clearly acknowledge Indigenous peoples' right to self-determination, stating that "all peoples have the right to freely pursue their economic, social and cultural development." (Corntassel, 2008). The United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP), the Convention on Biological Diversity, and the International Labour Organization Convention 169 (ILO 169) all uphold FPIC.

International recognition of Indigenous peoples' rights also helped them work on Indigenous ethical guidelines to move forward (Juutilainen, 2017). For example, UNESCO's Universal Declaration on Bioethics and Human Rights' (2005) gave specific attention to Indigenous peoples' interests in research affecting them, as well as communities' roles in providing consent for such activities. UNDRIP also highlights Indigenous peoples' collective right to exercise control over expressions of their cultural heritage and intellectual property. Article 31 states, "*Indigenous peoples have the right to maintain, control, protect and develop their cultural heritage, traditional knowledge, and traditional cultural expressions, as well as the manifestations of their sciences...*" (Khotimah, 2007).

[2] https://www.arcticscienceministerial.org/arctic/de/home/home_node

Ethical principles for research on Indigenous Peoples at the national level: Tri-Council Policy Statement 2 (1998, updated in 2018) – Chap. 9: Research Involving the First Nations, Inuit and Métis Peoples of Canada (Canadian Institutes of Health Research, Natural Sciences and Engineering Research Council of Canada, and Social Sciences and Humanities Research Council, 2018); Te Ara Tika Guidelines for Māori research ethics: A framework for researchers and ethics committee members (Hudson et al., 2010); and AIATSIS Code of Ethics for Aboriginal and Torres Strait Islander Research (2020). Canada also has various guidelines for cooperating and working with Indigenous peoples at regional level. Take, for example, *Draft Principles that Guide the Province of British Columbia's Relationship with Indigenous Peoples*; Ontario Human Rights Commission's report (2018); and Canada's Ministry of Health and Long-Term Care, *Relationship with Indigenous Communities Guideline* (2018).

According to Magga et al. (2020), in Canada, there are regional protocols as well as regional permitting processes for entering Indigenous communities and territories to conduct research. Polar Knowledge Canada (POLAR) has provided instructions for conducting research in Canada's North. These instructions showcase best practices as well as region-specific information for conducting research in Canadian North. The Gwich'in Traditional Knowledge Policy entitled, Working with Gwich'in Traditional Knowledge in the Gwich'in Settlement Region (2004), was drafted in preparation for including, but not limited to increased research interests in the Gwich'in Region and the Conducting Traditional Knowledge Research in the Gwich'in Settlement Area – A Guide for Researchers (2011) sets guidelines and requires research agreement to be completed for any research that documents Gwich'in Traditional Knowledge. This work is led by Gwich'in Tribal Council and their traditional knowledge policy (Gwich'in Tribal Council, 2004; Gwich'in Council Research, n.d.; Gwich'in Social and Cultural Institute, 2011. Magga et al. (2020) highlight some of the regional processes: the permitting authorities in Yukon, Northwest Territories, Nunavut and Nunatsiavut. In Nunatsiavut, Nunatsiavut Government requires research applications for any research conducted in Nunatsiavut and it can only happen with the full knowledge of the Nunatsiavut Government and Labrador Inuit. There are also research licenses for conducting research in both the Northwest Territories and Yukon (Magga et al., 2020).

In the Canadian context, principles of ownership, control, access, and possession (OCAP), is self-determination applied to research. OCAP is a political response to persistent colonial approaches to research and information management (Schnarch, 2004). The principles of OCAP inform the development of national ethics policies in Canada and guide researchers working with First Nations, Inuit, and Metis communities (Juutilainen, 2017: 29).

The development and consolidation of sustainable practices in Sámi research, especially the importance of ethical guidelines for Sámi research, has been discussed among Sámi and Sámi research since the 1970s (Holmberg, 2018, 2021). The Ethical Guidelines for Indigenous Health Research (2016) and the "Proposal for Ethical Guidelines for Sámi Health Research and Research on Sámi Human Biological Material" (Kvernmo et al., 2018) offer an overview of principles to ensure that research is considered safe from a cultural perspective, that it is respectful and responsible, of good quality, and useful to the Sámi communities as well as individuals. The guidelines intend to establish that research on the Sámi population and local Sámi communities, or their biological material, takes into account and respects the diversity and distinctive character that distinguishes Sámi culture and the Sámi communities, and ensures full equality and reciprocity throughout the research process (Kvernmo et al., 2018).

The Finnish Sámi Parliament has a procedure for seeking the FPIC of their Sámi constituency in research projects dealing with cultural heritage, traditional knowledge, and other activities that have or may have an impact on this heritage and knowledge (Sámi Parliament in Finland, 2019). The procedure aims to guarantee that the Sámi Indigenous rights are realized, promote the preservation of Sámi cultural heritage and traditional knowledge, and safeguard the Sámi self-determination. Based both on FPIC and the Akwé: Kon Guidelines, the procedure was adopted in 2016 and the English version became available in 2019 (Sámi Parliament in Finland). In 2018, a working group3 was established to develop ethical guidelines for research involving the Sámi in Finland. The Working group was set up by the experts on the Sámi and Indigenous studies from the Universities of Oulu, Rovaniemi, and Helsinki and from other relevant Sámi institutions.

All in all, each culture's uniqueness makes it impossible to develop general guidelines for the traditional knowledge of all cultures (Nordin Jonsson, 2011).

6.7 Ethical Considerations in Research and Science Cooperation

One of the areas where the ethics of dealing with Indigenous knowledge systems comes to the fore could be the area of food. Obviously, reindeer husbandry relates closely to our foodways. Therefore, food ethics would be an example where what we discussed above about Indigenous knowledge systems has to be implemented.

Food ethics has to observe that our modern food ways are in fact not sustainable in the long run, that our food production is out of sync with nature, that food security is not guaranteed on a global scale, and that our food production adds to climate change (Kaiser & Algers, 2016). And, furthermore, we have to add our more recent insight that mainstream food consumption is very often unhealthy and wasteful. What we have observed from the ethical point of view is that we in the industrialized nations have commodified all of nature and all the animals around us and that what we first thought were benefits quickly turned into problems.

Now, one can hold that respectful life and respect for nature is or should be a basic value for all of humanity. However, in real life, this is particularly true for all Indigenous communities. Somehow in the modern western world, we seem to have lost this tradition and forgotten this basic value. We forget that we have to interact *with* nature, and not against it. We don't have to subordinate it to our will and exploit its resource to the very limit, but, again, we have to work together with the laws of nature, seek harmony and maintain integrity. The case of modern food production is an example of disrespect for our environment and valuable cultural traditions.

This respect for nature is still very dominant in Indigenous cultures as it is for example in the Sámi culture or in the Māori culture. In that sense, one of our conclusions is that Indigenous food culture can be a guide, and maybe a benchmark for more ethical and sustainable food in the future. This is our basic message: Let us sit down and learn from each other, let us use these traditions, let us use these different frames of knowledge and these different value systems in order to mix them fruitfully and to learn from each other. We need to develop better the basic virtues of good dialogue across cultural boundaries and science. We have to open up for diversity in knowledge frames and the various lenses we apply to approach an issue. In terms of transdisciplinarity and co-production, we call for immediate ethical consequences and may guide us to better ethics in our dealings with food, with the environment, and the conditions of living together in culturally diverse societies.

6.8 Conclusion: The Urgency of Arctic Change

Indigenous Peoples in the Arctic have to deal with unexpected and unparalleled challenges which demand adaptation and resilience strategies in place (Tonkopeeva et al., 2022). Led by the generationally inherited knowledge, nomadic reindeer herders and caribou hunters are living on the frontlines of climate change and globalization (Markkula et al., 2019; Käyhkö & Horstkotte, 2017). However, as observed by Magga et al. (2020) the past Indigenous peoples' assimilation and ongoing marginalization, including inaccessible decision-making structures and science, aggravates adaptive capacity to these changes. Therefore, Indigenous communities are in an urgently need to develop creative ways that constructively support the future of their cultures, well-being, and daily lives (Magga et al., 2020).

New ways of positive cooperation between researchers and communities that make use of multiple ways of knowing – including science, Indigenous knowledge, and local knowledge – can facilitate holistic understanding, societal resilience, and adaptive capacity.

We now witness an explosion of research, development, and policy agendas in the Arctic. Complex global realities call for more collaborative relationships that can facilitate innovative educational strategies and integrated observation systems. It is necessary to secure future training for leadership capabilities in research activities and within Indigenous communities. Training should address long-term sustainable thinking based on the best available practices of knowledge co-production that would involve scientific, traditional, and Indigenous knowledge.

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Chapter 7
Trends and Effects of Climate Change on Reindeer Husbandry in the Republic of Sakha (Yakutia)

Lena Popova, Svetlana Avelova, Alena Gerasimova, Julia Lutz, Svein Disch Mathiesen, Anisiia Moiakunova, Alexandra Petrova, Mikhail Pogodaev, Vyacheslav Shadrin, Anna N. Shishigina, and Anatoly V. Zhozhikov

Abstract The Republic of Sakha (Yakutia), like other Arctic regions, faces severe climatic and environmental changes and hazards such as temperature increase, permafrost thaw, intense forest fires, earlier melting, and flooding. Significant climate and environmental changes over the past decades pose risks to the preservation of the traditional way of life of Indigenous peoples, including reindeer husbandry. Understanding trends and effects of climate change in the Republic of Sakha is needed to project and manage the future of reindeer husbandry, the resilience of Indigenous communities, and plan their economic adaptation. In this article, we analyze meteorological data from four weather stations located in different reindeer herding areas of Yakutia focusing on snow cover formation, permafrost conditions, and forest fires; provide the results of in-depth interviews with local people on the impact of climate change on reindeer herding. The financing of resilience develop-

L. Popova (✉)
M.K. Ammosov North-Eastern Federal University, Yakutsk, Russia

University of Manitoba, Winnipeg, Canada

S. Avelova
M.K. Ammosov North-Eastern Federal University, Yakutsk, Russia

International Centre for Reindeer Husbandry, Guovdageaidnu, Norway

A. Gerasimova
International Centre for Reindeer Husbandry, Guovdageaidnu, Norway

J. Lutz
Norwegian Meteorological Institute, Oslo, Norway

S. D. Mathiesen
International Centre for Reindeer Husbandry, Guovdageaidnu, Norway

Sámi University of Applied Sciences, Guovdageaidnu, Norway

A. Moiakunova · A. N. Shishigina
Arctic Research Center of the Republic of Sakha (Yakutia), Yakutsk, Russia

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ment in the Republic is discussed. In conclusion, suggest necessary measures that can be taken for adaptation and overcoming emerging threats and challenges for further development of reindeer husbandry which is the central basis of the identity of the Indigenous peoples of the North.

Keywords Reindeer husbandry · Indigenous peoples · Climate change · Climate adaptation · Sakha (Yakutia) Republic

7.1 Introduction

The Republic of Sakha (Yakutia) is located in the north-eastern part of the Eurasian continent and is the largest region of the Russian Federation. The Republic stretches from the Henrietta Islands in the far north to the Stanovoi mountain range in the south, covering 3.1 million km^2. It has some of the coldest climates and temperature extremes on the planet (where humans live permanently), some of the largest undisturbed habitats on Earth with rich and diverse biodiversity (protected areas cover approximately 37% of the territory), and traditional Indigenous livelihoods such as reindeer herding which have been practiced for centuries. The Sakha Republic is also a world hotspot for industrial development – the economy is based on the extractive industry. The region is extremely rich in natural resources - Yakutia accounts for 26% of the world's diamonds, 5% of tin, 4.5% of antimony, 3.4% of uranium, 2% of iron ore, and 2.5% of the world's forests. Some of the largest mega-projects in oil, gas, and mining are being developed in the region, particularly within South Yakutia. The territory of Yakutia is situated within four geographical zones: taiga forests (almost 80% of the area), tundra, forest tundra, and Arctic desert.

The Republic of Sakha consists of 35 political units, including 34 districts (ulus) and 1 city, Yakutsk. 990,538 people live within Yakutia (Rosstat, 2020) with an urban-rural population ratio of 65.45%: 34.55%.

Climate and economic factors have influenced settlement patterns, with the south of Yakutia experiencing a higher population density than the north. The density is one of the lowest in the Russian Federation, at 0.32 person per km^2.

A. Petrova · A. V. Zhozhikov
M.K. Ammosov North-Eastern Federal University, Yakutsk, Russia

M. Pogodaev
Arctic State Agrotechnological University, Yakutsk, Russia

V. Shadrin
Institute for Humanities Research and Indigenous Studies of the North – Siberian Branch of the Russian Academy of Science, Yakutsk, Russia

The region is ethnically very diverse, ethnic Sakha (Yakuts) make up the majority of the population (49.9%), followed by Russian (37.8%), Ukrainian (2.2%), Evenki (2.2%), Even (1.6%), Tatar (0.9%), Dolgan (0.2%), Yukagir (0.13%) and Chukchi (0.07%). The total population loss of the Republic from 1990 to 2020 was 12.6%. After a period of demographic decrease during the economic reforms of the 1990s and early 2000s, the population has been increasing, including a steady natural growth of the Sakha, Evenki, and Even populations, and a decrease in Russian, Ukrainian and Tatar populations (due to out-migration).

Indigenous small-numbered peoples of the North by special decree of Russia (List of Indigenous small-numbered peoples of the North, Siberia, and the Far East of the Russian Federation, 2016) are represented by Evenki (2.2%), Even (1.6%), Dolgan (0.2%), Yukaghir (0.13%) and Chukchi (0.07%). According to the 2010 census data, the number of the Indigenous peoples of the North has increased, but the increase was much lower than in 1989–2002. A distinctive feature of the demographic model of the Indigenous peoples of the North in the previous decades was a relatively high birth rate and a high death rate. At present, northern peoples are experiencing a decline in the birth rate due to demographic transition, assimilation processes, and other factors.

Reindeer husbandry remains the main type of traditional economic activity of the small-numbered Indigenous peoples of the North residing in the Arctic regions of Yakutia. At the same time, there is an annual decrease in the number of reindeer in the Sakha Republic (Yakutia), the small number of reindeer herds makes most of the traditional husbandry unprofitable. The main economic problems include extreme climatic conditions, lack of infrastructure, including transportation, that plays a significant role in these areas, as well as the small number of settlements. It is necessary to understand the scale of the task of managing such a huge region with a small population. Economic development is very much limited by competitive disadvantages, such as northern price increases for all goods and resources. Transportation costs are particularly high in the region.

7.2 Changes in Climatic Parameters in Yakutia's Reindeer Herding Areas

The climate of Russia in general, and the climate of Yakutia, in particular, are undergoing significant changes. The warming continues in the territory of the Russian Federation, as well as in the whole world, and its rate of temperature increase is much higher than the global average. The average increase rate of the mean annual air temperature in Russia from 1976 to 2019 was 0.47 °C per decade, according to the Federal State Budgetary Institution (IGCE). This is more than 2.5 times higher than the increase rate of the global temperature over the same period, which is 0.18 °C per decade, and more than 1.5 times higher than the average rate of the surface air warming over the Earth's land areas, which is 0.28 °C per decade (estimates from the Hadley Centre and the University of East Anglia). The global mean temperature of each subsequent decade since 1980 exceeded the temperature of the previous one. The temperature of the northern polar region has increased most rapidly, especially in recent decades: according to the Federal State Budgetary Institution AARI over the past 30 years (1990–2019), the average annual temperature increase was 0.81 °C per decade, i.e., 2.43 °C in 30 years (RosHydroMet, 2020).

In the Arctic zone of the Russian Federation, a warming trend has remained since the 1990s: milder winters; the duration of the growing season has increased; new absolute temperature records (2–4 °C); there is an increase in precipitation, including snow; in several places, the thickness of the snow cover is growing; surface wind speed is increasing everywhere; in the water area of the Arctic Ocean, the areas of perennial ice and their thickness have decreased (by almost 40%); over the coast and archipelagos, anticyclonic processes began to prevail in the atmosphere.

Lobanov and Kirillina (2019) identified spring and autumn maxima of temperature non-stationarity in the territory of Yakutia: spring-summer in the south and autumn-winter in the northeast. The area of greatest non-stationarity begins to form in April in the southeast of Yakutia, then it increases sharply and in June it covers more than half of the territory of Yakutia. In October, non-stationarity appears in the northeast, and in November it covers the entire northeast part of the territory (Fig. 7.1).

The time series of the yearly mean maximum and minimum summer temperatures for all four stations are presented in Fig. 7.2. One can see that the minimum temperature is especially increasing, which can be assumed to be the night temperature.

Four weather stations, located in four reindeer herding areas of Yakutia, were identified to analyze snow cover, precipitation, and air temperature: Nizhnekolymsky

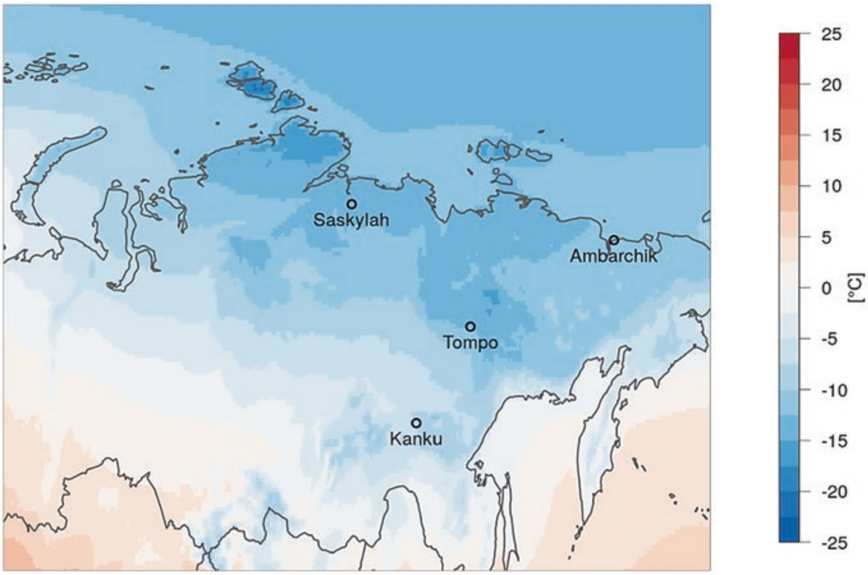


Fig. 7.1 Map of the four analyzed weather stations in Yakutia. The colors indicate the mean 2m temperature for the years 1980–2019, based on ERA5 data

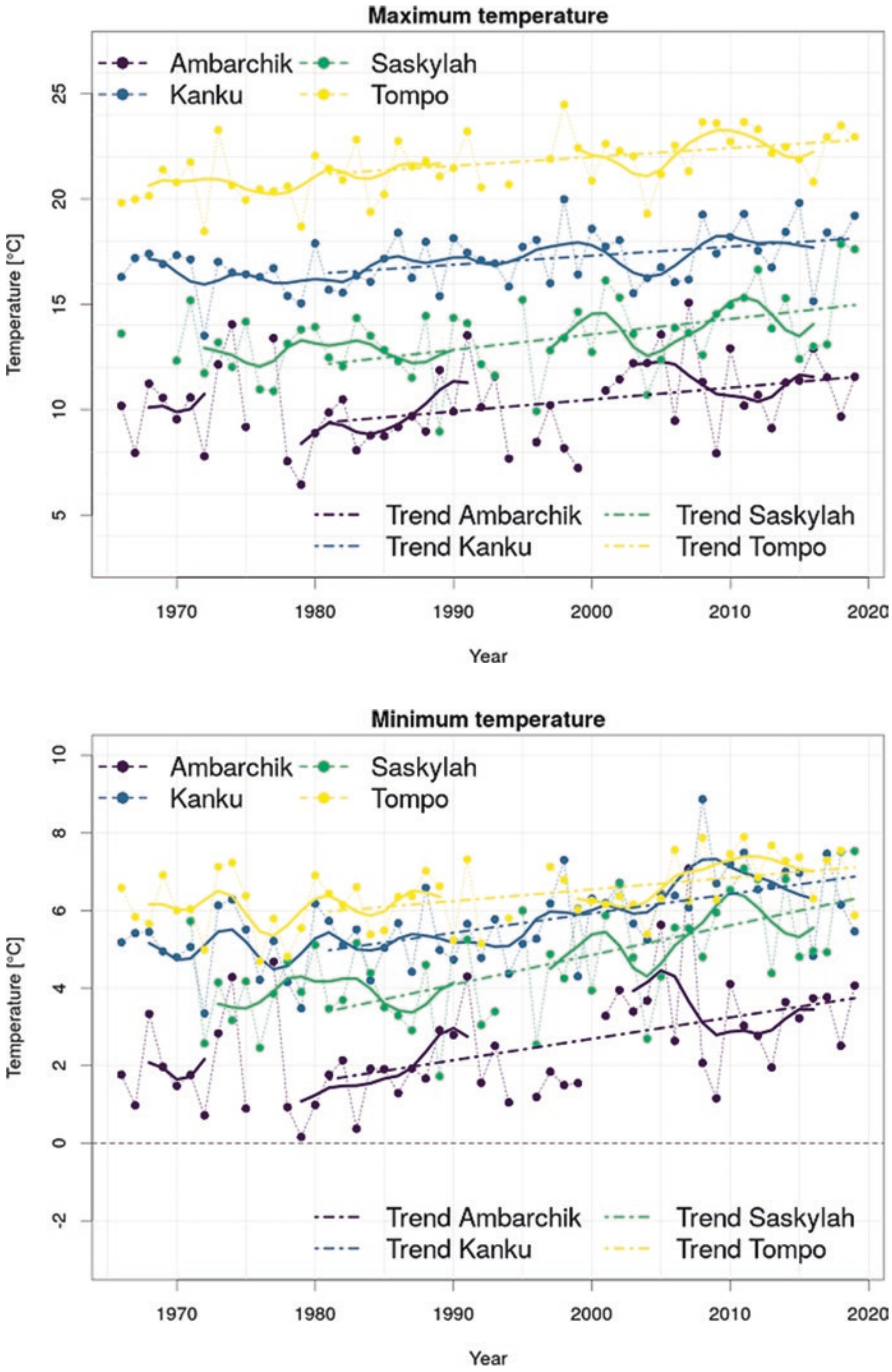


Fig. 7.2 Yearly means of maximum and minimum summer temperatures (June–August)

(Ambarchik station), Anabarsky (Saskylakh station), Tomponsky (Tompo station) and Aldansky (Kanku station). The location of the stations is shown in Fig. 7.1, where colours show mean air temperature averaged over 1980–2019 taken from the ERA5-Land reanalysis dataset (Sabater, 2019).

The Ambarchik station is located on the southern shore of the Ambarchik Bay in the East Siberian Sea, east of the mouth of the Kolyma River, 100 km northeast of the Chersky settlement. The station is 25 m above sea level. The terrain is flat (Primorsky Lowland), swampy, and has a surface full of small, rounded lakes. The terrain gets hilly 3–4 km south of the station. The vegetation cover is scarce, composed of mosses, lichens, and low herbaceous vegetation. Meteorological observations at the station began in 1933.

The Saskylakh station is located in the north of the Central Siberian Plateau, on the right bank of the Anabar River, 4 km south of the Saskylakh settlement. The width of the Anabar River valley near the station is 8 km. The station is 17 m above sea level. The relief is flat and hilly; the underlying surface is marshy and rich in lakes. The station is located at the northern border of the forest-tundra; the surrounding terrain is covered with rare low larch forests, shrubs, and sedges. Meteorological observations at the station began in 1933.

The Tompo station is located in the foothills of the Verkhoyansk Range, in the valley of the central Tompo River, where the tributary Khunhandy runs into it. The station is 380 m above sea level. The valley of the Tompo River near the station is 4–6 km wide. The terrain of the area is comprised of large hills; the height of certain hills reaches 300–400 m above the valley level. Vegetation consists of coniferous larch-dominated forests. Deciduous forests and shrubs grow along river valleys and the valleys between the mountains, while the floodplain is filled with flood meadows. Meteorological observations at the station began in 1933.

The Kanku station is located in the southern part of the Aldan Plateau, at the upper Kurung-Hoonku River (left tributary of the Timpton River), 1204 m above sea level. The relief is dissected and hilly, with hills and plantations covered with larch forest mixed with shrubs and birch. Meteorological observations at the station began in 1949 (Izyumenko, 1972).

The authors applied the following criteria to select stations for climate change analysis:

The stations are located in the reindeer husbandry areas in the tundra and taiga zones, at a sufficient distance from major settlements.

The stations have a long history of observations and are included in available databases.

Daily data from the Saskylakh, Ambarchik, Tompo, and Kanku stations for the entire period of observations (mean, maximum, and minimum temperature, precipitation) from the All-Russian Research Institute for Hydrometeorological Information – World Data Centre Database were used to analyze changes in air temperature and precipitation (RosHydroMet, 2020).

The general temperature trend (see Table 7.1) for all the stations under examination is positive. All trends were tested for statistical significance at the 5% level

Table 7.1 Average annual and seasonal air temperature increase rate from 1980 to 2019 [°C/10 years]

	Annually			Dec/Jan/Feb			Mar/Apr/May			Jun/Jul/Aug			Sep/Oct/Nov		
	Tmean	Tmin	Tmax	Tmean	Tmin	Tmax	Tmean	Tmin	Tmax	Tmean	Tmin	Tmax	Tmean	Tmin	Tmax
Ambarchik	0.9	0.9	0.8	0.5	**0.7**	0.3	**1.1**	**1.1**	**0.9**	**0.6**	**0.6**	**0.6**	**1.2**	**1.3**	**1.1**
Kanku	0.4	0.5	0.4	0	0.1	0.1	**0.6**	**0.8**	**0.6**	**0.4**	**0.4**	**0.4**	0.4	**0.6**	0.3
Saskylah	0.7	0.8	0.6	0.2	0.4	0.1	**1.1**	**1.2**	**1**	**0.7**	**0.7**	**0.7**	**0.9**	**1**	**0.8**
Tompo	0.4	0.4	0.4	0.1	0.2	0.1	**0.7**	**0.7**	**0.8**	**0.3**	**0.3**	**0.4**	**0.6**	**0.7**	**0.5**

The numbers in bold indicate a statistically significant trend using the Student's t-test. The largest increase can be found for all stations in spring (March–May, MAM) and autumn (September–November, SON). The winter months (December–February, DJF) show the lowest temperature increase (not statistically significant).

Territorial differences can be explained by the nature of atmospheric circulation, in particular by the more frequent landfalls of cyclones from the Pacific Ocean to the northeastern regions of Yakutia and the formation of autumn cyclones over the Arctic Ocean. The differences are due to geographical location: proximity or distance from the sea, mountain ranges and their orientation to the cardinal directions, altitude, and seasonality of atmospheric circulation. Territorial differences in temperature changes are particularly well observed during the transition seasons when there is a change in the types of atmospheric circulation.

During the period of transition from the warm to the cold season (September–November), the temperature increases at the Ambarchik and Saskylakh stations are apparent, and most noticeable after 2005 (see Fig. 7.3). These flat territories are open from the north to the Arctic air masses formed over the Arctic Ocean. Of course, the state of the sea ice in the Arctic is highly significant for the climate. The September ice coverage in the Northern Sea Route region decreased by 4–5 times in 2005 compared to the 1980s and ranges between 200–300 thousand km^2. In 2019, it

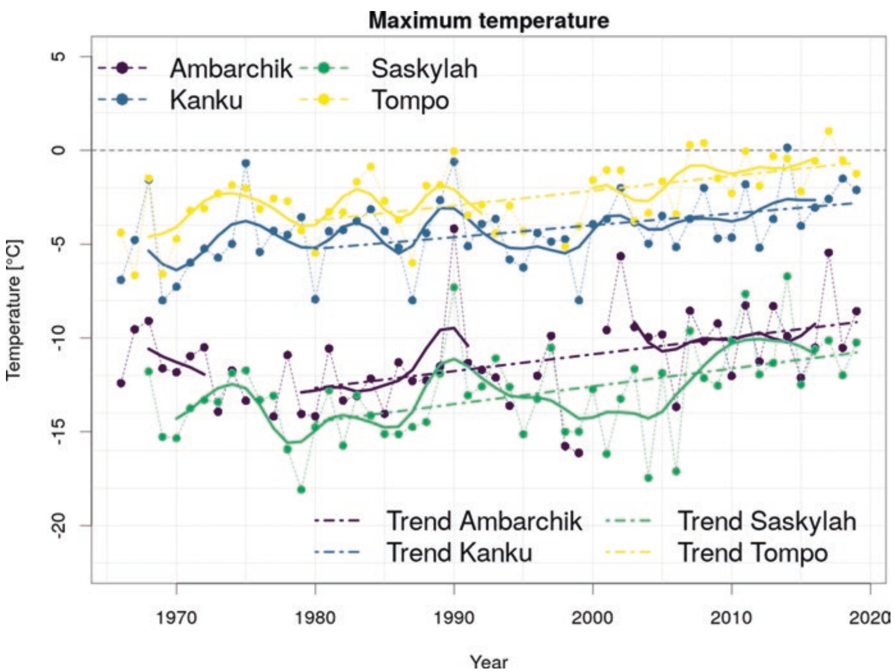
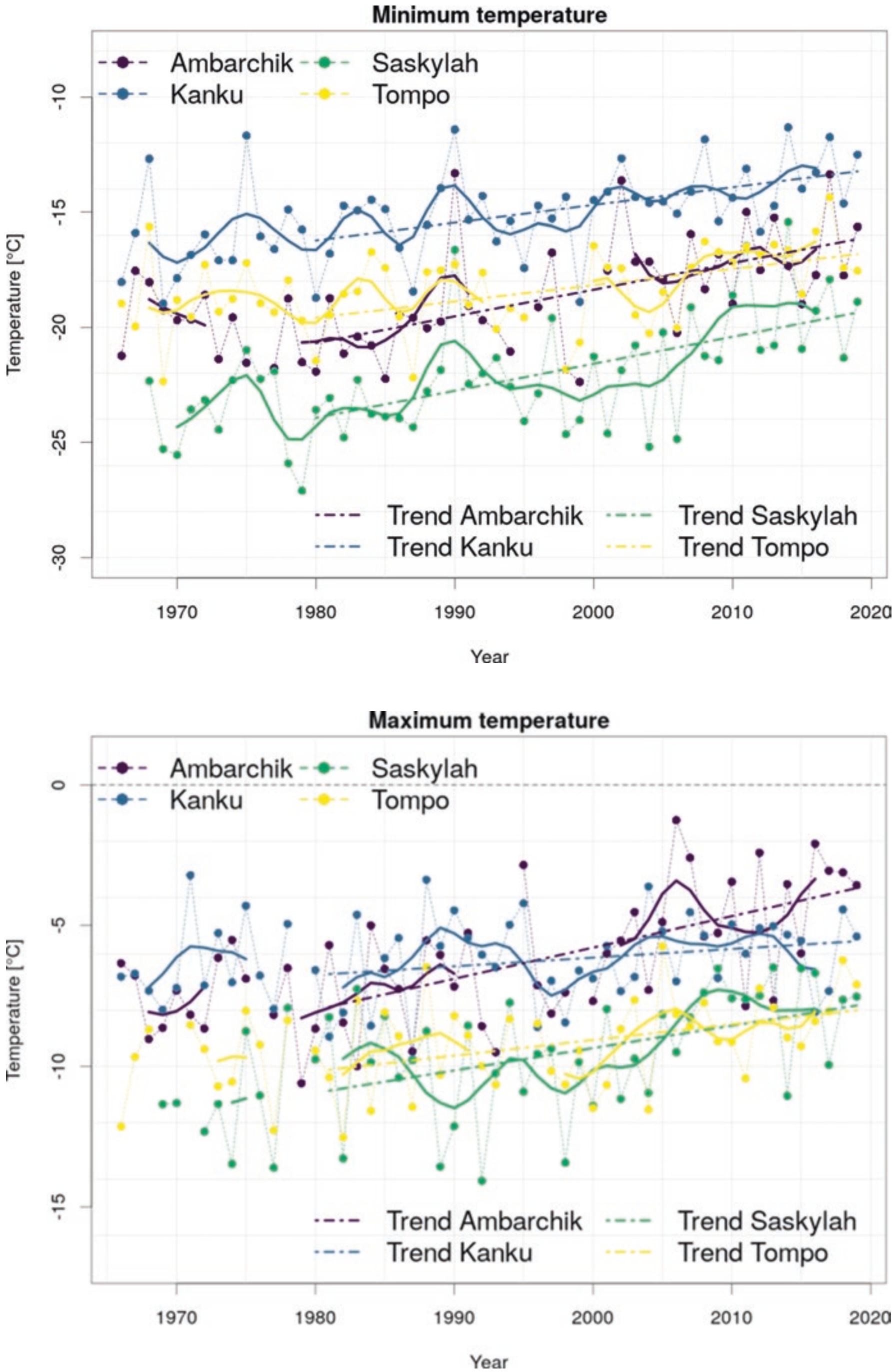


Fig. 7.3 Yearly means of maximum and minimum temperature for spring (March–May) and for fall (September–November)



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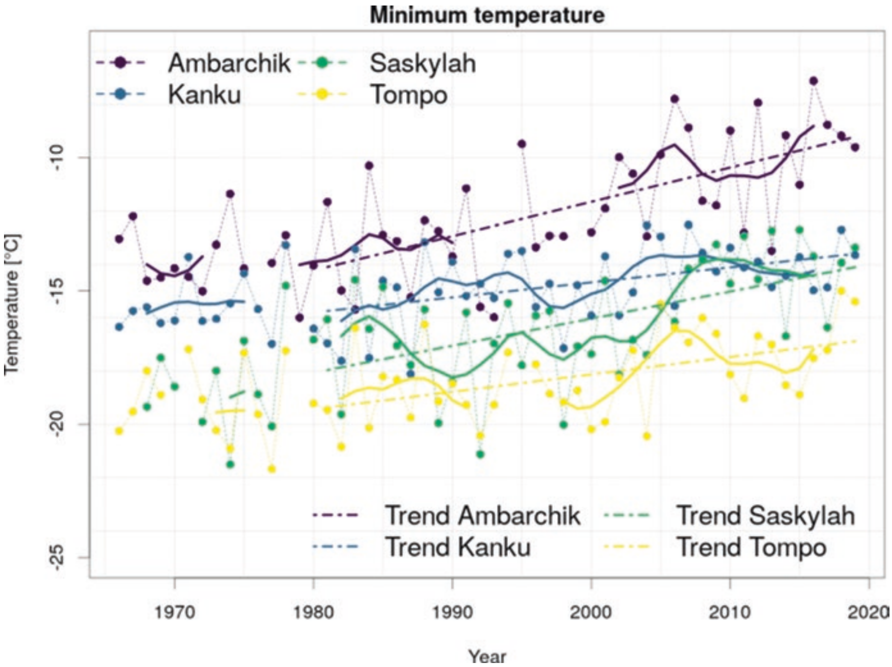

Fig. 7.3 (continued)

was about 100 thousand km^2 – the second-lowest amount after the record of 2012, when there was almost no sea ice (RosHydroMet, 2020).

An increase in the air and ocean temperatures, a decrease in the ice coverage, and therefore an increase in the period and area of open water causes a feedback effect, having a warming impact on the coastal areas. Global warming of the Arctic climate has led to the formation of new regions of polar cyclone development. An increase in temperature and an increase in the open water period in the Laptev Sea and the East Siberian Sea contribute to the formation of autumn mesoscale cyclones, similar to the well-known winter mesoscale cyclones over the Norwegian Sea, the Greenland Sea, the Barents Sea, and the Bering Sea. A study carried out by Zabolotskikh et al. (2015) shows that mesocyclones develop in this area of the Arctic with significantly lower heat flows from the sea surface. They predict that the melting of Arctic Sea ice, the likely emergence of the seasonality of the Arctic ice cover and the associated increase in the meridionality of atmospheric circulation may lead to more frequent landfalls of deep Pacific cyclones to the Arctic coast, which will cause an increase in cyclonic and mesocyclonic activity over the seas of the eastern part of the Arctic.

Compared to temperature, changes in precipitation in Yakutia are more even in space and time, but in general, they shift to opposite trends during different seasons of the year. During the cold season, especially during the period from December to March, there is a trend of decreasing precipitation, most apparent in the northeast of Yakutia. In the warm period of the year (from May to September), the opposite trend is observed – the precipitation amount increases (Lobanov & Kirillina, 2019).

Just as in the case of air temperature, the amount of precipitation for the four stations of interest shows the greatest changes in the transition periods – from March to May and from September to November (Table 7.2). The time series for spring and fall and the corresponding trends are shown in Fig. 7.4. In the spring period, there is a significant decreasing trend in precipitation in the northeast (Ambarchik), while there is a significant increase in precipitation at the Kanku station (Taiga area) in the south of Yakutia. In autumn, a significant increase can be found at the Tompo stations (subarctic climate zone) and Kanku in the south (see Table 7.2). Southern Yakutia increasingly often turns out to be in the zone of meridional transfer, when warm air masses arrive from the heat source forming over the north of China. Moving north, these air masses bring precipitation, which falls mainly in southern Yakutia.

The changes in the precipitation regime affect the formation of snow cover. Snow cover parameters depend on many factors, such as the amount and nature of precipitation, the thermal and wind regimes under which metamorphism and ablation processes occur, and the radiation balance. The simplest characteristic of a snow cover is its depth. Snow cover begins to form at the beginning of the cold period (October–November in Yakutia) and reaches its maximum depth from the end of February to the first half of April. Over the past decades, the average number of days with snow cover in Russia has been decreasing by 1.01 days per decade (RosHydroMet, 2017). In Yakutia, the change in the snow depth is geographically uneven.

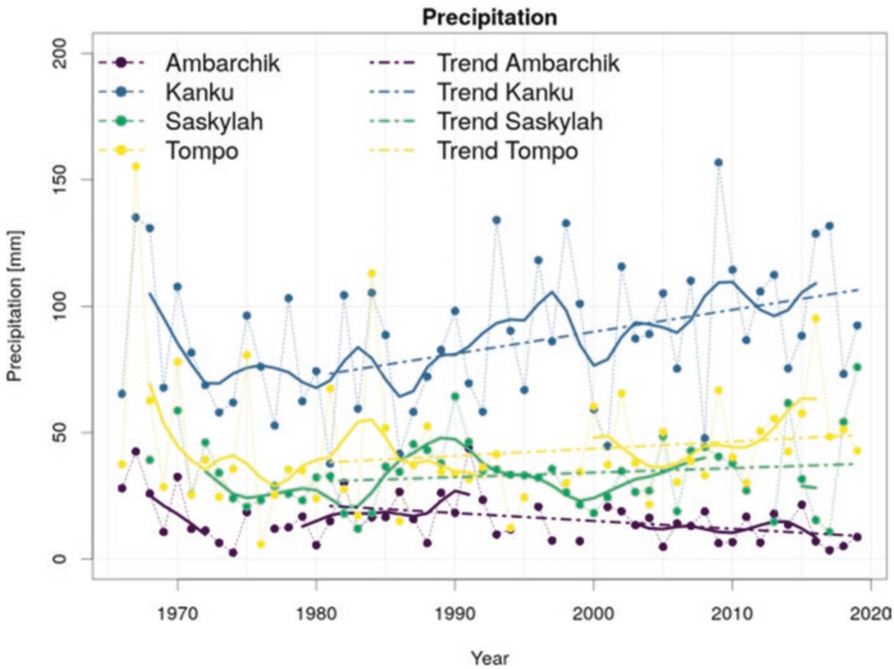

Fig. 7.4 Annual precipitation (in mm) averaged for March–May and September–November

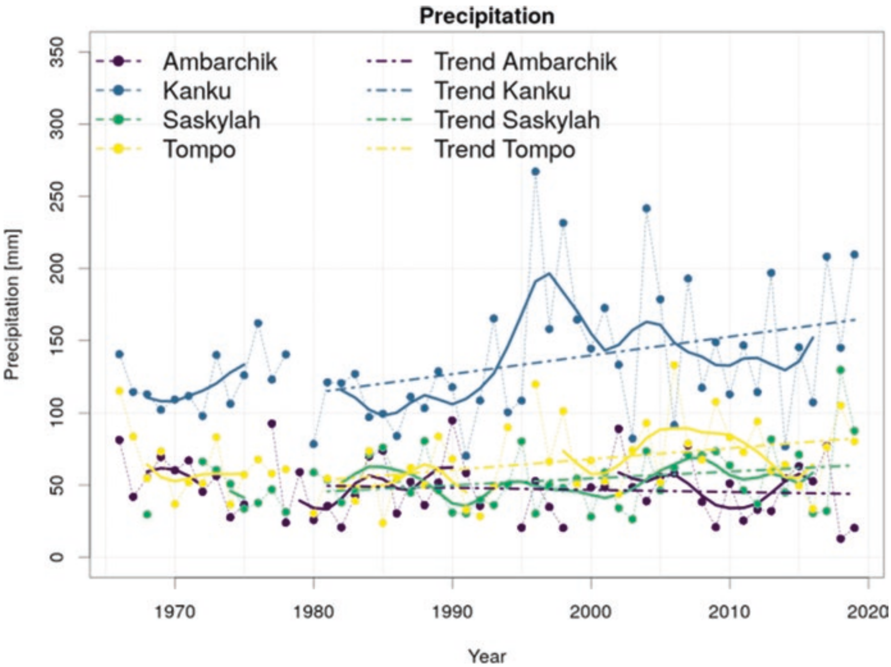

Fig. 7.4 (continued)

Table 7.2 Average annual and seasonal precipitation change rate from 1980 to 2019 [mm/10 years]

Station	Annually	Dec/Jan/Feb	Mar/Apr/May	Jun/Jul/Aug	Sep/Oct/Nov
Ambarchik	−12.3	−0.5	**−2.5**	−6.8	−0.6
Kanku	10.7	**−2.8**	**8.6**	−10.1	**14.2**
Saskylah	−1.8	−0.6	1.7	−7.3	4.2
Tompo	**22.1**	−0.6	3.4	11.2	**8.4**

The numbers in bold indicate a statistically significant trend

Figure 7.5 shows the time series of the monthly maximum snow depth for the four stations at the beginning (November) and the end (March) of the snow season. The most noticeable changes occurred in the northeast of Yakutia (Ambarchik and Tompo stations) in November when the snow cover begins to form. The increase in the amount of solid precipitation in this area is due to the more frequent landfalls of cyclones from the Sea of Okhotsk to the Kolyma basin.

The snow cover is formed through solid precipitation accumulation. At the same time, its structure and stratigraphy are subject to change over time and geography, which is due to the diversity of meteorological conditions during the period of solid precipitation and between snowfalls, thermal regime, and wind conditions. These cause metamorphism and ablation, fundamentally changing the characteristics of the snow covers in comparison with fresh snowfall. The main large-scale processes

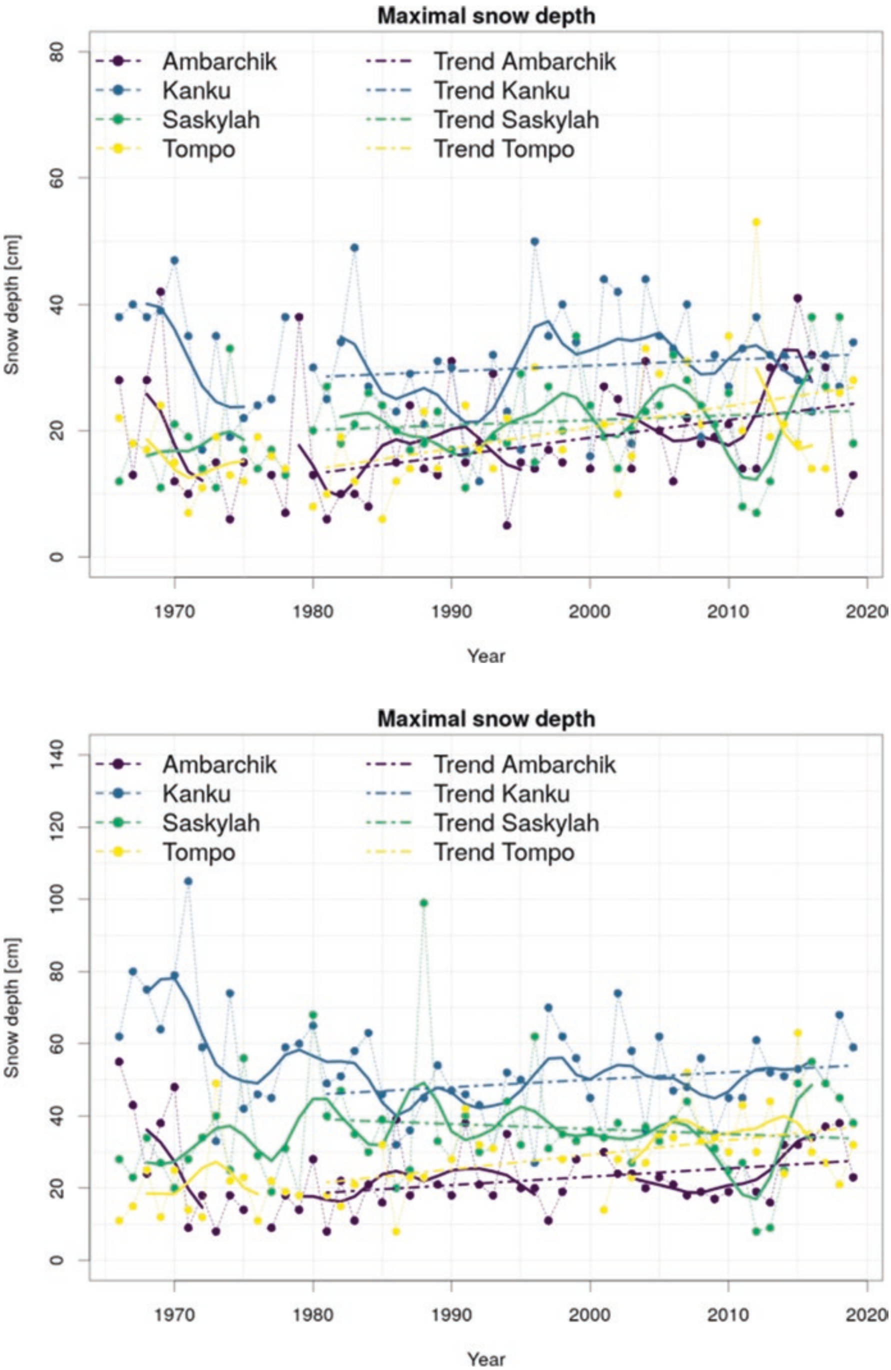

Fig. 7.5 Time series of monthly maximums of the snow depth for November and March

affecting the formation of snow cover are the incoming shortwave and outgoing longwave radiation (radiation balance) and atmospheric circulation.

The radiation balance in the northern and central regions of Yakutia has negative values between October and March, reaching its minimum in December. In southern Yakutia, the radiation balance is negative between November and February. The deficit of the incoming solar energy defines the thermal regime and the duration of the cold period. The cold period in the tundra area with a mean daily temperature below 0 °C lasts for 250–260 days between the second half of September and the end of May. The mountainous area in the northeast experiences cold periods between the second half of September and the second half of May (220–240 days). As for southern Yakutia, stations located on the flat relief indicate cold periods between early September and late April (200–210 days) and from mid-September to mid-May (210–220 days) on the uplands. Due to the radiation regime in Yakutia, the snow cover duration coincides with the cold period.

Circulation processes also have a distinct seasonal character. The major baric formation in the cold period of the year is the northeast ridge of the Siberian anticyclone, which center is located above northern Mongolia. The Siberian anticyclone system is formed by anticyclones invading eastern Siberia along the polar and ultra-polar axes along the western periphery of the eastern troughs, as well as anticyclones moving from the west and southwest. The Siberian anticyclone creates favorable conditions for cold spells over the Earth's surface, as there is a low amount of cloud cover most of the time. In the mountainous areas located in the well-developed part of the Siberian anticyclone, surface cooling is intensified by the accumulation and stagnation of cold air masses flowing from uplands into concave relief forms. Extremely low temperatures are formed in this specific area, called the Asian Cold Pole (Kobysheva et al., 2001).

Air masses from the Atlantic Ocean reach Yakutia with negligible moisture content. In winter, Arctic front cyclones develop over the marginal seas of the Arctic Ocean and Taimyr. However, they meet an obstacle when moving eastward of the Verkhoyansk Range.

Air masses from the Pacific rarely cross the mountain range barrier in northeast Yakutia. They significantly impact only the Kolyma River basin. The Aleutian Low exists over the Pacific Ocean in winter. It is associated with the formation of deep cyclones on the Pacific Polar Front, which often regenerate on the Okhotsk Arctic Front. The trajectories of these cyclones usually pass through the south of the Sea of Okhotsk to Kamchatka and further on to the Bering Sea, but some cyclones pass directly through the Sea of Okhotsk to the Kolyma River basin. The outflow of relatively warm and wet masses along the cyclone periphery is followed by strong winds and significant snowfalls. Occasionally, cyclones from the Sea of Okhotsk bring warm air to the south, southeast, and center of Yakutia, causing short-term warming. The duration of this eastern process is 3–4 days; in some cases, it can reach 8–10 days.

Therefore, dry, and cold Arctic and continental air masses at moderate latitudes predominate in the area of interest. As a result, the amount of precipitation in most of the territory is low, with an average snow cover height of 30–35 cm in the north-west, 40–50 cm in the tundra of the Kolyma Lowland, and 60–80 cm in southern Yakutia (RosHydroMet, 2020). In the mountainous areas of the northeast, the height of the snow cover is distributed quite unevenly.

The first snowfall of the season is close to the autumn zero-crossing date. Often the first snow melts because of thaws, and a stable snow cover is established on average 1–2 weeks after the first snowfall: in the tundra zone and south of it in the second and third weeks of September, around approximately 64°N in the first 10 days of October and south of 64°N in the second half of October; in mountainous areas, the stable snow cover depends on the altitude.

The time frame of the stable snow cover also depends on the weather type corresponding to the atmospheric circulation in the pre-winter period. The difference in the dates of stable snow cover formation can be as much as 30–45 days. Once a stable snow cover is formed, its height gradually increases. Active snow cover growth occurs between October and November, the months with the highest cyclonic weather frequency. Snow cover reaches its maximum height in the north in the first half of April, and for other territories in the last third of March and the first third of April.

Starting from the first and second weeks of April, and in the north from the third weeks of April, the snow height starts to decrease, followed by daytime thaws, occasionally there is rain and snow mixed precipitation, and the snow starts to melt and thicken.

The degradation of the stable snow cover takes less time than its formation. In southern Yakutia, the snow cover melts by the end of the first week of May and in the tundra zone by the first weeks of June. The number of days with snow cover in Yakutia ranges from 200–210 in southern Yakutia to 250 days in the tundra zone.

Snow cover density depends on meteorological conditions that cause precipitation, deposition and re-deposition, condensation, turbulent heat, and moisture exchange. Most of the Yakutia territory is characterized by low snow cover density due to very low air temperatures, low wind speeds, and a low number of snowfalls. Relatively high snow density in the southwestern part of Yakutia and the Aldan Plateau is associated with slightly higher wind speeds, higher air temperatures, and relatively high snow cover capacity. High snow cover densities on the Laptev and the East Siberian Sea coasts and in the tundra zone are mainly due to strong winds and open terrain. Snow cover density, as well as snow height, increases during winter and peaks during the snowmelt period.

There are considerable variations in the structure of snow cover in open areas (fields, tundra) and the forest. Snow accumulation in the forest depends on the thickness of the vegetation, but in general maximum height and density are often observed at the forest edge. Inside the forest, snow is more evenly distributed than in open areas; the snow is loose, and it is less exposed to wind and daily temperature changes, which slows down recrystallization processes in the snow cover and reduces the chances of ice crust formation on the snowpack.

In the Arctic, in open tundra areas, where temperatures remain low for a long time in winter accompanied by constant winds, sublimation processes occur intensively in the snow cover. As a result, the snow cover surface becomes dense and finely structured while its layer is filled with irregular grains with hard, flat faces.

Such granular, recrystallized snow beneath the top layer of dense, fine-grained snow can adversely affect reindeer grazing.

In the mountainous areas of the northeast, snowfall is most often accompanied by strong winds; freshly falling snow is being redistributed and rolled down a slope by wind and its weight, forming deep snowdrifts. During the winter, the snow cover is constantly exposed to the wind, which results in a very dense layer of wind-packed snow (snow slab), under which there is a layer of recrystallized, coarse snow.

Earlier Melting & Flooding. Due to climate change, snow and ice have been observed to start melting 2 weeks earlier in Sakha (Yakutia) in comparison to 30 years ago. This creates abnormal seasonal floods that threaten biodiversity and land use and are also a barrier to nomadic peoples involved in reindeer husbandry. In Sakha (Yakutia) there are extreme river level fluctuations caused by frequent ice dams and jams at the rivers that drain northwards to the Laptev Sea and the East Siberian Sea. In the southern part of the region, the rivers break out rapidly, resulting in numerous ice jams in the streambeds of the northern rivers. The situation is often accelerated by the complicated geomorphic structure of the streambeds. Flooding is common on permafrost soils (which cover much of the territory), as these frozen soils have little or no water storage potential. Rapid snow and ice melting in spring cause significant flooding, but high levels of rainfall will also cause flooding (this also causes a 'second wave' of flooding and is a characteristic of Sakha (Yakutia).

Thus, a summary of the observed changes in climatic conditions is as follows:

1. The melting of Arctic Sea ice causes a feedback effect, which has a warming impact on the coastal areas of the Laptev Sea and the East Siberian Sea, resulting in an increase in autumn temperatures and an associated shift of the beginning of the cold period. Due to the increasing intensity of cyclones, the wind speed grows, which causes compaction of the snow cover (formation of a 'snow slab').
2. The contribution of meridional transfer increases when cyclones come from the Sea of Okhotsk to the northeast of Yakutia, which causes an increase in the amount of solid precipitation, as well as in the number of winter thaws and the number of cases of ice crust formation.
3. Meridional outflows of warm air masses from the north of China and Primorye are the reason for the increase in precipitation and the number of thaws in southern Yakutia.

7.3 Temperature Projections for the Republic of Sakha (Yakutia) for the End of the Twenty-First Century

Several global climate projections describe changes in the global climate under continued anthropogenic forcing. These projections are produced using Coupled Global Climate Models (IPCC, 2013). In order to get projections on a regional scale, it is necessary to downscale these large-scale simulations. Benestad et al. (2008) have developed Empirical Statistical Downscaling (ESD) techniques that can be applied to stations with observational series of good quality, to downscale global temperature projections at these locations. It is a tool with low computational costs that makes it possible to provide a summary and a regionalization of global climate projections for regions of interest in a quick manner (Benestad, 2021). Here, ESD was used to downscale the simulated temperature of 81 global climate model runs (CMIP5 multi-model ensemble, Taylor et al., 2012) following the RCP8.5 scenario (Moss et al., 2010) at the four stations analyzed in the previous section. We chose the high-emission scenario in this analysis to get the clearest climate change signal and be aware of the possibly large impacts future climate change can have in the region.

The results of the downscaling of the whole ensemble, together with the observations, are shown in Fig. 7.6. The largest spread in the model simulations can be found for the two coastal stations Ambarchik and Saskylah. For the two inland stations (Tompo and Kanku), the spread is smaller, i.e., the results are more robust.

To determine the temperature change for the end of the twenty-first century, we have compared the mean of 2071–2100 of the simulations with the mean of 1971–2000 of the simulations for all the seasons (see Table 7.3). For winter, the largest temperature increase of 8.5 °C in 100 years (reaching −24.4 °C at the end of the twenty-first century) can be found at Saskylah station. Ambarchik station exhibits the smallest increase with 5.3 °C (reaching −23.8 °C). For spring, the largest increase of 7.5 °C (to −8.3 °C) can be found for the Ambarchik station. Tompo exhibits the smallest increase with a change of 4.1 °C (to −6.8 °C). The summer temperatures show the largest increase at Kanku with 6 °C (to 17.1 °C), while Ambarchik station features the smallest increase with 2.6 °C (to 8.2 °C). For autumn, the largest increase of 5.7 °C (to −3.7 °C) can be found for the Ambarchik station. Kanku station features the smallest increase with 2.8 °C (to −7.6 °C). Thus, the temperature increase for all stations is largest in winter and spring and the largest changes occur at the coastal stations Ambarchik and Saskylah. Note that following the RCP8.5 scenario provides results that can be seen as a relatively pessimistic but possible estimation of future developments in terms of greenhouse gas concentrations. A detailed analysis of the projected changes according to lower emission scenarios is out of the scope of this study but can be expected to show pronounced temperature increases as well, although with a smaller amplitude than under RCP8.5.

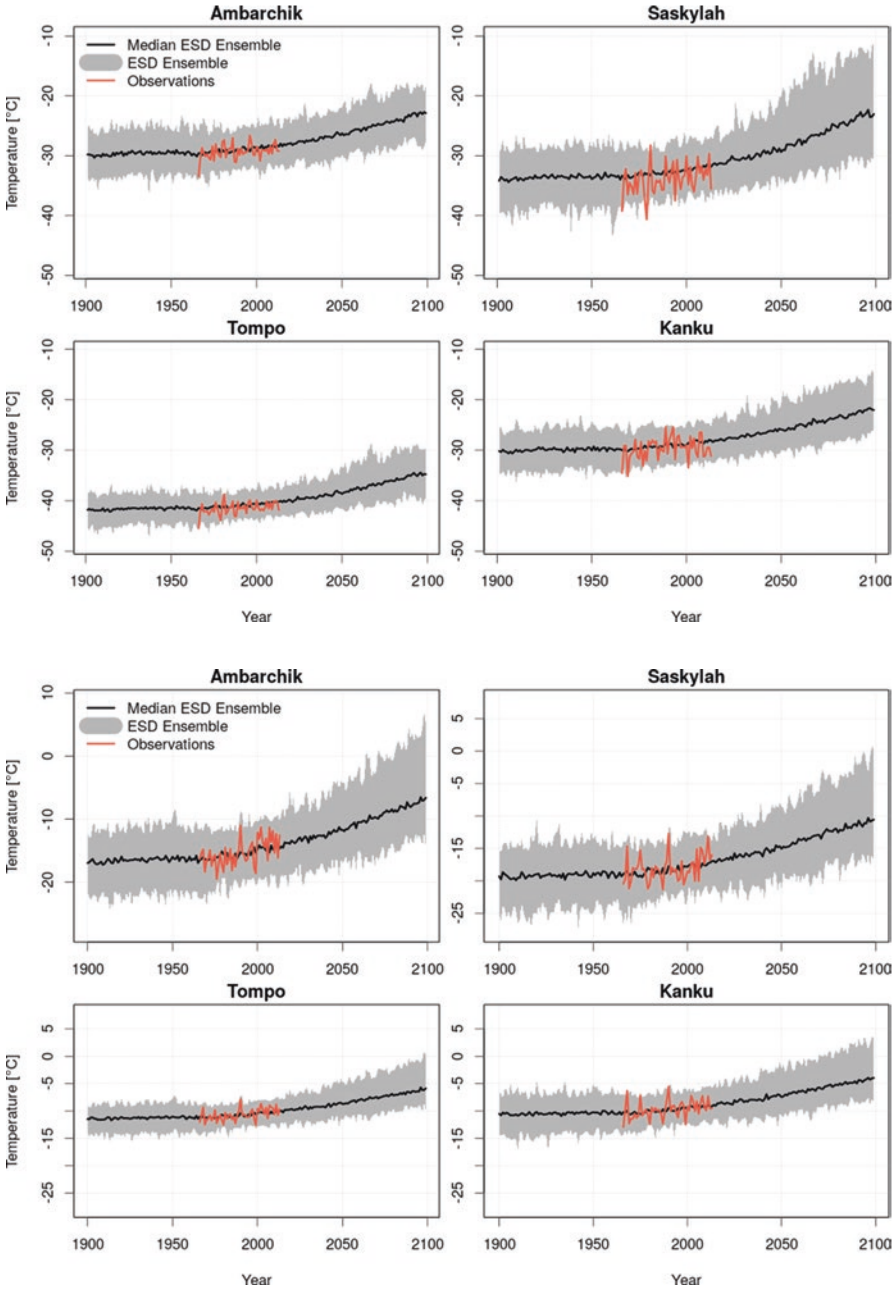

Fig. 7.6 Seasonal mean temperature for winter (DJF), spring (MAM), summer (JJA) and fall (SON) for the years 1900–2100 from the CMIP5 ensemble, downscaled using ESD at Ambarchik, Saskylah, Tompo, and Kanku for March-May, December-February, June-August, September-November. The observations are shown in red, while the black line denotes the ensemble median and the grey shaded area shows the ensemble spread

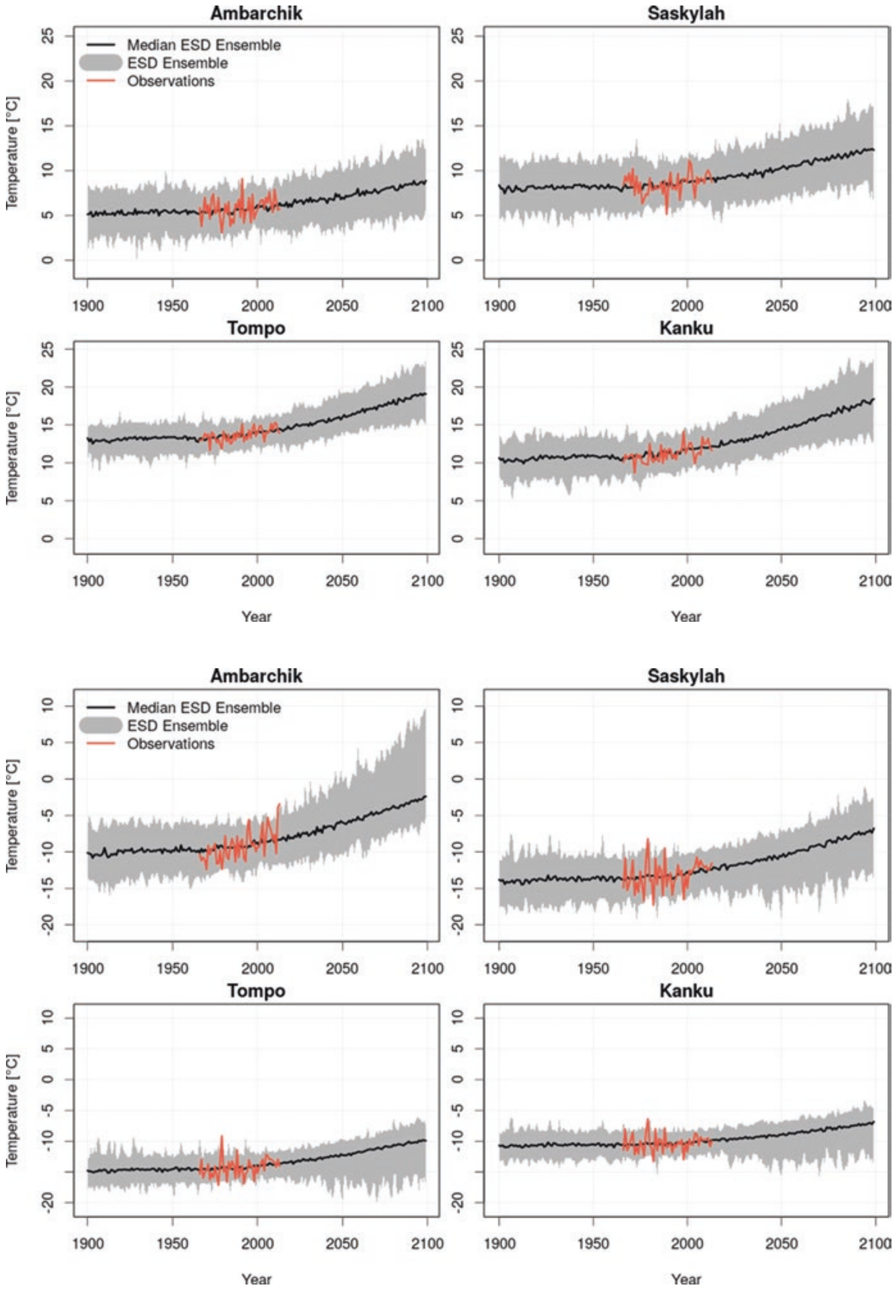

Fig. 7.6 (continued)

Table 7.3 Mean air temperature [°C] for the end of the twentieth century (1971–2000) and the end of the twenty-first century (2071–2100) for the different seasons

Station	1971–2000				2071–2100 (ΔT)			
	Dec/Jan/Feb	Mar/Apr/May	Jun/Jul/Aug	Sep/Oct/Nov	Dec/Jan/Feb	Mar/Apr/May	Jun/Jul/Aug	Sep/Oct/Nov
Ambarchik	−29.1	−15.8	5.6	−9.3	−23.8 (+ 5.3)	**−8.3 (+ 7.5)**	8.2 (+ 2.6)	**−3.7 (+ 5.7)**
Kanku	−29.2	−10.0	11.1	−10.4	−23.1 (+ 6.2)	−5.0 (+ 5.1)	**17.1 (+ 6.0)**	−7.6 (+ 2.8)
Saskylah	−32.9	−18.5	8.4	−13.4	**−24.4 (+ 8.5)**	−11.8 (+ 6.7)	11.7 (+ 3.3)	−8.1 (+ 5.3)
Tompo	−41.1	−10.9	13.5	−14.3	−35.6 (+ 5.5)	−6.8 (+ 4.1)	18.2 (+ 4.7)	−10.5 (+ 3.8)

The future projections follow the RCP8.5 emission scenario. The change between the twentieth century and the twenty-first century can be found in parentheses. The station with the largest change for each season is marked in bold

7.4 Permafrost Conditions

In Russia, the total area with permafrost is 10.7 million km^2, which is about 63.5% of the entire territory of the country. Depending on the degree of closeness of the permafrost according to Callaghan and Jonasson (1995), the region is distinguished between the continuous, discontinuous, and insular distribution of permafrost. On the territory of Russia, the largest area (61.8% of the total permafrost area) is occupied by a continuous permafrost zone, the boundaries of which cover most of the Arctic islands and stretch continuously along the entire coast from the Kara Sea in the west to the Chukchi Sea in the east, penetrating deep into the continent in central Siberia and Yakutia (Jones & Moberg, 2003).

During field studies in 2005 (Kirpotin et al., 2008), a paradoxical situation was discovered: in the southern area of flat-hilly bogs, thermokarst is much less active than in the northern ones (in the area of the Arctic Circle 65.5–66°N 074–075.5°E). This is because frozen peat plays the role of a heat-insulating screen, and its thick layer protects the underlying soil from melting. Therefore, on shallow flat-hilly bogs of the Arctic Circle (where peat thickness is less than 0.5 m), despite the more severe climate, thermokarst is much more pronounced than in the southern area, where the thickness of the peat layer averages from 1.5 to 2 m. The identified regularity is quite understandable and is determined by the gradual decrease in the thickness of the peat deposit of hilly bogs from south to north due to a decrease in the annual growth of mosses in this direction. One of the important tasks of modern research in the northern territories of Eurasia is to identify the features of the impact of global warming on the state of permafrost.

The permafrost boundary is constantly shifting to the north. There are many marked simultaneous changes, e. g.:

- an intensive thawing of frozen soil up to 4 cm per year,
- deformations of buildings and structures are noted in several regions; the area of the Arctic ice cover has decreased by 1.5 times, while the thickness has decreased almost twice,
- huge volumes of methane gas under the ice shell can penetrate the air, increasing the problems associated with flooding.

The melting of permafrost is associated with environmental risks such as forest destruction, waterlogging, and other types of land degradation, which is causing a reduction of grazing lands for reindeer herders, fishermen, and hunters.

The assessment of the degradation of the Arctic and subarctic territories of Russia in the twenty-first century can be carried out not only by using traditional measurement methods recorded by industry statistics but also by the application of the method of remote sensing. Comparative assessments of changes in zonal ecosystems in the Arctic and subarctic regions of Russia have been obtained (see Table 7.4).

Permafrost is covered by a layer of soil and plant detritus with a thickness of 30 cm to 1.5 m. This soil – the so-called active layer – usually thaws every summer

Table 7.4 General results from changes in areas (km^2) of arctic and subarctic regions of Russia with different indicators of land degradation and restoration from 2000 to 2015

	Significant degradation (km^2)	Average degradation (km^2)	Stable cover (km^2)	Renewal (km^2)	Significant renewal (km^2)
Arhangelsky region	2042	7268	396,683	5780	1330
Nenets autonomous Okrug	1586	11,364	162,157	1653	49
Magadan region	1127	10,762	411,981	37,102	427
Kamchatka region	13,417	28,555	394,203	34,368	1757
Tyumen region	59,905	162,411	1,060,299	126,824	25,561
Komi Republic	42,035	98,927	634,028	99,235	26,964
Murmansky region	12,692	41,057	86,345	4084	723
Republic of Sakha (Yakutia)	79,536	247,562	2,540,310	204,930	11,662
Chukotka autonomous Okrug	17	2990	706,292	12,057	124
Krasnoyarsky region	58,496	128,389	1,924,399	188,327	40,389
Yamalo-Nenets autonomous Okrug	7904	30,645	681,323	27,497	2931
Khanty-Mansiisk autonomous Okrug (Yugra)	19,769	49,060	401,218	55,843	8910
Republic of Karelia	10,690	21,740	122,673	19,377	6040

Data of A.N. Krenke

and refreezes in winter. But in the spring of 2018, Sergey Zimov, the director of the Northeast Scientific station, and his team found that the surface around the Chersky settlement in the Nizhnekolymsk ulus in the northeast of the Republic did not freeze. It was unheard of: in January in Yakutia, there are usually such severe frosts that can sometimes freeze human breath with a ringing sound, which the Indigenous Sakha people call the whisper of the stars. According to researcher Sergey Zimov, the average annual soil temperature above permafrost ranged from −6 to −8 °C 30 years ago, later increasing to −2 °C and then to −1 °C. In 2018, the temperature was +2 °C. Globally, the ground temperature above the permafrost has been rising for half a century. On the Alaska North Slope, it has risen by 5.8 °C in 30 years, especially in hotbeds of melting. For example, during the construction and development of mineral deposits, the surface of the Earth is damaged, allowing heat to pass through – the erosion of the coast is corroded, roads and houses are destroyed, pipelines burst and ice cellars (where Arctic hunters store walrus and whale meat) collapse. Climate change is beginning to change the lives of Arctic inhabitants. In 2018, a new cataclysm (winter thaw) was observed in the Arctic region.

7.5 Forest Fire Occurrences from 1998 to 2020

Forest fires are a large threat to reindeer pastures. Much attention has always been paid to the fight against them since fires destroy moss pastures for a long time (20–25 years). Also, due to the freshly burnt areas, reindeer migrations to seasonal pastures are difficult. The combination of frequent forest fires and climate warming creates critical conditions for natural ecosystems, the economy, and traditional activities, including reindeer husbandry.

Light coniferous forests prevail in the Republic; they are formed mainly by two species – pine and larch – of which larch occupies almost 90% of the forest ecosystem of the Republic. Such light coniferous forests are more flammable than, for example, dark coniferous forests. These wood species are pyrophytes – plants whose distribution and reproduction are facilitated by fire (Isaev, 2020). The arid climate and low amount of precipitation in Yakutia also contribute to forest fires. But it should be noted that many fires are caused by humans (Fig. 7.9).

In November 2020 and January 2021, so-called *zombie* or holdover fires were spotted in the Tompo region, by the village of Saydy and Udarnik. These peatland areas suffered extremely dry weather. These fires continue to burn in air temperatures of −50 °C (Siberian Times, 2021). The winter burning of such northern peatlands will have major consequences. Continuing to burn in spring, they will cover vast areas and destroy the environment, also releasing carbon into the atmosphere.

The main types of anthropogenic impact on the state of the reindeer forage base include deforestation and forest fires, mining industry development, and various types of agriculture and industry in the territory of Yakutia. According to Utkin (1965) and Timofeev et al. (1994), almost all forest areas in the Republic of Sakha to varying degrees were affected by forest fires. Surface fires, destroying the ground cover of woodlands, have a particularly strong effect on the state of lichen pastures of reindeer. The succession processes of vegetation at the sites of fires are long, especially in lichen sites. Strong surface fires have the potential to entirely destroy existing phytocenoses, prevent their restoration, and result in the formation of communities that are not typical (Chernyavsky, 1974). Anthropogenic impacts on the environment have strongly increased, especially in recent decades, which is associated with the development of the mining industry, and the introduction of new natural gas, oil and diamond deposits into the number of operating new fields (Mordosov & Krivoshapkin, 2008).

Figures 7.7 and 7.8 are based on data from the state institution Yakut Aviation Forest Protection Base, which is responsible for air patrolling Yakutia's forest reserves, which are not covered by the forest fund, in order to detect forest and other landscape fires; extinguishing forest fires using the parachutes and airborne fire service and aircraft in the areas of aviation protection of forests, reindeer pastures, and hunting grounds, and other important functions (Department of Forestry Relations of the Republic of Sakha (Yakutia), 2017).

Figure 7.9 shows the causes of forest fires in the Republic of Sakha (Yakutia). Forest fires occur due to various reasons and factors, but the most common are

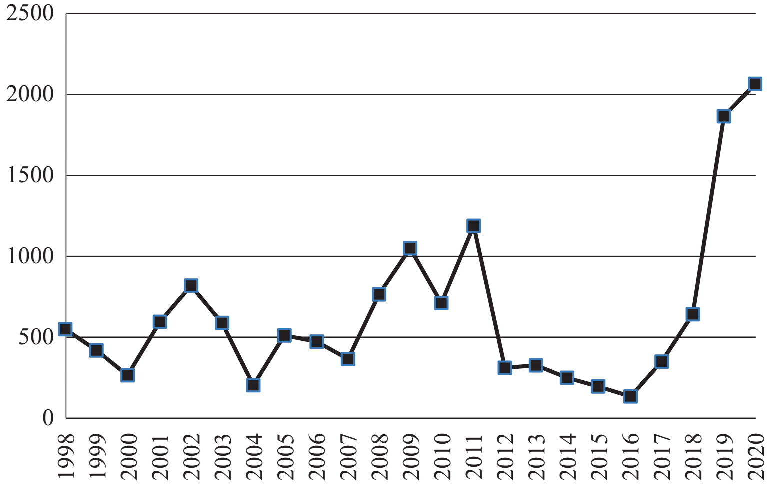

Fig. 7.7 The number of detected fires in the Republic of Sakha (Yakutia) from 1998 to 2020

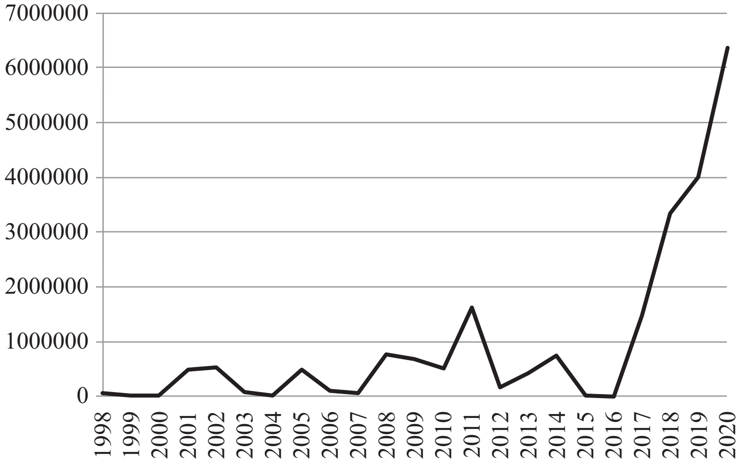

Fig. 7.8 The area of the territory covered by fires (in hectares) in the Republic of Sakha (Yakutia) for 1998–2020

thunderstorms and human activity. Other reasons include the occurrence of fires from linear objects (including power lines, railways and highways, pipelines, and other objects) during logging operations, agricultural burns, and unknown causes. We have divided the territory of the Republic of Sakha (Yakutia) into six groups for a better visual demonstration of the dynamics of fires for the years 1998–2020 according to physical and geographical characteristics, also with responsible forestry departments (Fig. 7.10). For example, all central, southern, and western uluses

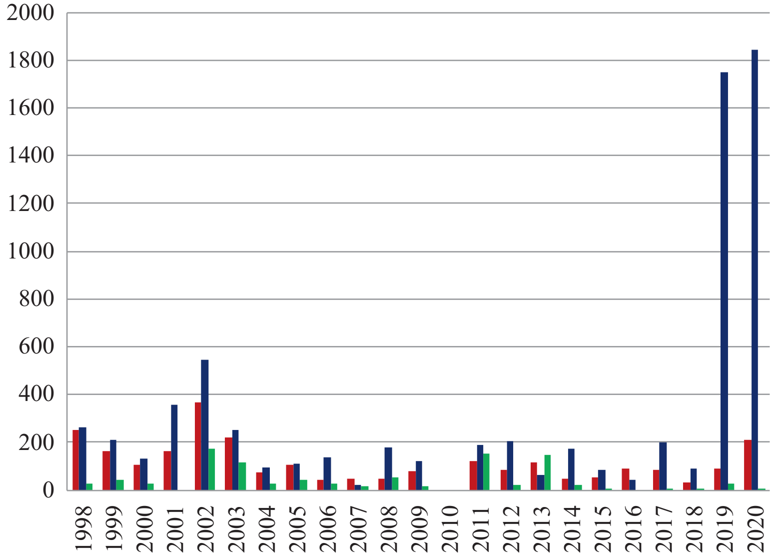

Fig. 7.9 Causes of fires in the Republic of Sakha (Yakutia) for 1998–2020 by number. Red – as a result of the violation of fire safety rules in forests by citizens (including the local population and tourists); blue – from thunderstorms; green – for other reasons

Fig. 7.10 Division of the Republic of Sakha (Yakutia) into the territories by physical and geographical characteristics and forestry departments

(districts) have their forestry departments, while the territory of Anabarsky, Bulunsky, Oleneksky, and Zhigansky uluses have a common forestry department (Zhigansky). It should also be mentioned that the mountainous group did not include the Momsky and Kobyaysky districts, most of which territories belong to the high-mountain landscapes, but since their territories are under the other departments' forest protection zoning, they were included in the northwestern and northeastern groups, respectively.

The six groups of regions are (see Fig. 7.10):

1. The northwestern group includes Anabarsky, Bulunsky, Oleneksky, Zhigansky, and Kobyaysky uluses.
2. The mountainous area includes Ust-Yansky, Verkhoyansk, Even-Bytantaysky, Tomponsky, and Oymyakonsky uluses.
3. The northeastern group includes Allaikhovsky, Abyisky, Nizhnekolymsky, Srednekolymsky, Verkhnekolymsky, and Momsky uluses.
4. The Vilyui-Lena group includes Mirninsky, Suntarsky, Nyurbinsky, Verkhnevilyuisky, Vilyuisky, and Lensky uluses.
5. The central group includes Gorny, Namsky, Ust-Aldansky, Khangalassky, Megino-Kangalassky, Churapchinsky, Tattinsky, Amginsky, Ust–Maisky uluses, and Yakutsk urban district.
6. The southern group includes Olekminsky, Aldansky, and Neryungrinsky uluses.

Numbers and areas of fires by territorial groups are represented in Figs. 7.11 and 7.12. In some cases, some types of fires are vital for the forest ecosystem, but in other cases, they have a destructive power on the environment, especially if the cause is human activity. The negative consequences of forest fires, such as reduced productivity of soil cover, destruction of natural forest resources, CO_2 emissions, loss of biological biodiversity, pollution of water resources, and other consequences, strongly affect reindeer husbandry.

7.6 Perception of Climate Change and its Impact on Reindeer Husbandry Among Indigenous Peoples of the Arctic

For the purposes of the study, in-depth interviews were conducted with 14 representatives of Indigenous peoples of the North who have experience in reindeer herding and permanently live in the Nizhnekolymsk ulus. The interviews were aimed at identifying perceptions of climate change and its impact on reindeer herding. The interviews were analyzed using content analysis methods.

The interviews were conducted during the years 2020–2021 by Anna Shishigina in Russian, which the interviewees have a good command of. The interviews were conducted in the settlement of Chersky, were digitally recorded, and lasted from 30 to 70 min. In the interviews, residents of the Arctic regions of Yakutia talked about

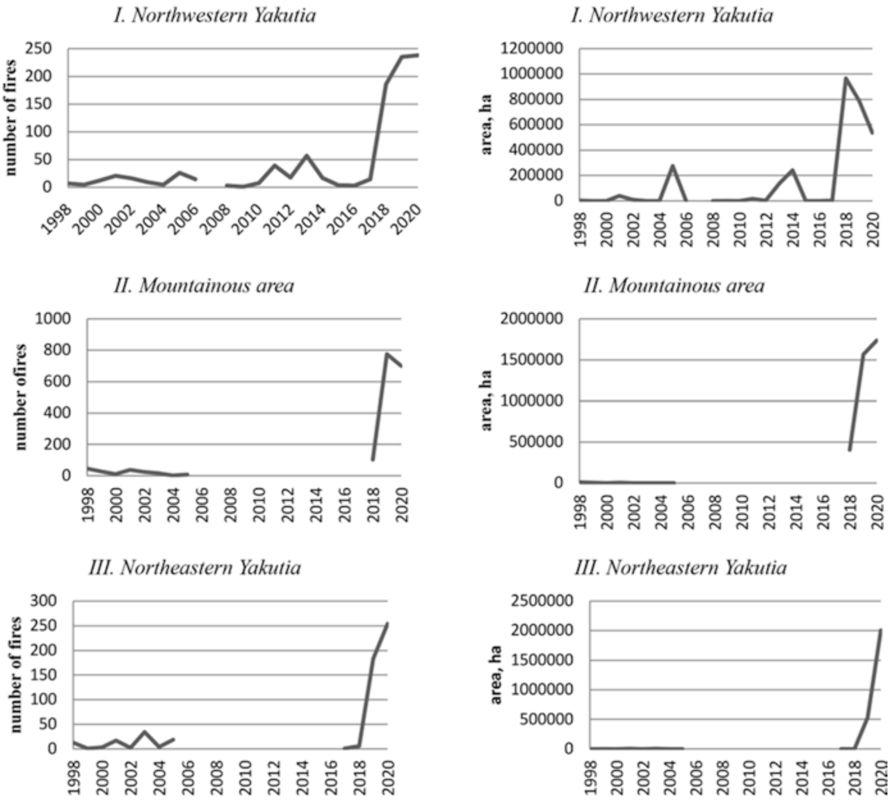

Fig. 7.11 Number and area of fires shown by territorial groups

their daily lives, observations of environmental changes, and how various circumstances affect reindeer herding. The codes and developed categories show how everyday life has changed over time (see Fig. 7.13).

First of all, we should note that all respondents recognize the reality of climate change. Respondent 8 put it this way: "The climate is changing all over the world. Our climate is also changing, just like the rest of the world – we live on the same planet."

Based on the frequency with which certain features are mentioned, they most often cite issues related to water resources (lakes disappearing, islands appearing on the river) and changes in the natural cycle (the rivers freezing later, winter becoming warmer, spring coming earlier) as factors of change (Fig. 7.13).

For example, old residents of the Nizhnekolymsk district note: "Now it starts freezing very late, because earlier, winter was considered to start before October 1. The ice was already thick. It was in the early 60's - late 50's, but the spring was early all the time. On May 1 we – the schoolchildren in the village of Kolyma, the children, and all the adults in boots wandered in the mud. And now it's not like that, now May 1 is winter. <…> And now, on the contrary, for some reason, it freezes very

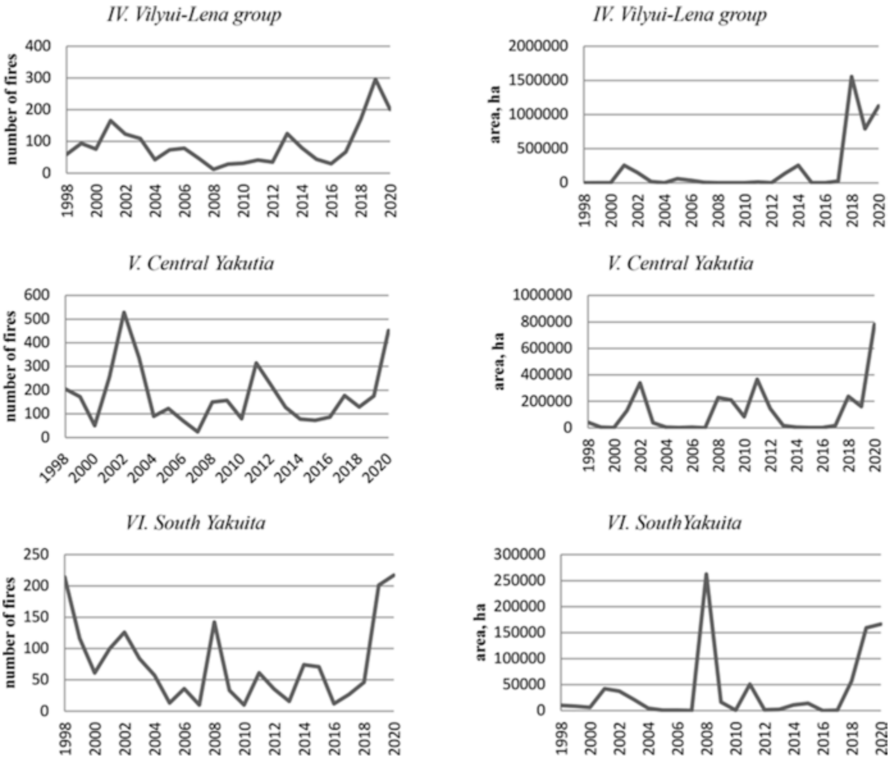

Fig. 7.12 Number and area of fires shown by territorial groups

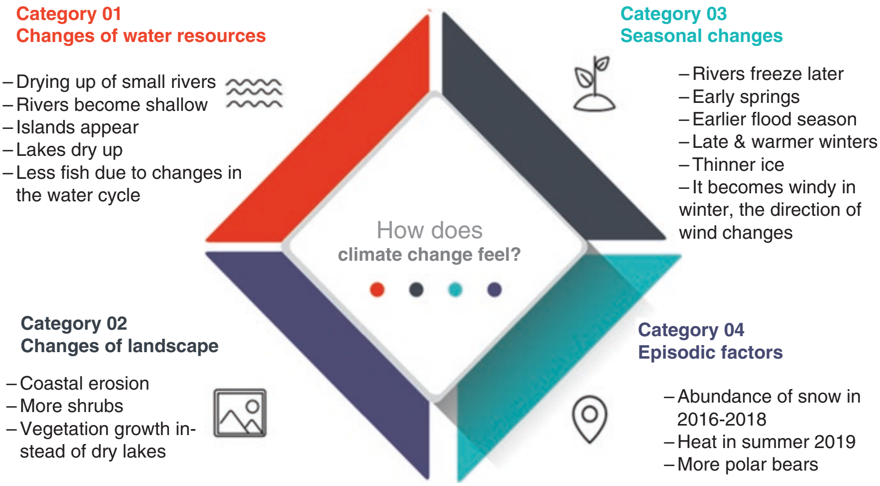

Fig. 7.13 Climate and weather change features in the perceptions of local people (residents of rural areas) of the Arctic regions of the Sakha (Yakutia) Republic

Fig. 7.14 Reindeer herd near Neryungri, Republic of Sakha (Yakutia). (Photo: A. Gerasimova)

late. It freezes late." (Respondent 1); "The river freezes later. About 20 days later. Earlier from October 5 to 9, the river was already covered with ice. It was obligatory during this period. Obligatory. In summer, too, at the end of May – from 27 to 2-3 June, the ice was melting. Not so now. In 2019, the river froze somewhere on the 20th, and once it was even in November. Almost a month late" (Respondent 9).

There are no negative factors about how it affects reindeer husbandry, these factors are rather accepted as a fact: "The cycle has changed… even calving is later, earlier it started a little bit earlier. The calves were born earlier and now they are born later. And the rutting also happens later, because the temperature affects it and the animals feel it, I guess. They have a certain moment, they … the rutting is going on. They're covering their females. And it looks like with the warming, they're a little bit off their schedule for almost a month. You can see that. It doesn't feel that way. It's only uncomfortable in the fall. In autumn, let's say, we make a cage and drive the herds, but the ground is not frozen. It used to freeze over before. And now it freezes later in autumn. The ground is not frozen and … the rut is breaking because it is not frozen" (Respondent 11).

Meanwhile, some respondents still expressed the opinion that warm winter weather is not the most favorable for reindeer husbandry: "It is … so bad for reindeer husbandry because the herd needs movement. When it is warm for a long time, the reindeer are already used to it being cold.

Residents sometimes directly state that fishing suffers from these changes more than reindeer breeding (Respondent 1): "For example, we have the spawning season for the chirp – at the end of August and September. And in September, the lakes haven't frozen yet. And in October, around October 7-8, we set our nets and we only catch a tail, and now they've finished spawning, and the rest of the fish go to the river, we catch them"; "Due to the change of freezing period, there seems to be no fish in the river. That's why they say: fish go away sometime. We have October - if earlier it was supposed to be at the beginning, now it's 15 days later that the Kolyma River freezes up and the fish are gone" (Respondent 3).

Of the range of information that relates to water resources, the most numerous mentions relate to drying lakes. However, regarding the extent to which this phenomenon is related to climate change, namely to the processes of melting permafrost, residents are unsure: “Why do lakes flow out? Because there is probably no permafrost. Or I don’t know. This is my assumption that there is no permafrost” (Respondent 4), “Because they say some cracks are formed, there are cracks in the tundra and the lakes are drying up” (Respondent 10), “And the lakes are disappearing. It looks like it’s getting warmer and thawing out. I don’t know. And these lakes are disappearing - they are flowing out” (Respondent 11).

Changes concerning water resources, although among the most frequently mentioned, are not unambiguously referred to as negative factors by the respondents themselves, still have quite a serious impact on the daily life of reindeer herders.

First, small rivers and lakes play a major role as objects of orientation in quite large areas.

Respondent 1 wonders: “There on the bank of the river you can clearly see how it changes. A year ago, I was driving past and there was a river here. Now we drive up this year - there is no river. It’s gone to a completely different place. Three years in a row I hunted right down this river, right on the way out to the sea. We drove up there, I didn’t understand what happened. And I ended up in a totally different place. First time I noticed that.” Respondent 4 notes: “They give me a point. Where are you? There this, there that…on a dry lake. And I remember where this dry lake is. I used to go nomadic, this lake was fishy, and there were a lot of teals. I have a navigator in my memory - I can’t complain. I have a good navigator. I know my place. These are the places I roamed. And I remember. Where is this dry lake? They say - dry lake, where is the southern shore, the eastern shore. I remember and remember where this dry lake is. And I look at the map, is this where it is?”

Second, fish caught in northern rivers and tundra lakes play an important role in the food traditions of both reindeer herders and local residents, and such changes cannot go unnoticed: “Fish have become scarce. You can feel it by the fishing. We used to catch here, for ourselves. And now we catch some for the kids. We didn’t catch for sale. It used to be okay - the yukolu there…”. (Respondent 14); “We can say that there is fewer fish. There’s no reason to fish, you could say. We used to have only fish. Now you can’t survive with fish only. If only you are lucky. Bajanai, if he shares. There is fewer fish on the river - omul, vendace. This year there is a little more vendace. It probably depends on the water. How the river flows.” (Respondent 5).

Not all of the interviewees – residents of Nizhnekolymsk District – correlate the processes of river melting and the appearance of islands on rivers with climate change. Thus, respondent 3 notes: “It seems to me that the river is shallowing not because of the climate. It seems to me that Magadan is water dumping. They discharge water and you can imagine the tonnage of water going in when there are scheduled discharges in the fall, and that’s why we have so many islands. And we get, as they say, it used to be good when the ships came in. And now when the water goes away, shallowing is going”, i.e., they connect these processes with anthropogenic impact – construction of Hydro Power Plant on Kolyma. Another respondent also connects these processes with the suspension of permanent dredging, which was conducted during the Soviet time: "There is a big island opposite Chersky, too. It's become long. I went to Kolymskoye, I used to take the same (route) almost every year, and here one time – the hooks, what is it? And they told me – don't you know, there's an island here. When did it appear? Yes, that's it. In that period. They used to go, what's his name? Maybe that's why".

As for the dried-up lakes, these processes are more tangible for reindeer breeding, but also on this issue the opinions differ, but nevertheless, the majority still note the negative factors.

Thus, respondents 13 and 8 categorically refer to this factor as negative: "A lot of bushes have grown in the tundra. Plants that were not there before have grown. They displaced the endemics. Plants. And it turns out that there is waterlogging of tundra, i.e., there is not much moss growing. There is a problem with it too. They lose pastures. And we can't herd more than 14 thousand reindeer. This problem is one of the main problems for today"; "Shrubbery is growing capitally. Shrubs started growing in the *yagel* (reindeer lichen) areas – that's not good either. *Yagel* will dislodge. Grass will start growing".

Others, on the contrary, note the positives: "It's probably a good thing for reindeer husbandry. Why? Well, the lake came out, and the next year grass grew there. On the place of this lake. And the grass stands there very well." (Respondent 4). Respondent 10 talks about the same thing, "And on these places, like reeds, tall grass grows. And deer graze there in the fall and spring.

But there are also those herders who see both positive and negative sides to this. So, respondent 11 notes: "It depends on what side you look at. For reindeer – bushes are greenery, they eat them. It's good for roaming. Because there's no firewood in the tundra and we pick up *tunduks* (thalder) to make fire. The bushes grow and it is profitable for us that the bushes grow. But, on the other hand, on bushes, it's … *kopytka* (foot rot). They get hurt and sick (reindeer)". Respondent 13 also notes the problem of hoofing in places where shrubs grow on dried-up lakes.

Experienced reindeer herders also note such factors of climate change as an increase in the number of polar bears in human settlements. Thus, respondent 8 correlates this phenomenon with the melting of ice: "This is also climate change. There was no such thing before. They are always on the ice." In addition, he adds: "There's a lot of creeks now in the spring that you can't get through. It didn't use to be like that. There's more snow now, in the mountains. <…> it's impossible to migrate. But it's not for long, of course. During thawing. Here. That's why it feels, of course.

Some note the windiness. Thus, respondent 10 believes that the winds "now seem to be frequent", and respondent 9 shares such observations about the change in wind direction in a particular season: "In winter, mostly now the south-easterly wind – a cold wind. The wind direction, that is, has changed since around the 90s and early 2000s. It wasn't like that before".

In general, it should be noted that experienced reindeer herders believe that the problem of climate change is not the most pressing at the moment – "Well, not so noticeable. For us. Slowly, slowly changing" (Respondent 8). Thus, Respondent 3, in this regard, expresses the opinion that the problem is more noticeable for the villagers than for reindeer herders: "The reindeer herders, who are really hereditary, say that the climate does not change that much. But for us, the villagers, everything seems to be changing so much."

All interviewees noted negative events in recent years – deep snow, warm winters, and strong heat in the summer.

But it is also a common opinion that all these are the coming whims of nature. Respondent 7 said the following: "I just wondered, before the fall froze up around October 10, we were already setting nets. That was in the 70-80s. Almost until the beginning of the 90s. And then it got to the point, that we were still floating on the Kolyma River until October. Generally, we wondered what it was. At the end of October 25, the Kolyma River was just rising, and the fish were already all gone. It is not waiting for Kolyma to freeze or not to freeze. But on the other hand – you wouldn't know either. This year it also got up early – it's ok, it got up early. At first, it seemed as if some kind of thaw had set in, some warming went on because the Kolyma River is already late in freezing. And there's a big difference with the year." "And you wouldn't know. Things are changing faster." – he adds. Respondent 12 puts it the same way: "It changes every year. You can't tell for sure anyway. No one will tell." "One year there's a lot of snow, one year there's a flood, one year there's nothing. It varies." – Respondent 8 cites his opinion.

Respondents 1 and 2 recall that such natural disasters as rain in December and January, which are extremely harmful to reindeer husbandry, have happened before, including at the beginning of the twentieth century. Respondent 10 recalls that such phenomena have occurred two or three times in her memory – in the 1990s and 2000s.

Respondent 13 says that even though the weather varies from year to year, nevertheless all these processes are due to climate change – "At least during our generation, there was no such thing. We still tend to think the climate is changing. Maybe wrong."

During fieldwork, the author was convinced that the key informants are united by a great sense of dignity, and love for their land, their roots, and their work. Probably that is why, despite all the observed changes and natural cataclysms, many interviewees say that reindeer herders with timely actions can overcome the vagaries of nature: "What is the worst for reindeer? It's how it (nature) freezes in autumn. If it was raining heavily and then suddenly it froze. And along with the snow. And everything is covered with a crust of ice. The crust is ok, it's nothing. But the moss - it becomes hollow. Everything inside becomes watery. And what does the reindeer practically eat? Ice. So what do the reindeer eat? It just stuffs the stomach and is of no use. And the reindeer start to be exhausted. So, what is the most important thing we did for this? We were looking for protection in the forest zone. In the places where the forest was thicker, in winter we tried to stay in those places. Because the branches held back the moisture. The rain remained on branches and under them the moss was dry. It is not soaked with water. And the reindeer in these places he knows himself, he knows himself where the *iak* is good" (Respondent 1); "I was afraid that in this heat the reindeer will not survive, but on the contrary, all the living remained – they left in time towards the sea, managed" (Respondent 2); "Reindeer herding is a science, and the main teachers are his feet." (Respondent 4).

7.7 Threats and Challenges to the Development of Reindeer Husbandry and Proposals for Overcoming Them

Climate change poses risks to the preservation of the traditional way of life of Indigenous peoples, including reindeer husbandry. Due to more frequent thaws, an ice layer can occur on the surface of the snow cover and on the ground, which restricts access to food for reindeer. Melting permafrost, changes in the parameters of snow cover, earlier ice drift and later freezing of rivers lead to the disruption of traditional reindeer migration routes between winter and summer pastures. The warming of the climate and the reduction of ice coverage in the Arctic Seas together with changes in the migration routes of wild reindeer and their food supply may lead to a reduction in the traditional industry of Indigenous peoples of the Arctic (RosHydroMet, 2017).

It should be noted that for the Indigenous peoples of the North and the Arctic, the development of reindeer herding is not only socially but also politically important, as it forms the basis of their identity and is the main traditional occupation of their life.

The unpredictability of long-term changes in the productivity of the marine, terrestrial, and wetland ecosystems determines the need to develop different possible scenarios for the development of climatic and environmental changes in the Russian Arctic. One should aim to find for each of them a robust set of adaptation measures for the population and economy which do not damage the environment. Early adaptation action can bring tangible economic benefits and minimize threats to ecosystem conservation, human health, sustainable economic development, and the safe operation of infrastructure. The strategies for adapting the economy and society to changes in climatic and natural conditions in the Arctic should include scientific assessments of the risks, vulnerability as well as potential benefits of the projected climatic changes, taking into account the natural, geographical, economic, social, and other features of the Russian Arctic. In this context, one of the important tasks is to conduct economic assessments of the costs and benefits of the proposed adaptation measures.

The development of measures for the protection and rational use of reindeer pastures and the conservation of biodiversity in them, along with other conservation measures, is extremely important for the restoration and further development of reindeer husbandry as an important economic activity.

Melting permafrost affects the state of reindeer pastures in particular and human life in the Arctic in general. For the Indigenous peoples of the North and the Arctic, the development of reindeer husbandry has not only social but also political significance, since it forms the basis of their identity and is the main traditional occupation of their lives. For this reason, the development of reindeer husbandry in the Republic of Sakha (Yakutia) is of great importance. The maintenance of reindeer husbandry is based on pasture fodder. That is why a rational use of reindeer pastures based on the study of yield, changes in plant phytomass under the influence of grazing, and technogenic impact is relevant. The development of measures for the protection and rational use of reindeer pastures and the preservation of biological diversity on the pastures based on traditional knowledge, along with other nature conservation measures, is of exceptional importance for the restoration and further development of reindeer husbandry as an important economic activity.

This is possible not only by studying changes in the composition of the vegetation cover of reindeer pastures under the influence of grazing and anthropogenic influences but also by developing methods for their rational use. In this regard, a comprehensive study of the ecology and dynamics of pasture vegetation and methods of using pastures in a changing environment under the influence of various natural and anthropogenic influences is not only of the theoretical value for understanding the evolutionary process and patterns of changes in the species composition and functioning of pasture vegetation but also acquires applied significance in the development of reindeer husbandry as the basis for the life of the local population. Climate change, melting permafrost, and degradation of reindeer grazing lands require scientifically based solutions for the survival and adaptation of reindeer herders to the new conditions. Therefore, the rational use of reindeer pastures based on the combination of traditional knowledge of reindeer herders and scientific knowledge is important.

In order to avoid forest fires and reduce their number in the Republic of Sakha (Yakutia), the following measures can be taken:

- conduct intensive forestry. Clean forests of felling residues decrease the amount of combustible material due to forest ecosystems.
- performing prescribed burning in forests for preventive purposes. For example, carrying out controlled burning of dry grass, taking into account the optimal period when the forest is not ready to burn and the situation will be under human control. At the moment, in Russia, agricultural burns are prohibited at the legislative level.
- provide long-term weather forecasts, which will allow for assessing and preparing for a forest fire situation in certain places.

For the implementation of such plans, the issues of financing such measures are important. Thus, the main investor in the Arctic regions of Russia is the state, which also provides state investments and infrastructure support. The budget of the Sakha Republic for 2021 is about 250 billion rubles, which is about $3.4 billion. In the Arctic regions of the Sakha Republic, much of the infrastructure was built during the Soviet era and is now quite old and poor. It needs renovation and, of course, requires very large investments to renovate houses and build new schools, kindergartens, hospitals, energy infrastructure, roads, and communications. The state budget of the Sakha Republic for the next 4 years envisages about 45 billion rubles for the Arctic regions. There is not enough funding for infrastructure development. There are problems with banking services in some settlements. Getting loans or mortgages is a big problem because banks have their systems of economic expediency. In very small localities, there are no ATMs, no bank offices, and no communication, because it is not economically feasible for the banks.

The adaptation of Indigenous peoples is also related to the economic development of their small communities based on the production of traditional products, mainly food, the development of creative industries, and various services. Reindeer husbandry, as one of the main traditional activities of Indigenous peoples, will continue to play an important role in preserving the culture, language, and traditions of Indigenous peoples. At the same time, it should play a central role in the economic development and modernization of Arctic Indigenous peoples. New economic models for reindeer husbandry that incorporate Indigenous traditional knowledge combined with new and innovative technology are needed to achieve this goal. Access to markets and the expansion of existing markets, including international markets, is crucial in this regard. Therefore, projects such as the use of the Northern Sea Route as a tool to access international markets are very important.

Among other methods, the development of a climate change adaptation strategy can consist of the study and application of the snow and snow cover knowledge systems of the Indigenous peoples whose wellbeing is associated with pastoral reindeer husbandry. Its most interesting and valuable aspect is understanding the state of snow cover in close relationship with the state of weather, vegetation, and wildlife. The accumulation of knowledge about the state of snow and snow cover in combination with the features of other environmental components is typical for all Northern peoples and gives an example of successful adaptation to difficult climate conditions. The holistic approach underlying the system of traditional knowledge about weather and climate can be called a forerunner of modern interdisciplinary research. The interdisciplinary approach allows us to cover the totality of processes occurring in the climate system as a whole, including the atmosphere, hydrosphere, biosphere, and upper layer of the lithosphere. In the Arctic and subarctic, where the effects of climate change are compounded by globalization and changes in traditional husbandry practices, traditional knowledge of weather and climate and their impact on traditional livelihoods like reindeer husbandry can play an important role in developing a climate change adaptation strategy.

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Chapter 8
Comparative Analyses of Local Historical and Future Climate Conditions Important for Reindeer Herding in Finnmark, Norway and the Yamal Nenets Autonomous Okrug, Russia

Inger Hanssen-Bauer, Rasmus E. Benestad, Julia Lutz, Dagrun Vikhamar-Schuler, Pavel Svyashchennikov, and Eirik J. Førland

Abstract In Finnmark, average winter (Dec-Jan-Feb) temperatures in the period 1961–1990 were about −5 °C at the coast, slightly lower in the fjords, and typically 10 °C lower inland. In the Yamal Nenets Autonomous Okrug (YNAO) average winter temperatures were even lower, ranging from −20 to −25 °C. Temperatures are presently increasing in the area, and towards the end of this century, winter temperatures in the YNAO may, under a medium high emission scenario, resemble the previous conditions in the interior of Finnmark, while inland Finnmark may experience conditions that were earlier found along the fjords. The snow season in 1961–1990 typically lasted from 6 to 8 months in Finnmark. Higher temperatures lead to a reduced snow season and model calculations indicate a 3-month reduction along the coast, where it is shortest today, while the inland snow season may be one month shorter towards the end of the century. Along the coast, a 60% reduction in the winter maximum snow amount is projected towards the end of the century. In the interior of Finnmark, considerably smaller changes are projected in maximum snow amounts, as average precipitation is projected to increase, implicating increased snowfall during winter. Maximum snow amounts may even increase slightly at some inland sites. Higher winter temperatures will lead to changes in the snow

I. Hanssen-Bauer (✉) · R. E. Benestad · J. Lutz · D. Vikhamar-Schuler · E. J. Førland
Norwegian Meteorological Institute, Oslo, Norway
e-mail: ingerhb@met.no

P. Svyashchennikov
St. Petersburg State University, St. Petersburg, Russia

Arctic and Antarctic Research Institute, St. Petersburg, Russia

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structure. Compared to herders' reports, the SNOWPACK model successfully reproduced high-density snow layers during the past decades. To describe future snow structures of relevance for reindeer grazing conditions in Finnmark and YNAO, more detailed climate projections are needed.

Keywords Climate change · Snow conditions · Reindeer pastures

8.1 Introduction

Weather affects reindeer and reindeer husbandry in a number of ways, both directly and indirectly (e.g., Mysterud et al., 2001; Tyler et al., 2008, 2021; Uboni et al., 2016; Eira et al., 2018; see also Chaps. 3 and 4). Global warming implies changes in weather conditions, and according to IPCC (2021) the areas of maximum warming are those at high northern latitudes, including northern Eurasia. Knowledge of present and future climate in this area is thus important for assessing possible impact of climate change on reindeer ecology and husbandry.

Previous climate analyses from northern Eurasia (Fig. 8.1) show that from Finnmark in the west to Chukotka in the east, these areas are mostly characterized by permafrost, cold and reasonably dry winters, a long snow season, but rather small amounts of snow (Vikhamar-Schuler et al., 2010a; AMAP, 2017a, b). From Finnmark to the Republic of Sakha Yakutia (hereafter referred to as Sakha) the winters (Dec-Jan-Feb) become gradually colder and dryer towards the east

Fig. 8.1 Stations used in the climate analyses of northern Eurasia. The named stations are also used in the Finnmark – Yamal Nenets Autonomous Okrug (YNAO) comparison

(AMAP, 2017a). In Sakha the average winter temperature is usually between −35 to −45 °C. Further east, in Chukotka, the winters are milder, but still colder than in the west. In summer (Jun-Jul-Aug) the temperature differences between east and west are smaller, but in general coastal stations tend to be cooler than inland stations, because of the cooling effect by the cold ocean. The study areas in general experience a large year-to-year variability in temperature, which in the western parts is correlated to the North Atlantic Oscillation (NAO). Positive NAO phase is usually associated with advection of mild air masses from the west into these areas, while negative NAO is associated with blocking of the mild air masses. Further east, in Sakha, the NAO correlation is more variable and in Chukotka it tends to be negative (Vikhamar-Schuler, Førland, et al., 2010a). The temperature along the coast is largely affected by the year-to-year variability in sea ice concentrations in the area (AMAP, 2017b), especially in winter.

This chapter provides a more detailed description of air temperature, precipitation and snow conditions in Finnmark in Norway and Yamal Nenets Autonomous Okrug (hereafter YNAO) in Russia. The data and methods applied are described in Sect. 8.2. Climate descriptions are given for the past, present and – where local projections were available – also for the future. The climate descriptions are given at two levels of detail. For both Finnmark and the YNAO, basic climatology (1961–1990) is described and temperature projections for the end of the twenty-first century are given (Sect. 8.3). For Finnmark, it has also been possible to give more spatially detailed climate information concerning climatology, as well as past and future temperature, precipitation and snow conditions (Sect. 8.4).

Snow conditions, including snow structure, are crucial for the existence and livelihoods of reindeer herding communities; being critical for maintaining food supply, for tracking and for travel (Eira et al., 2018, Eira, 2022). Snow structure is not observed regularly but for one site in Finnmark, it has been possible to model snow layer structure based upon historical regular climate observations (Sect. 8.5). The snow model has not yet been run for projections but gives promising prospects for establishing scenarios for future snow structure.

8.2 Data, Methods, and Models

The historical analyses in this chapter are based on temperature, precipitation and snow data made available by the Norwegian Meteorological Institute (MET Norway) and the Arctic and Antarctic Research Institute (AARI). Data from the climate stations named in Fig. 8.1 were applied in Sects. 8.3.1, 8.3.2, 8.3.3, and 8.3.4, while also daily gridded datasets based on all high-quality Norwegian stations were used in the more detailed analyses for Finnmark in Sect. 8.4.

Several analyses are performed on a seasonal basis. Unless other definitions are given, winter is defined as Dec-Jan-Feb, spring Mar-Apr-May, summer Jun-Jul-Aug and autumn Sep-Oct-Nov.

The projections for changes in local temperatures under continued global warming in Sect. 8.3.5 are based upon output from coupled global climate models (IPCC, 2000, 2013). The results from these models are fairly realistic on a large scale, but downscaling is necessary to establish good local projections. Benestad et al. (2008) developed empirical statistical downscaling (ESD) techniques for downscaling temperature projections at stations with good quality observational series. By interpolating station values in a geographical information system, Benestad (2011) developed temperature projections valid for the period 2017–2100 for an area including Finnmark and the YNAO.

For Finnmark, also fine-scale temperature and precipitation projections from Hanssen-Bauer et al. (2015, 2017) are presented in Sect. 8.4. These were based upon regional climate model output, re-gridded and bias adjusted. These, as well as the observationally based gridded temperature and precipitation fields were applied as input in a hydrological model (HBV; Beldring et al., 2003) to produce maps showing historical snow conditions as well as projected changes.

For modeling snow properties (Sect. 8.5), the SNOWPACK model (Bartelt & Lehning, 2002; Lehning et al., 2002a, b) was applied. This model was developed in Switzerland for snow avalanche warning purposes but has later been validated for boreal conditions in Finland (Rasmus et al., 2007). It simulates snowpack development during winter based on meteorological input data. The resulting outputs are layer stratigraphy of, e.g., snow temperature, grain type, grain size, liquid water content and snow density. In the present study, 6-hourly meteorological observations from the Kautokeino weather station over the period 1956–2010 were applied. In addition to routinely observed weather data, the SNOWPACK model needs data for shortwave and longwave radiation as well as snow surface and ground temperatures. Incoming long-wave radiation was estimated using observed cloudiness from the weather station, while the potential incoming short-wave radiation was estimated by a method described in Hock (1999). Ground surface temperature was derived from available observations of air temperature and snow depth applying a ground surface temperature model (Vikhamar-Schuler et al., 2013). Validation of the modeling results was carried out in Kautokeino for the winter season 2009/2010. Snow profiles were measured twice a month and snow temperature was recorded every hour by sensors located at 0, 10 and 35 cm snow heights. Comparison of measured and modelled snow temperatures showed high correlation (R2 = 0.9). Some systematic errors were noticeable with small deviations at high temperatures (0 to −5 °C), and increasing deviations at lower temperatures (below −5 °C). As snow metamorphose is most efficient around 0 to −1 °C this is regarded to have minor influence on the results.

The figures in this chapter are, if no reference is given in the figure caption, produced by the authors especially for this book.

Table 8.1 Information on the stations used in the comparative analyses: Altitude is given in meters above sea level. Average annual temperature (°C) and average annual precipitation sum (mm) are given for the period 1961–1990

Station name/Nation	National number	Altitude	T (°C) 1961–1990	Precip. (mm) 1961–1990
Nordreisa/Norway	91750	1	1.4	661
Suolovuopmi/ Norway	93300	377	−2.4	456
Karasjok/Norway	97250	155	−2.2	365
Vardø/Norway	98550	10	1.3	583
Ust’-tsilma/Russia	23405	68	−1.8	567
Tarko-sale/Russia	23552	27	−6.4	480
Salekhard/Russia	23330	35	−6.6	451
Mare-sale/Russia	23032	24	−8.5	298

8.3 Comparative Analyses for Finnmark and the Yamal Nenets AO

The climate stations used in these analyses are those named in Fig. 8.1. Some basic information is given in Table 8.1. Nordreisa is representative of fjord areas in Finnmark. Vardø represents outer coastal areas. Suolovuopmi and Karasjok are inland stations representing different altitudes. In the YNAO, Mare Sale represents the coast, while the other stations represent an inland profile from west to east. Ust’Tsilma is situated in a neighboring region west of the Ural mountains, and represents the climate west of the YNAO. ‘Present climate’ is defined by the WMO standard climatological normal period 1961–1990, as the 1991–2020 climatology is not available for all stations. Though there has been a temperature increase during the later decades (see information for Finnmark in Sect. 8.4), the geographical temperature patterns are largely the same as reported by AMAP (2017a). However, changes in these patterns are expected when the winter sea ice concentration along the coast of YNAO is seriously reduced (AMAP, 2017b).

8.3.1 Temperature Climate in the Twentieth Century

Both Finnmark and the YNAO include coastal and inland areas. The western coastal stations in the region are strongly influenced by the temperate ocean currents in the Norwegian Sea. In Finnmark, this is reflected in the typical difference between the mild winter (about −5 °C) and the cool summer (less than 10 °C) climate at the coastal station in Vardø, and the colder winter/warmer summer climate in Karasjok (Fig. 8.2). In mid-winter, Karasjok is on average more than 10 °C colder than Vardø and in mid-summer about 5 °C warmer. Nordreisa, situated in a fjord area, has temperatures that lie between the values of the inland and the coastal stations in winter,

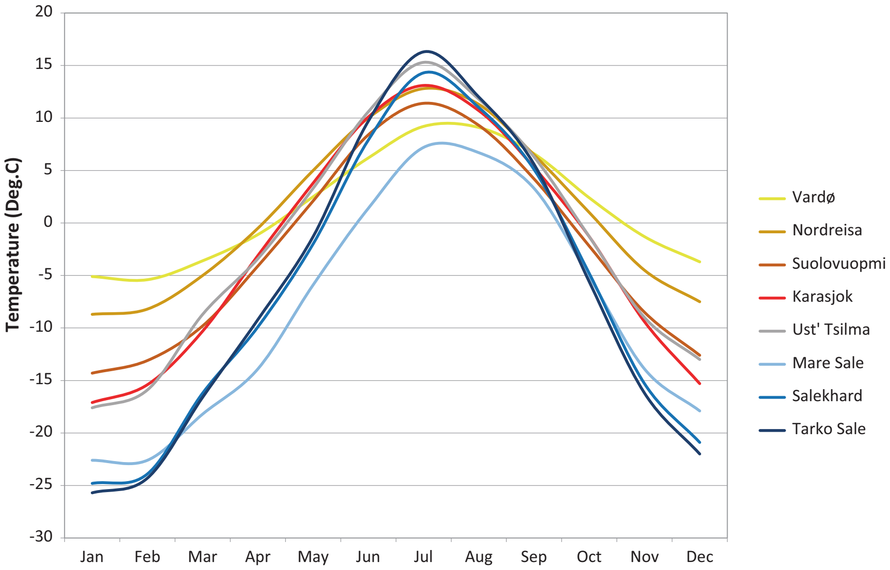

Fig. 8.2 Average monthly temperature (°C) for the period 1961–1990 at selected stations in Finnmark and the YNAO

while the summer temperatures are closer to the inland stations. Suolovuopmi, situated at a higher altitude than Karasjok, is on average slightly milder in winter when temperature inversions dominate this area, but cooler than Karasjok in summer, when temperatures normally decrease with altitude.

While Ust'Tsilma experiences winter temperatures close to those of Karasjok, the inland stations of the YNAO are significantly colder, with average January temperatures around −25 °C. The temperatures at the more coastal station Mare-Sale are almost as low as the inland stations. This "continental signature" of the Mare-Sale winter climate is caused by the sea ice which usually covers the Kara Sea in winter, and effectively shuts off heat transfer from the ocean. This is also reflected in the average number of "cold days" (Fig. 8.3). Both Salekhard and Mare-Sale have, on average, more than 20 days per year with mean temperature below −30 °C. The inland stations further west have fewer days with average temperature below −30 °C, while coastal areas in Finnmark normally have no such days. In Vardø, there are also few days with a mean temperature below −15 °C, while Salekhard and Mare-Sale on average have about 110 such days per year, and Karasjok and Ust'Tsilma about 60.

While the difference in winter temperatures between coast and the interior are smaller in the YNAO than in Finnmark, it is the other way around when it comes to summer temperatures (Fig. 8.2). The cold ocean limits the temperatures in Mare-Sale in summer, resulting in the lowest average summer temperature of all the stations, while the inland stations in the YNAO have higher July temperatures than any of the Finnmark stations. There are also systematic differences concerning annual mean temperatures, as the coast usually is warmer than interior Finnmark (Vardø:

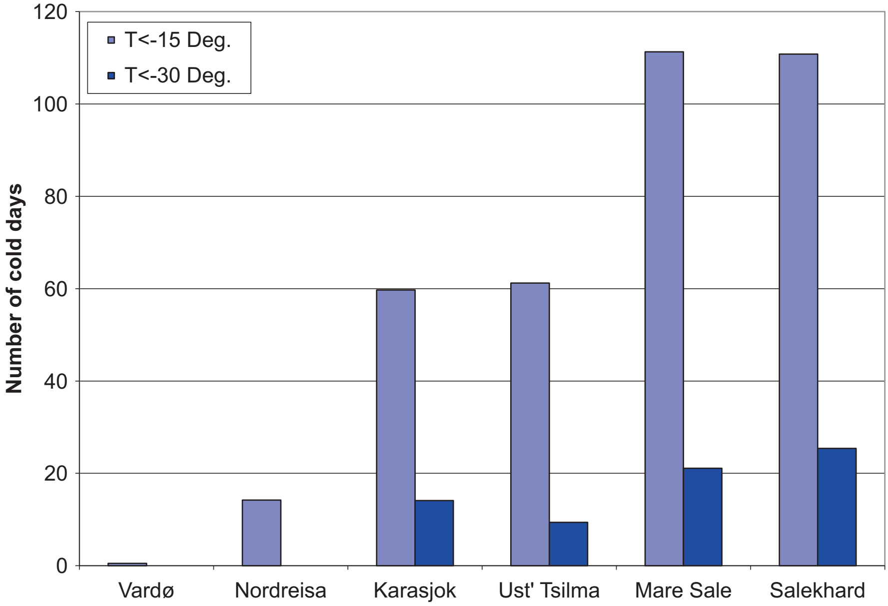

Fig. 8.3 Average annual number of days with mean temperature below −15 °C and −30 °C in the period 1961–1990 at selected stations in Finnmark and the YNAO

+1.3 °C, Karasjok: −2.3 °C), while the coast is colder in the YNAO (Mare-Sale: −8.5 °C, Salekhard: −6.6 °C).

Analyses of annual temperature series from Finnmark and the YNAO through the twentieth century show large inter-annual and inter-decadal variability (Vikhamar-Schuler et al., 2010a). In both areas, the decades around 1900 and around 1970 were cold. The 1930s were warm in Finnmark (cf. Fig 8.3), while the 1940s were warm in the YNAO, and from the 1990s it has been warm in both areas. The difference between warm and cold decades was up to 2 °C, while the mean annual temperatures increased typically by +0.5 to +0.7 °C during the century. Spring temperatures typically increased by 1.5 °C, and spring was the only season for which the long-term temperature trends were statistically significant during the twentieth century. Since 2000, the long-term temperature increase has continued and the annual trends are now statistically significant, at least in Finnmark, where updated series have been analyzed (Hanssen-Bauer et al., 2015, 2017).

8.3.2 *Growing Season*

The growing season is here defined as the period of the year when the average daily temperature is above 5 °C (Førland et al., 2004). The station Nordreisa, which represents fjord areas in Finnmark, has the longest growing season (almost 140 days;

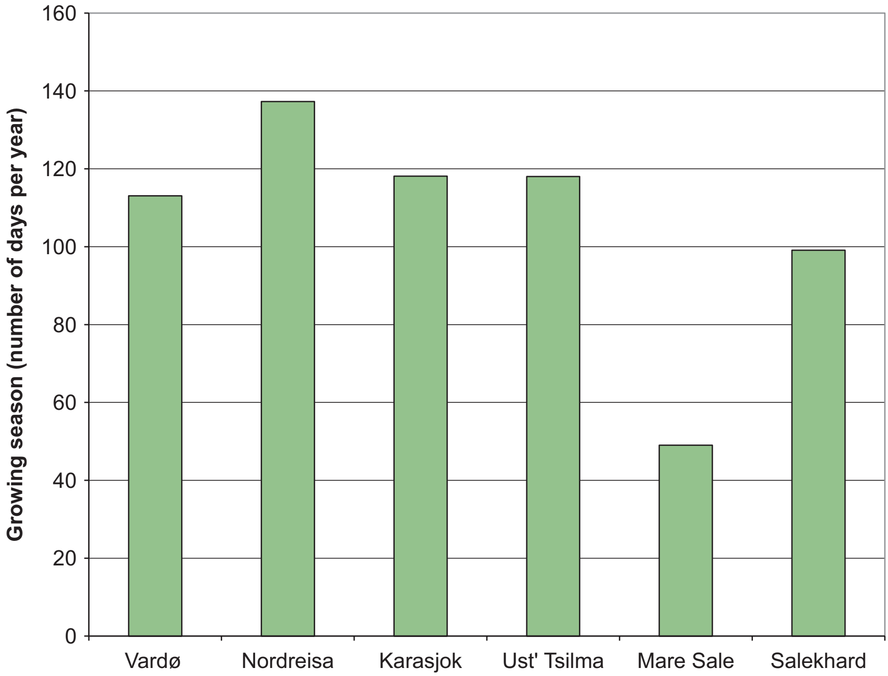

Fig. 8.4 Length of growing season: Average annual number of days with mean temperature above 5 °C in the period 1961–1990 at selected stations in Finnmark and the YNAO

Fig. 8.4). Even though the summer is warmer in most of the inland stations, the spring and autumn temperatures are higher in Nordreisa (Fig. 8.2), and the growing season usually starts before mid-May and lasts until the end of September. Both at the coast of Finnmark (Vardø) and in the inland areas (Karasjok), the growing season on average lasts between 110 and 120 days, and similar values are found in Ust'Tsilma. Even though the growing season is of similar length at these stations, the higher summer temperatures in the interior lead to higher heat sums (growing degree days, not shown) in Karasjok and Ust'Tsilma than in Vardø. In Salekhard, which represents the inland of the YNAO, the growing season on average lasts about 100 days, while Mare Sale has a growing season of less than 60 days.

Time series of the length of the growing season during the twentieth century show large variability from year to year, but there has been a trend toward a longer growing season since the 1960s (Vikhamar-Schuler et al., 2010a).

8.3.3 Precipitation in the Twentieth Century

In Finnmark, the annual precipitation is typically greater in coastal areas than inland. While Nordreisa and Vardø on average receive 550–600 mm precipitation per year, Suolovuopmi receives about 100 mm less, and Karasjok 200 mm less.

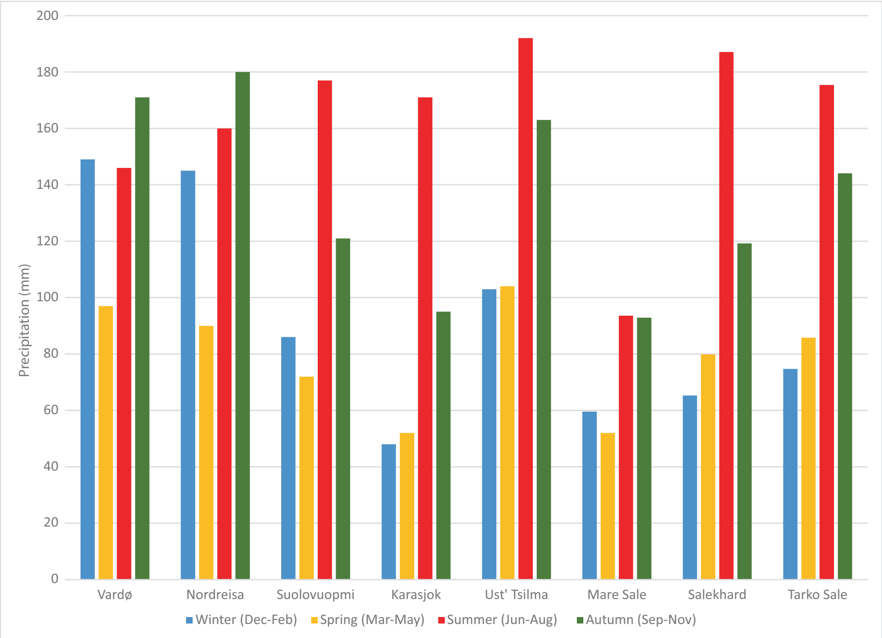

Fig. 8.5 Average seasonal precipitation (mm) during 1961–1990 at the selected stations in Finnmark and YNAO

Another difference is that the coastal stations get most of their precipitation in autumn and the least in spring, while the inland stations get most precipitation during the summer and have low values in winter and spring (Fig. 8.5).

The reason for these differences is that autumn and winter precipitation is often associated with weather systems to which the coastal stations are more exposed. The low inland winter temperatures also limit the air's capacity of carrying precipitable water. In summer, on the other hand, showers are dominating as the warmer inland stations have a larger potential for developing weather conditions favorable for convective precipitation.

The average annual precipitation sums at the inland stations in the YNAO are similar to the values from Suolovuopmi and – as with the inland Finnmark stations – these stations normally receive most of their precipitation during summer and the least in winter and spring. In spite of its coastal position, the winter sea-ice along the coast of Mare Sale leads to a "continental signature" and thus little precipitation during winter. In Mare Sale, the summer precipitation is also low, as low summer temperatures limit convective activity. Mare Sale is therefore the driest of all stations with an average annual precipitation of about 300 mm.

Time series during the twentieth century show that although the inter-annual and inter-decadal variation is considerable, there has been a statistically significant increase in annual precipitation in the area (Vikhamar-Schuler et al. 2010a, b). All stations with complete data series show an increase of more than 20%. The increase is in most cases more substantial in winter and spring.

8.3.4 Snow Climate of the Twentieth Century

The average number of days per year when the ground is covered by snow is slightly below 250 in the YNAO, both at the coastal station in Mare Sale and in Salekhard further inland (Fig. 8.6). In Finnmark, the average snow season is almost as long at the high-altitude inland station Suolovuopmi, but about 50 days shorter in Karasjok and Nordreisa.

Due to the limited number of daily snow data, the snow depth on the 31st of March is used as an indicator of snow accumulated on the ground during the snow season. This amount is usually larger at Suolovuopmi than at Karasjok and Nordreisa (Fig. 8.7). The reason for lower snow amounts in Karasjok compared to Suolovuopmi is that Karasjok generally gets less precipitation in autumn, winter and spring.

Nordreisa, on the other hand, has higher temperatures, so even if it gets more precipitation than Suolovuopmi, the snow accumulation starts later in the autumn and the total amount of snow is smaller. Data on snow depth are sparse at Mare-Sale, but the generally low precipitation level indicates that the average snow depth is rather low, even though the snow season is long. In the inland area, the conditions seem to be variable. Tarko Sale has on average a larger snow depth than all the Finnmark stations. The combination of relatively low temperatures and much precipitation during autumn at Tarko Sale may explain this. The average snow depth at the end of March in Ust'Tsilma is comparable to Karasjok. This is difficult to explain, as it receives considerably more precipitation, and the temperature conditions are similar. However, different conditions concerning drifting snow might explain this.

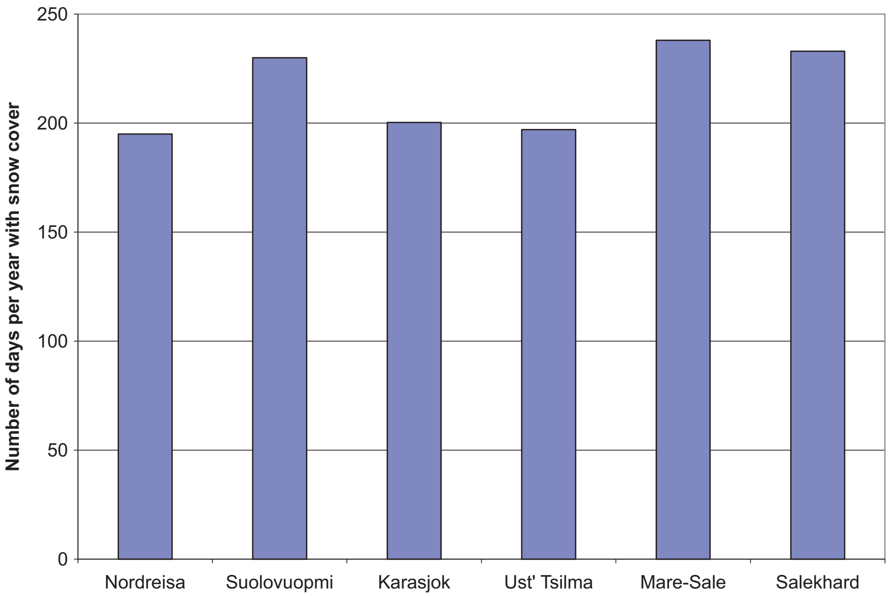

Fig. 8.6 Average annual number of days with 50% or more of the ground covered with snow in the period 1961–1990 at selected stations in Finnmark and the YNAO

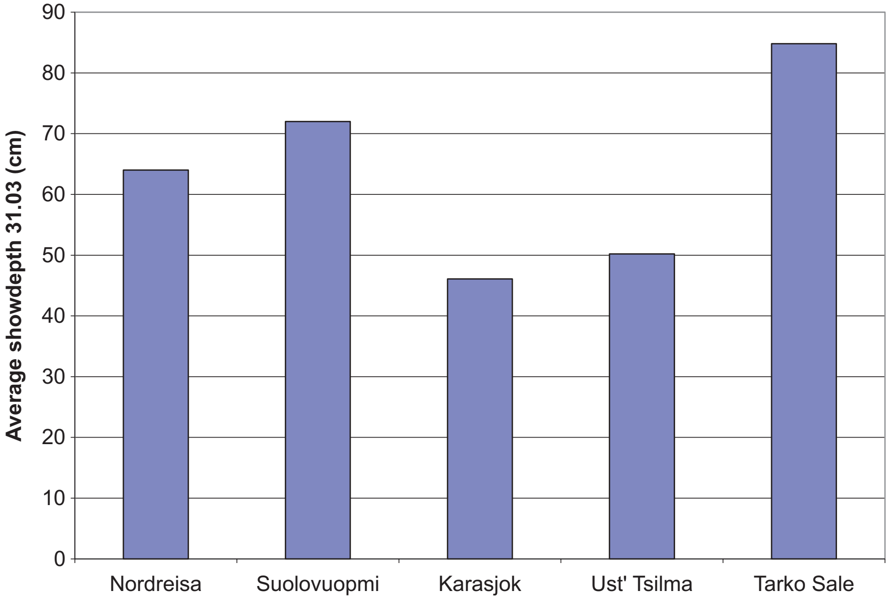

Fig. 8.7 Average snow depth (cm) on March 31st in the period 1961–1990 at selected stations in Finnmark and the YNAO

In Finnmark, the length of the snow season has decreased from the 1960s to 2018, while there has been a small increase in the average March snow depth. AMAP (2017b) indicates that also YNAO has seen a decreased length of the snow season during the later decades, while the signals concerning the winter maximum snow depth are more variable.

8.3.5 Temperature Projections for the End of the Twenty-First Century

As climate modeling is uncertain, projections should always be based upon results from several models. Figure 8.8 thus shows statistically downscaled winter temperature projections based upon 50 global models, run with a medium high emission scenario (A1B; IPCC, 2000). This work was updated by Benestad et al. (2016) for the Barents region, using the more recent scenario RCP4.5 (IPCC, 2013). The main features of the warming patterns remain the same as shown in Fig. 8.8, though the absolute value of the warming is somewhat lower under the more moderate RCP4.5 emission scenario. A comparison of the two emission scenarios is given by Hanssen-Bauer et al. (2015). In winter, there are regions in both the YNAO and in Finnmark where the projected warming is more than 7 °C towards the end of the century, assuming the A1B emission scenario (Fig. 8.8). Both Karasjok and

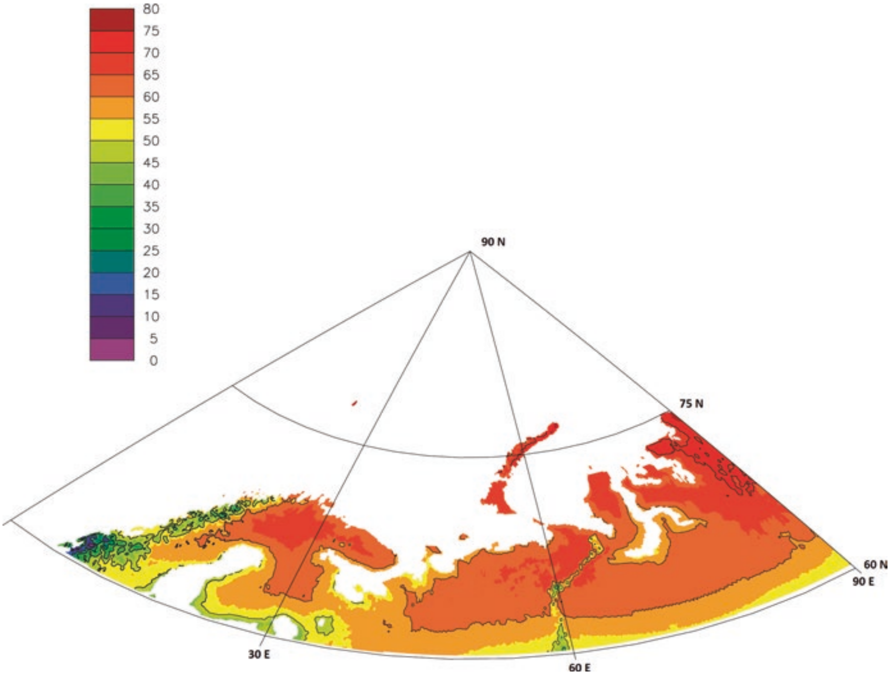

Fig. 8.8 Estimated winter temperature increase (°C) from 1975 to 2085. The estimates are averages based upon 50 downscaled climate models run with emission scenario A1B. The color scales are given in steps of 0.5 °C

Salekhard are situated in such regions. This implies that while the projected winter temperature in Salekhard is comparable to the present winter temperature in Karasjok, the future winter temperatures in Karasjok may be similar to present conditions in Nordreisa (Fig. 8.9). The geographical pattern of the projected winter temperature shows, for the most part, less increase further south on the continent, and also in mountainous areas and along the coast. An exception is coastal areas (e.g., Mare Sale) where ice-covered sea so far has been dominating in winter, but where projections indicate reduced ice cover (AMAP, 2017b). In such areas the temperature increase in winter may be larger than anywhere else. In summer (not shown), the projected warming is smaller, and more geographically homogeneous than in winter. For the YNAO and Finnmark, the average projected summer warming is around 3 °C under the A1B scenario.

8.4 Detailed Analyses for Finnmark

For Finnmark, more detailed analyses of both the present climate and possible future climate trends have been performed. A denser network of climate stations with available data (Fig. 8.10), as well as available projections not only for

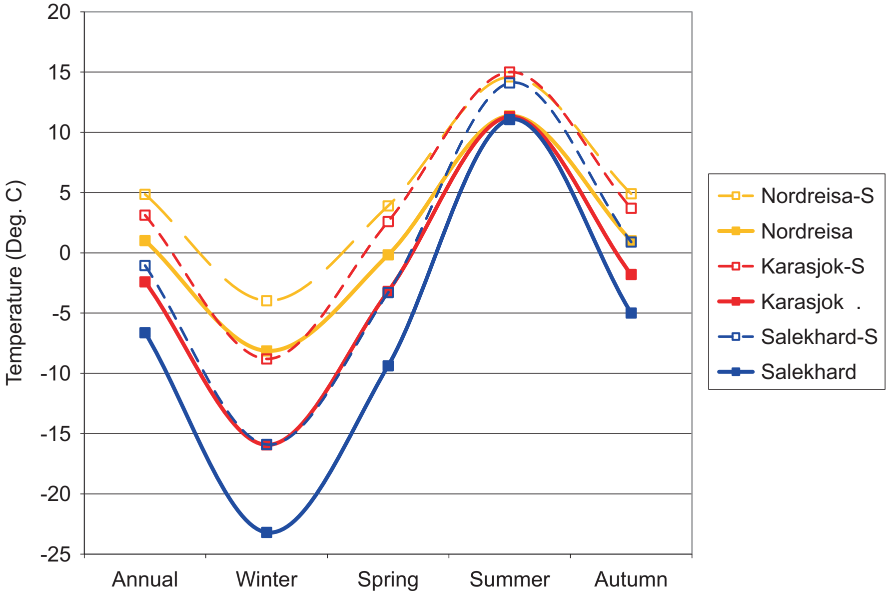

Fig. 8.9 Annual and seasonal temperature averages (°C) for 1961–1990 measured at Nordreisa, Karasjok, and Salekhard (solid lines) and the similar projections for the year 2085 calculated from 50 downscaled climate models (dotted lines)

temperature, but also for precipitation, snow season and snow water equivalent (SWE; the amount of water the snow contains) have made this possible.

8.4.1 Temperature in Finnmark

The average winter and summer temperatures in Finnmark shown in Figs. 8.11a and 8.11b confirm the impression from Sect. 8.3.1. Winter temperatures in the interior are about 10 °C lower than along the coast, while the fjord areas in general have winter temperatures between these extremes. In summer, the differences are smaller and the highest temperatures are found at low altitudes in the interior areas. The 1991–2020 climatology for Finnmark shows annual temperatures about 0.8 °C higher than the 1961–1990 values along the coast, and up to 1.2 °C higher inland (Tveito, 2021), but the main spatial features are still the same.

Winter temperature contrasts between coast and inland are especially strong for minimum temperatures. For example, while the average monthly minimum at the inland station Karasjok in January is −40 °C, it is −23 °C at the fjord station Nordreisa, and only −15 °C at the coastal station Vardø (Figs. 8.12a, 8.12b, and 8.12c). On the other hand, the average monthly maximum temperature for January is similar in Karasjok and Vardø (+2 to 3 °C) and just a few degrees more in Nordreisa. Note that the average monthly maximum temperature is above zero for all the winter months at all stations. Thus, melting events may occur in mid-winter,

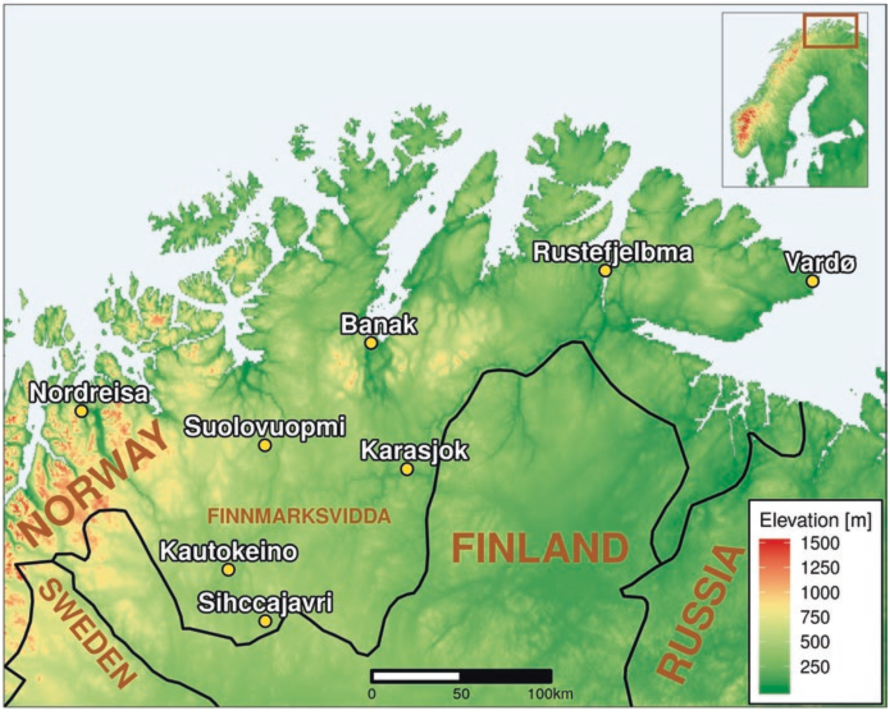

Fig. 8.10 Stations used in the detailed Finnmark climate analyses

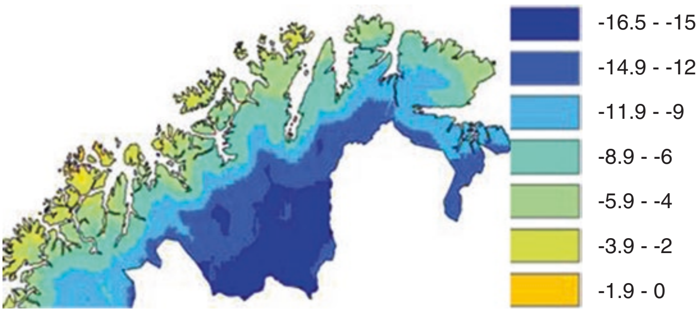

Fig. 8.11a Average winter (upper panel) temperature (°C) in Finnmark for the period 1961–1990. (Source: Norwegian Meteorological Institute)

even in the interior. In summer, the maximum temperatures are – as the average temperature – in general higher in Karasjok than in Nordreisa and lowest in Vardø (Figs. 8.12a, 8.12b, and 8.12c).

The average daily minimum temperatures are similar at all stations, while the extreme minimum temperature is lowest in Karasjok, which is the only one of the three stations where below zero temperatures have been observed in July during the

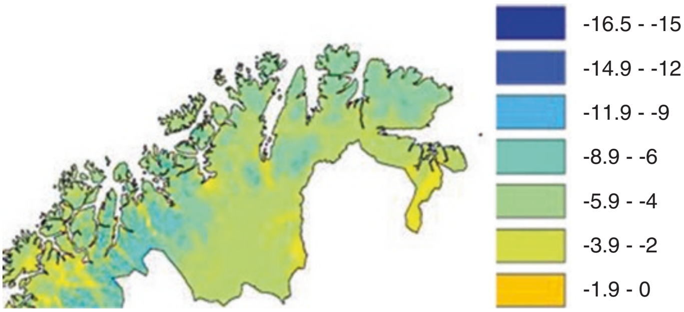

Fig. 8.11b Average summer (lower panel) temperature (°C) in Finnmark for the period 1961–1990. (Source: Norwegian Meteorological Institute)

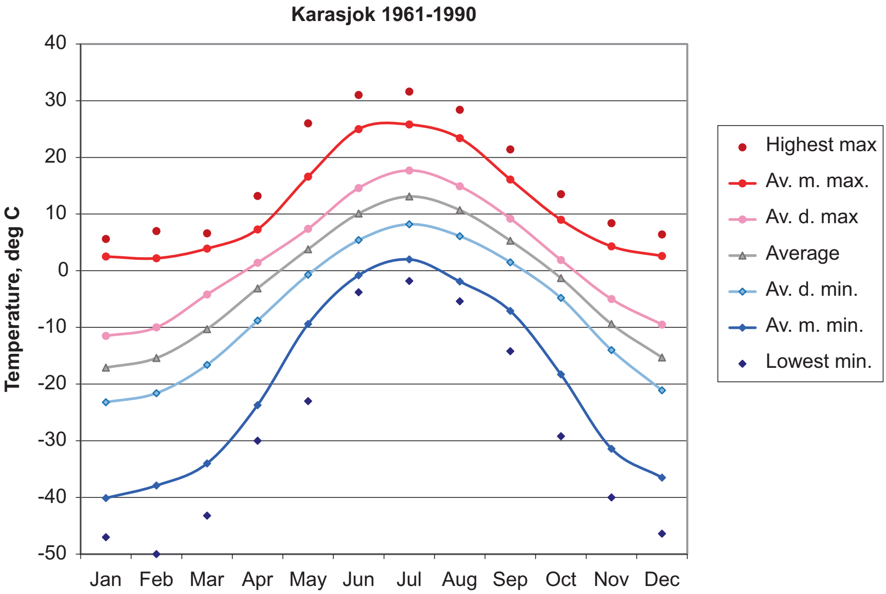

Fig. 8.12a Monthly average and extreme temperatures in Karasjok over the period 1961–1990. For each calendar month, "Highest max"/"Lowest min" are the highest maximum/lowest minimum temperatures observed at the stations, "Av. m. max"/"Av. m. min" are the averages of the highest monthly maxima/lowest monthly minima from each year (averages of 30 values), and "Av. d. max"/"Av. d. min" are the averages of all the daily maxima/minim from that specific month each year (averages of about 900 values)

period 1961–1990. The temperature variability is thus larger than at the other stations both in summer and winter. Karasjok and Kautokeino are the stations in Norway with the largest difference between the highest measured maximum and the lowest measured minimum temperature (>80 °C).

Historical series of annual mean temperatures from 1900 to 2019 show that the inter-annual temperature variation during the last 120 years is larger inland,

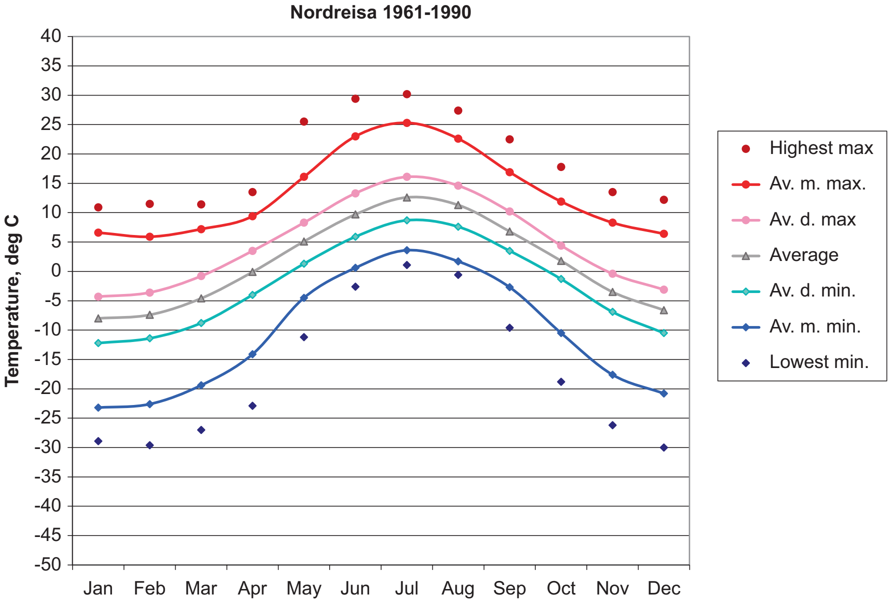

Fig. 8.12b Monthly average and extreme temperatures in Nordreisa over the period 1961–1990. For each calendar month, "Highest max"/"Lowest min" are the highest maximum/lowest minimum temperatures observed at the stations, "Av. m. max"/"Av. m. min" are the averages of the highest monthly maxima/lowest monthly minima from each year (averages of 30 values), and "Av. d. max"/"Av. d. min" are the averages of all the daily maxima/minim from that specific month each year (averages of about 900 values)

represented by Karasjok, than at the coast, represented by Vardø (Figs. 8.13a, 8.13b, 8.14a, and 8.14b). Further, clusters with several cold or warm years lead to variability on a decadal and even on 30-year timescale which also is more pronounced in the interior areas. On the 30-year timescale, both series show positive trends before the 1930s, followed by negative trends toward 1970, and positive trends from 1970 to 2019. Winter and autumn temperatures show similar patterns, while spring temperatures show small trends before 1970, and thereafter an increase.

In Figs. 8.13a, 8.13b, 8.14a, and 8.14b, the historical time series are plotted together with the projected future temperature trends under a medium scenario for future climate gas emissions (RCP4.5; IPCC, 2013), downscaled by regional climate models. "M" shows the median in an ensemble of ten projections under this scenario, while "H" and "L" show the spread of the trend projections in the ensemble (Hanssen-Bauer et al., 2015, 2017). Note that the grey lines only show the projected trend, and that there will always be interannual variation around the long-term trend, similar to what is seen in the historical series. The observed temperature trend during the later decades fits well with the ensemble of projected trends. The average ESD projection from Benestad (2011), presented in Sect. 8.3.5, is also included in Figs. 8.13a, 8.13b, 8.14a, and 8.14b. The emission scenario used by Benestad is higher than RCP4.5, and thus on average expected to give somewhat higher

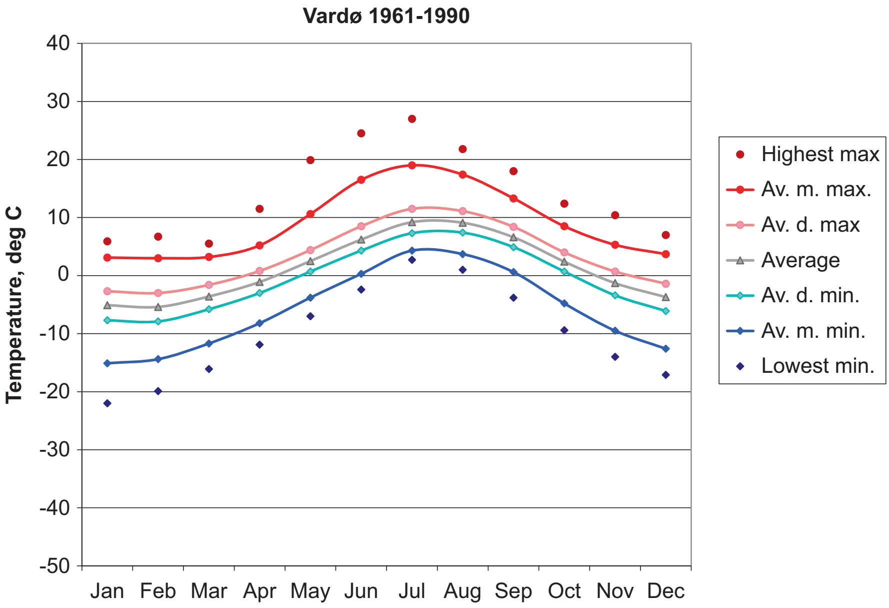

Fig. 8.12c Monthly average and extreme temperatures in Vardø over the period 1961–1990. For each calendar month, "Highest max"/"Lowest min" are the highest maximum/lowest minimum temperatures observed at the stations, "Av. m. max"/"Av. m. min" are the averages of the highest monthly maxima/lowest monthly minima from each year (averages of 30 values), and "Av. d. max"/"Av. d. min" are the averages of all the daily maxima/minim from that specific month each year (averages of about 900 values)

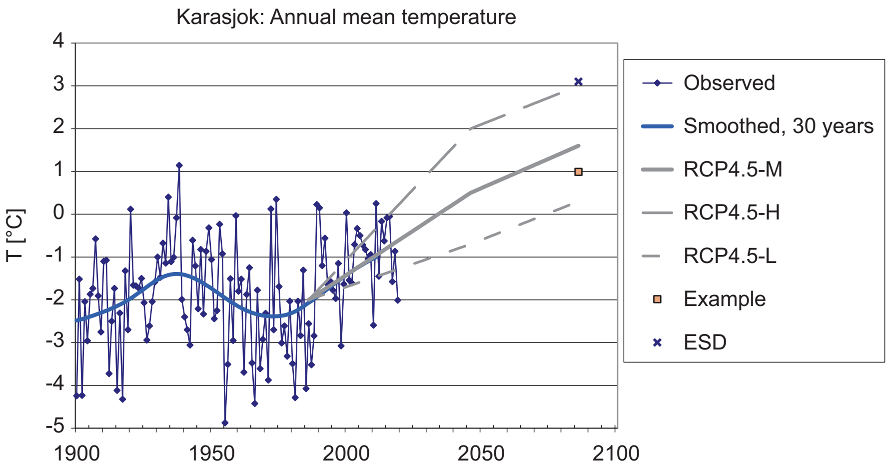

Fig. 8.13a Annual temperature series (°C) from 1900 to 2019, and temperature projections for 2031–2060 and to 2071–2100 in Karasjok. The historical series are given as curves smoothed at a 30-year time scale. For annual mean temperature, single values are also given. Grey lines show future projections for long-term trends based on a medium greenhouse gas emissions scenario (RCP4.5). "M", "H" and "L" show median, 90-, and 10-percentile from an ensemble of ten downscaled models. The cross shows the ESD projection from Sect. 8.3.5 (see Fig. 8.8). The yellow square represents the projection used in Sect. 8.4.3 to estimate future snow conditions

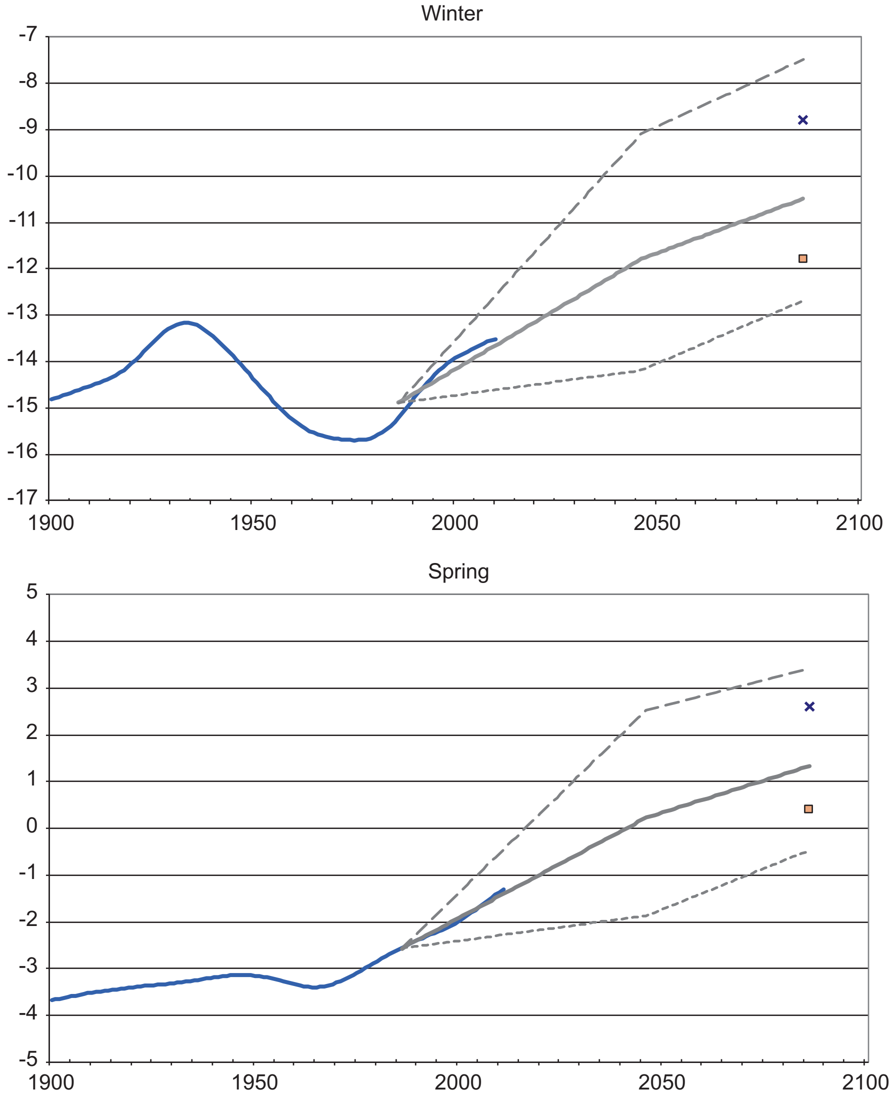

Fig. 8.13b Seasonal temperature series (°C) from 1900 to 2019, and temperature projections for 2031–2060 and to 2071–2100 in Karasjok. The historical series are given as curves smoothed at a 30-year time scale. For annual mean temperature, single values are also given. Grey lines show future projections for long-term trends based on a medium greenhouse gas emissions scenario (RCP4.5). "M", "H" and "L" show median, 90-, and 10-percentile from an ensemble of ten downscaled models. The cross shows the ESD projection from Sect. 8.3.5 (see Fig. 8.8). The yellow square represents the projection used in Sect. 8.4.3 to estimate future snow conditions

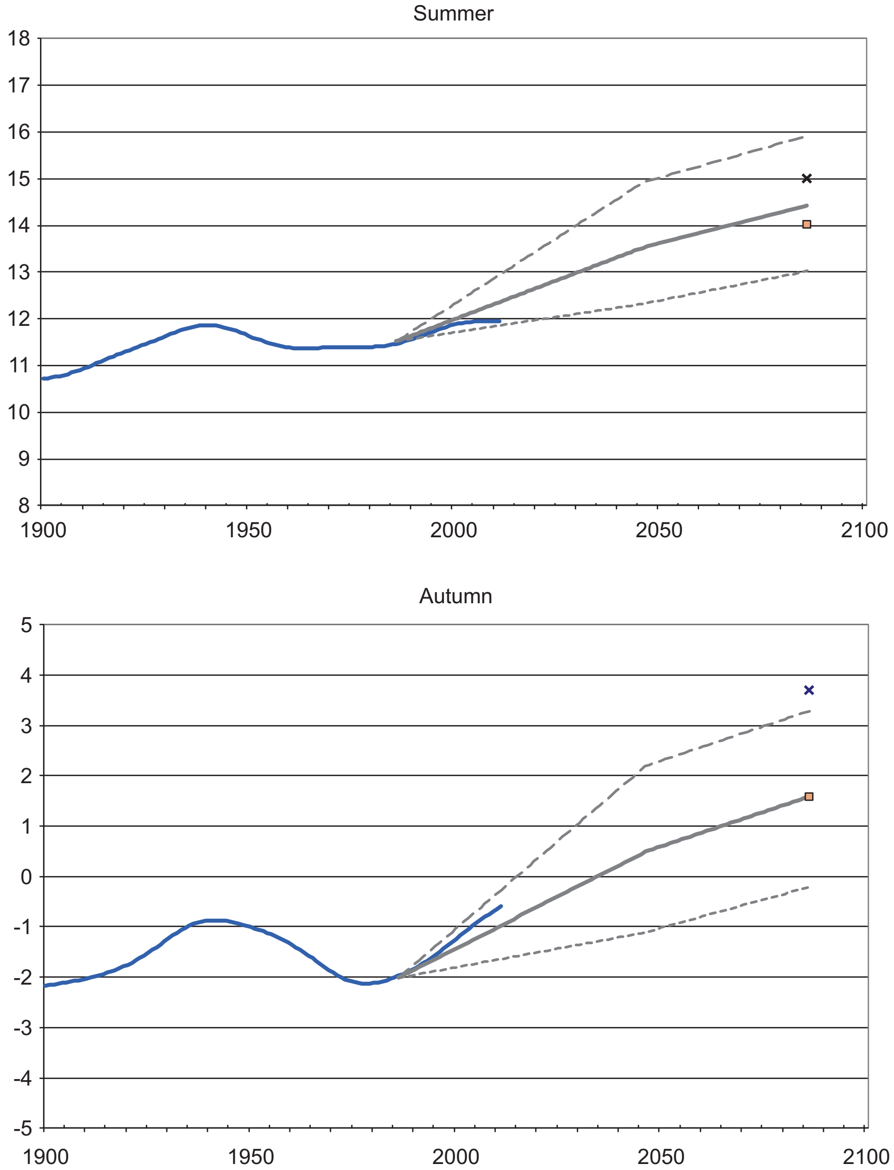

Fig. 8.13b (continued)

temperature projections. This is the case in Karasjok, where it is matching the high RCP4.5 projection. In Vardø, it is close to the medium projection. A reason for this may be that the ESD-technique better reflects the differences between coast and interior and thus indicates higher temperature increases in Karasjok than in Vardø.

Nilsen et al. (2020) studied past and projected future changes in the number of days when the temperature crosses 0 °C in different parts of Norway. For the future,

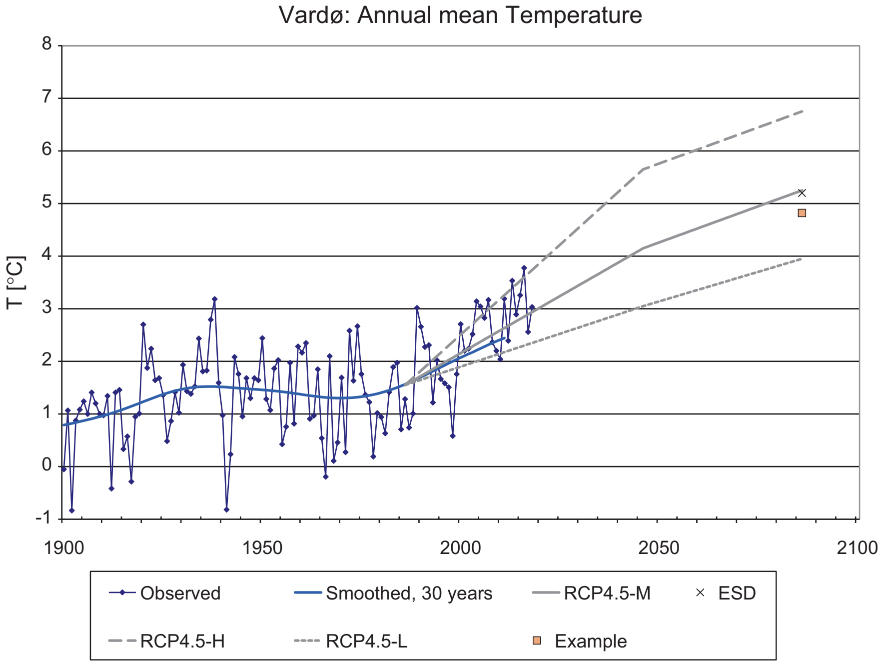

Fig. 8.14a Annual temperature series (°C) from 1900 to 2019, and temperature projections for 2031–2060 and to 2071–2100 in Vardø. The historical series are given as curves smoothed at a 30-year time scale. For annual mean temperature, single values are also given. Grey lines show future projections for long-term trends based on a medium greenhouse gas emissions scenario (RCP4.5). "M", "H" and "L" show median, 90-, and 10-percentile from an ensemble of ten downscaled models. The cross shows the ESD projection from Sect. 8.3.5 (see Fig. 8.8). The yellow squares represent the projection used in Sect. 8.4.3 to estimate future snow conditions

they applied the climate projections shown in Figs. 8.13a, 8.13b, 8.14a, and 8.14b. They concluded that the number of such days in Finnmark during the later decades has increased significantly in spring, and that it will continue to increase throughout this century, both in winter and spring.

8.4.2 Precipitation

Some inland areas in Finnmark measure less than 400 mm precipitation in an average year and are among the areas in Norway with least precipitation. Figure 8.15 shows that annual precipitation usually increases toward the coast, and that coastal areas in western Finnmark on average receive more than 1000 mm a year. Fjord areas and eastern coastal areas receive less precipitation than the west coast, but more than the interior. As indicated in Sect. 8.3.3, the contrasts between coast and the interior are at a maximum in winter, when the inland precipitation is very low,

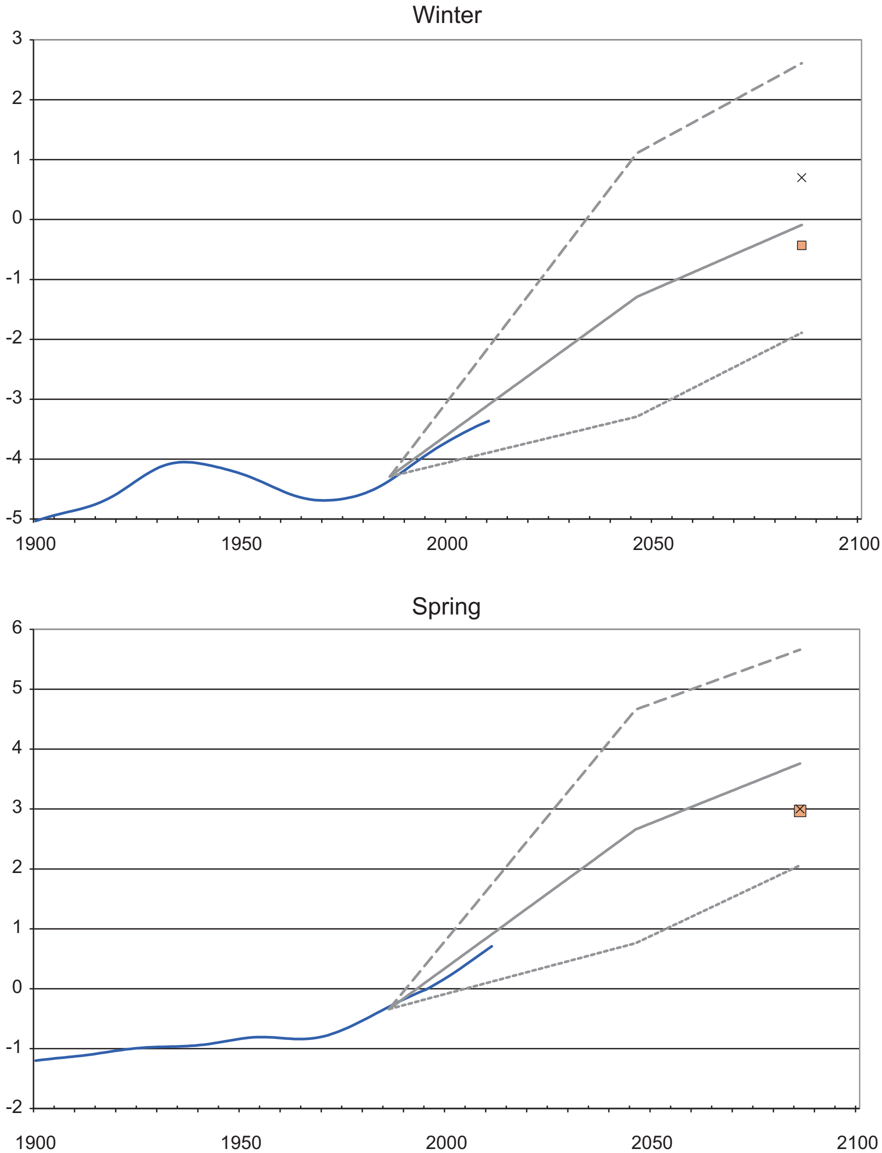

Fig. 8.14b Seasonal temperature series (°C) from 1900 to 2019, and temperature projections for 2031–2060 and to 2071–2100 in Vardø. The historical series are given as curves smoothed at a 30-year time scale. For annual mean temperature, single values are also given. Grey lines show future projections for long-term trends based on a medium greenhouse gas emissions scenario (RCP4.5). "M", "H" and "L" show median, 90-, and 10-percentile from an ensemble of ten downscaled models. The cross shows the ESD projection from Sect. 8.3.5 (see Fig. 8.8). The yellow squares represent the projection used in Sect. 8.4.3 to estimate future snow conditions

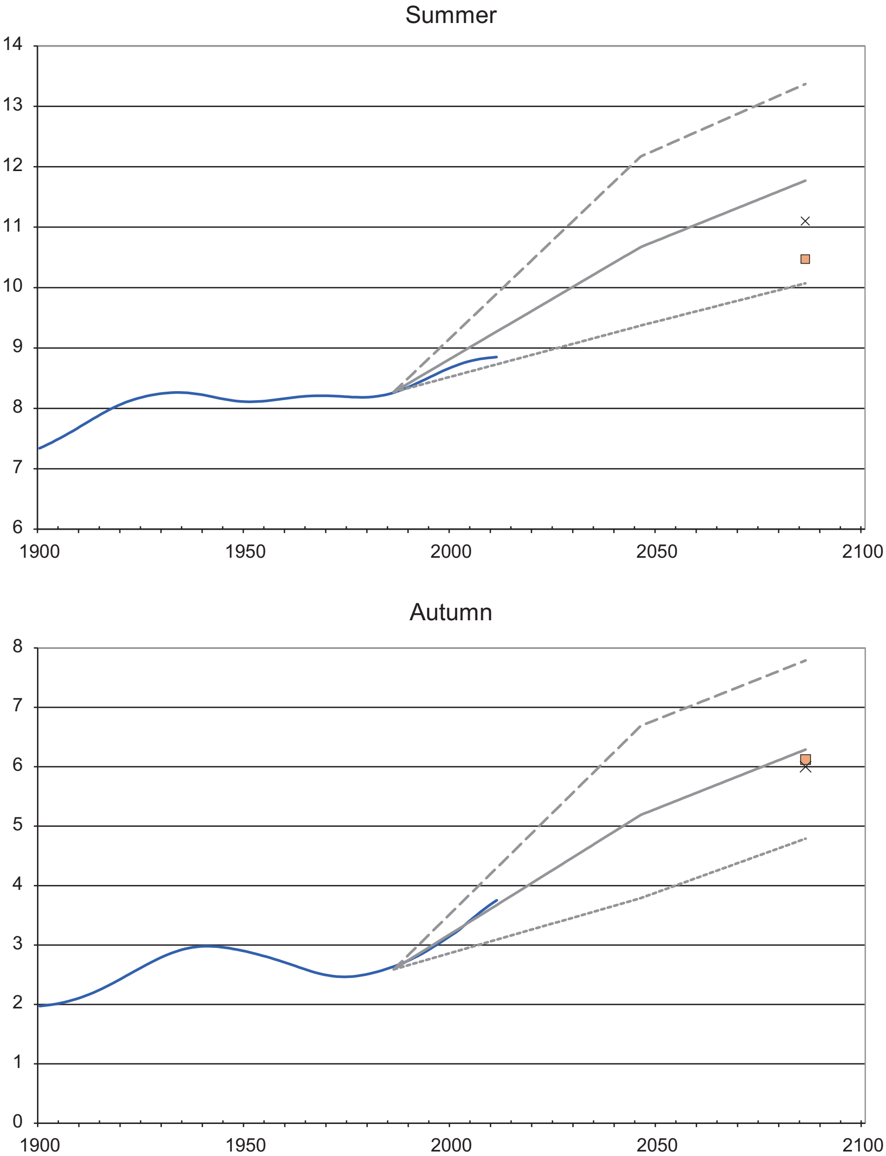

Fig. 8.14b (continued)

and in autumn, which is the wettest season at the coast. Spring is a dry season in all regions, while summer is rather wet, especially inland. The 1991–2020 climatology for Finnmark shows an increase in annual precipitation of about 12% relative to 1961–1990, mainly caused by increased winter- and spring precipitation (Tveito, 2021).

Fig. 8.15 Average annual precipitation (mm) in Finnmark for the period 1961–1990. (Source: Norwegian Meteorological Institute)

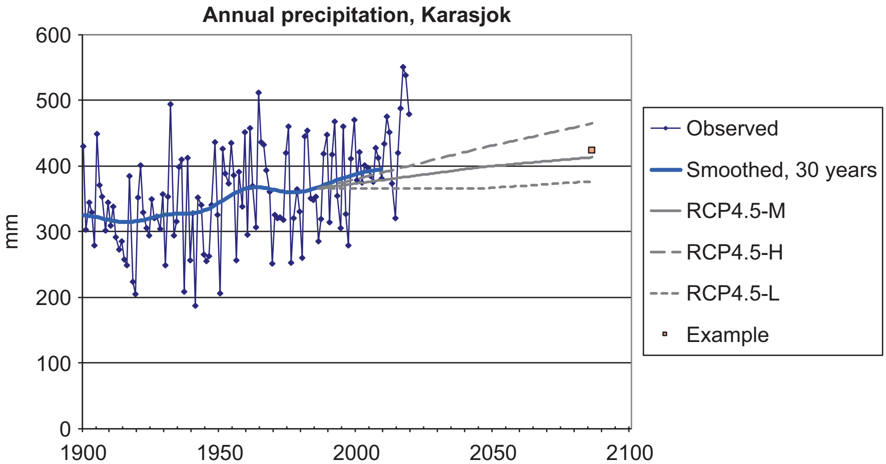

Fig. 8.16a Historical series of annual precipitation (mm) with curves smoothed at a 30-year time scale, and "high", "medium" and "low" precipitation trend projections from 1971–2000 to 2031–2060 and 2071–2100 for Karasjok. The yellow squares represent the projection used in Sect. 8.4.3 to estimate future snow conditions

Historical series of annual precipitation show that precipitation increased by almost 20% from 1900 to 2014 both in western and interior Finnmark, while there was no trend in the north-east (Hanssen-Bauer et al., 2015). In Figs. 8.16a, 8.16b, and 8.16c, these three regions are represented by Nordreisa, Karasjok and Vardø, respectively. The figure shows that the future precipitation projections under the medium emission scenario RCP4.5 indicate a continued increase of at average 10–15% during the twenty-first century, while the "low" projection indicates only minor change and "high" indicates up to a 30% increase (Hanssen-Bauer et al., 2015). As for temperature, interannual variability is projected to continue around the trend lines. The fit between observed trends during the later decades and

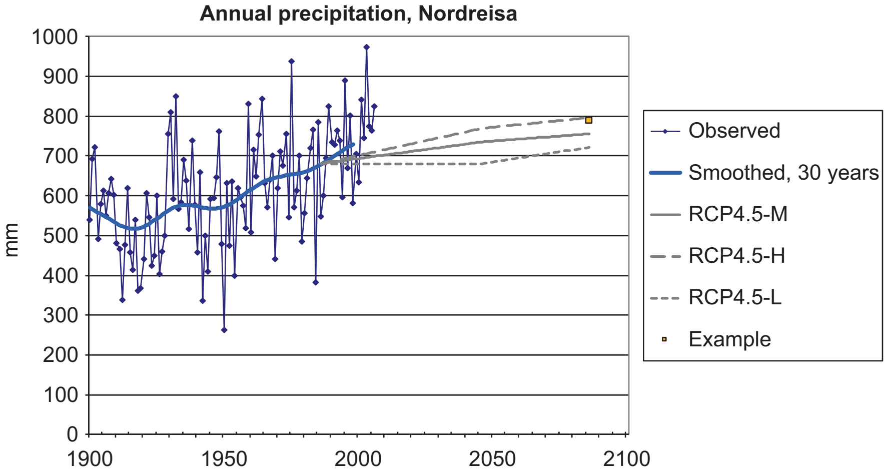

Fig. 8.16b Historical series of annual precipitation (mm) with curves smoothed at a 30-year time scale, and “high”, “medium” and “low” precipitation trend projections from 1971–2000 to 2031–2060 and 2071–2100 for Nordreisa. The yellow squares represent the projection used in Sect. 8.4.3 to estimate future snow conditions

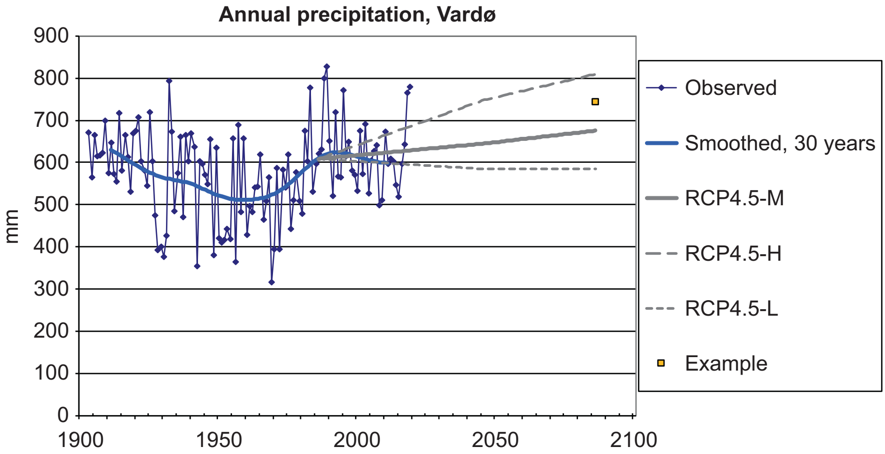

Fig 8.16c Historical series of annual precipitation (mm) with curves smoothed at a 30-year time scale, and “high”, “medium” and “low” precipitation trend projections from 1971–2000 to 2031–2060 and 2071–2100 for Vardø. The yellow squares represent the projection used in Sect. 8.4.3 to estimate future snow conditions

projected trends is not as good as for temperature. While the observations are close to the L trend in Vardø, it is comparable to the H trend in Karasjok, and in Nordreisa, it is even above the H trend. This illustrates that the model skills are poorer for precipitation than for temperature, partly because of the larger spatial variation in precipitation. Thus, a larger model ensemble is probably needed to map the real uncertainty of the projections.

8.4.3 Snow

There are few stations with high quality long-term snow measurements, and results from a hydrological model are used as a supplement to measurements in order to describe the snow conditions (Vikhamar-Schuler et al., 2006). Measurements indicate an average snow season of about 200 days in Karasjok, 230 in Suolovuopmi and 195 in Nordreisa for 1961–1990 (Fig. 8.19). Figure 8.17 shows that the results from the hydrological model are reasonably consistent with this, giving snow season durations between 176 and 225 days in coastal and fjord areas and in low altitude inland areas, but above 225 days in most of the interior.

The reason for the shorter snow season along the coast is that the temperatures are higher in spring and autumn, consequently the snow season starts later in autumn and the melting starts earlier in spring (Vikhamar-Schuler et al., 2010b). The reason for the shorter snow season in low altitude inland sites like Karasjok is little precipitation in winter, and thus small amounts of snow, as seen in Figs. 8.17 and 8.18. Figure 8.18 shows the average winter maximum snow equivalent (the water value of the snow) for the period 1961–1990 from the hydrological model. Though the values are not directly proportional to maximum snow depth, as the snow density varies, the map clearly indicates small amounts of snow inland, especially at low altitudes, and larger amounts closer to the coast, and especially at high altitudes.

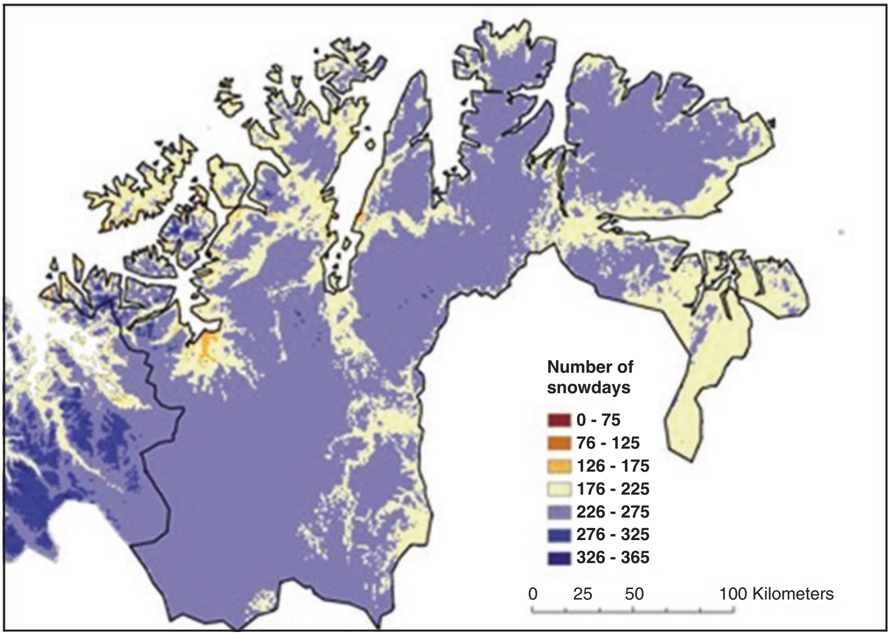

Fig. 8.17 Average number of days with snow cover in Finnmark for the period 1961–1990 calculated by a hydrological model. (From Vikhamar-Schuler et al., 2006)

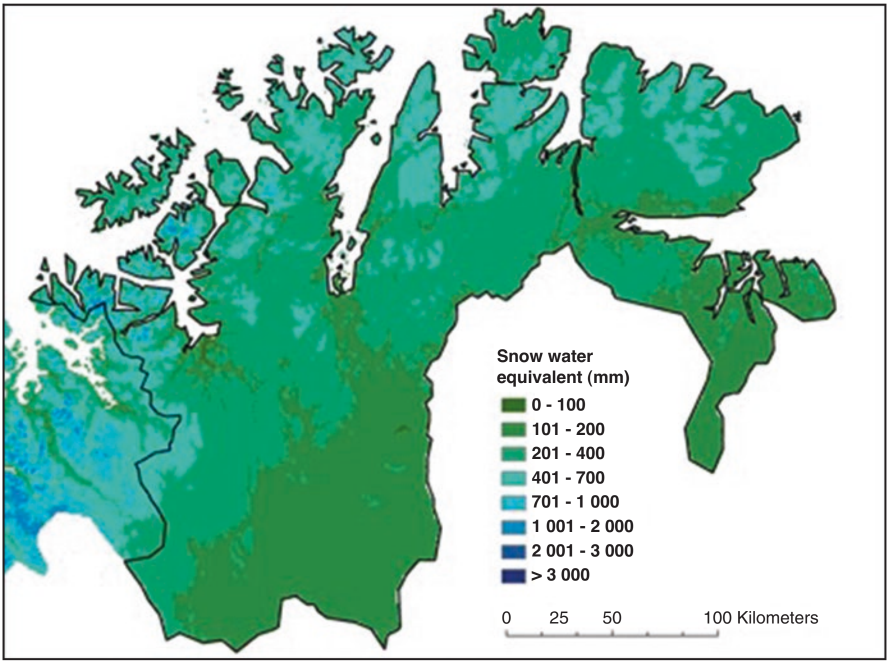

Fig. 8.18 Average maximum snow water equivalent (unit: mm) in Finnmark for the period 1961–1990 calculated by a hydrological model. (From Vikhamar-Schuler et al., 2006)

Trend analysis of historical time series from the twentieth century indicate that the snow season typically decreased by around 3 weeks from 1900 to 2019 at the stations with sufficiently long observational series, but that there is large inter-annual variation (Fig. 8.19). Vikhamar-Schuler et al. (2010b) showed that, especially in Karasjok, the main change is that the snow melts earlier in the spring now than it did around 1900. In Nordreisa, there is also a clear trend toward delayed start of the snow season.

Drifting snow may cause large local variations in snow depth. Trend studies of maximum snow depth are thus vulnerable to small relocations of the site of measurements, and also in its environments. The series from Karasjok and Nordreisa are believed to be reasonably homogeneous, while Suolovuopmi is not. Nordreisa shows no trend during the twentieth century, while the measurements indicate a trend toward higher maximum snow depth in Karasjok (Vikhamar-Schuler et al., 2010b).

The hydrological model which was used to produce the maps for snow cover and maximum snow water equivalent for 1961–1990 was also used to calculate a snow projection for 2071–2100, based upon the temperature and precipitation "example projections" which are plotted in Figs. 8.13a, 8.13b, 8.14a, 8.14b, 8.16a, 8.16b, and 8.16c. The results indicate a reduction in the average snow season everywhere towards the end of the twenty-first century (Fig. 8.20). The least reduction is

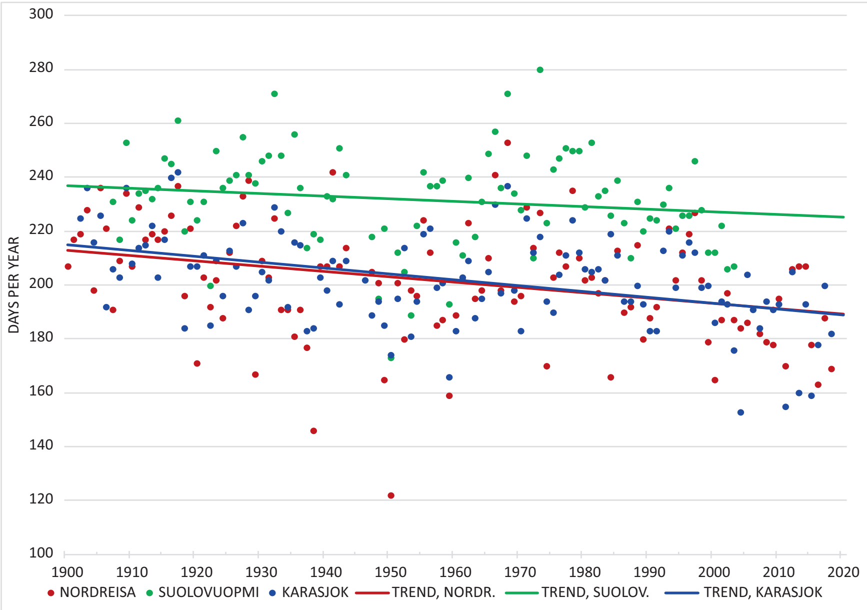

Fig. 8.19 Number of days per year with 50% or more snow cover in Karasjok, Suolovuopmi, and Nordreisa

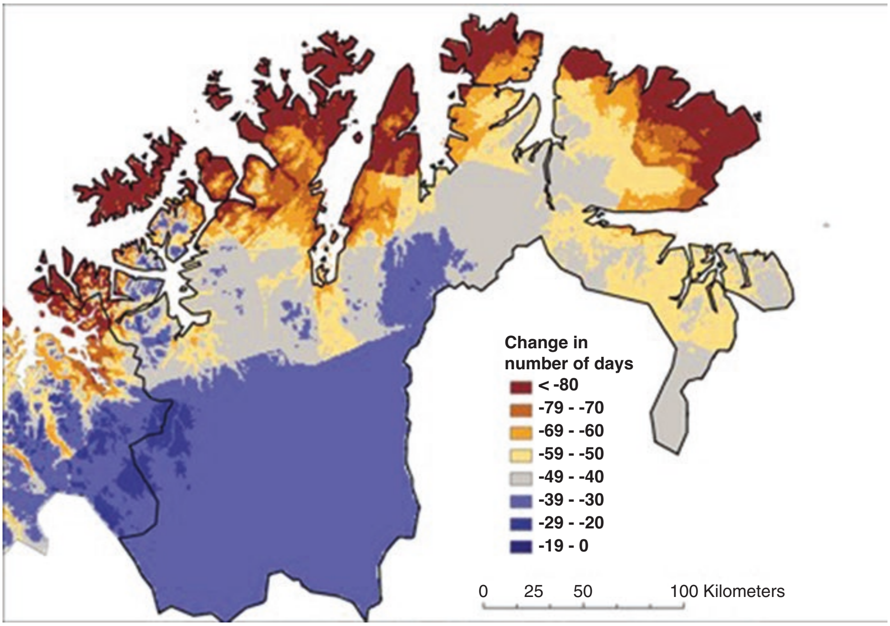

Fig. 8.20 Projected change in average number of days with snow cover in Finnmark towards 2100 according to the example projection. (From: Vikhamar-Schuler et al., 2006)

projected inland, where a reduction of 4–5 weeks is indicated over large areas. In the inner fjord areas, a reduction of 6–8 weeks is typically projected, while fjord mouths and coastal areas according to the projection may have a reduction of almost 12 weeks.

The projected changes in the average maximum snow water equivalent are also larger along the coast, where reductions of more than 60% are indicated in some areas. In the inner fjords, a 20–40% reduction is more typical. In inland areas, the projected reduction is smaller, and for a few sites, the average maximum snow water equivalent is even projected to increase slightly (Fig. 8.21). The reason for this is that the projected increase in precipitation can lead to larger snow accumulation even though the snow season is reduced. This may be the case for larger inland areas in the short run, and is consistent with the fact that there has been a trend towards higher maximum snow amounts in Karasjok so far.

When studying single years in the projection period, Vikhamar-Schuler et al. (2006) found that also in some inland areas where the average maximum snow water equivalent is projected to decrease, the maximum values for some individual years in the projection period are larger than they are in the reference period 1961–1990. This implies a possibility for increased variability in maximum snow amounts from one winter to the next in the future when compared to present conditions.

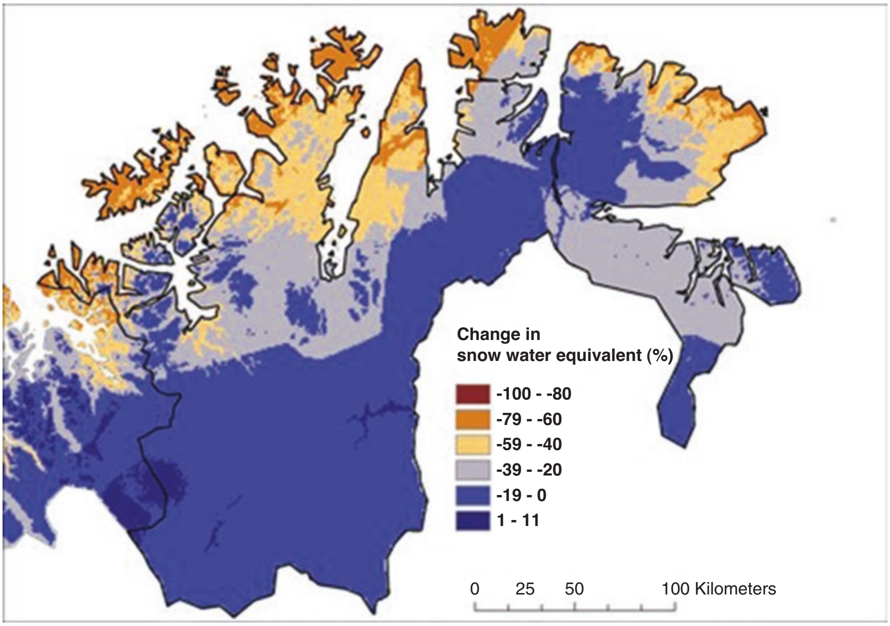

Fig. 8.21 Projected relative change in average maximum snow water equivalent (unit: % of the 1961–1990 values) in Finnmark towards 2100 according to the example projection. (From: Vikhamar-Schuler et al., 2006)

8.5 Modeling Snow Properties in Kautokeino, Finnmark

The ability of reindeer to access pasture through the snow has its own term (*guohtun*) in the Sámi language. Difficult grazing conditions are usually snow structures rather than snow amounts, e.g., ice-layers in the snowpack or at the snow-ground interface. On the other hand, loose snow structures (depth hoar) increase the accessibility of food below the snowpack. A review by Tyler (2010) questions snow conditions and the causes of the decline of circumpolar reindeer and caribou populations.

Structures in the snow layer are not observed regularly at climate stations. However, applying the SNOWPACK model (see Sect. 8.2) the EALÁT project was probably the first to set up such a model in order to describe *guohtun* (Eira, 2012). The goal was to simulate the evolution of the snow cover stratigraphy under past and present climate conditions. A summary of the study is given below. More details can be found in Vikhamar-Schuler et al. (2013).

8.5.1 Modeling the Snowpack over the Last 50 Winters in Kautokeino

In order to validate the SNOWPACK model, information from reindeer herders on the winter grazing conditions is crucial. Difficult winter conditions include ice layers in the snow, too deep snow or long snow season, while good conditions imply deep hoar layers, loose snow structures or shallow snow cover. From the limited information from reindeer herders that can be found in the scientific literature, it is clear that these conditions have varied greatly from year to year (Tyler et al., 2007; Lie et al., 2008; Päiviö, 2006). The information indicates difficult winter grazing conditions over the entire or parts of the Finnmark plateau during the winters 1917/18, 1957/58, 1961/62, 1966/67, 1967/68, 1989/1990, 1996/97, 2000/2001 as well as during the 1990s in general (Tyler et al., 2007; Lie et al., 2008). Good winter grazing conditions have been reported during the 1980s in general. The unfavorable grazing conditions during the winters 1957/58, 1961/62, 1967/68 were caused by ice layers in the snowpack (Lie et al., 2008). These ice layers were formed after mild weather events followed by extreme cold. For northern Sweden, Päiviö (2006) describes historical winter grazing conditions in the Jokkmokk region. He describes 1967/68 as a catastrophic year for reindeer herding, in addition to 1935/36 and 1955/56. Furthermore, he describes the second part of the 1970s and the entire 1980s as years with favorable winter grazing conditions, while the 1990s had unfavorable conditions. The present study is restricted to analyzing the weather situations that lead to the formation of high-density snow layers (ice layers) and to compare the modelled years with the documented years of favorable or unfavorable grazing conditions.

Model results for the catastrophic year 1967/68 are shown as an example. Observations from the Kautokeino weather station from autumn 1967 show rain-on-snow events occurring in the beginning of November (Fig. 8.22), followed by periods of cold weather. This created a very hard snow layer. Modelled snow density for the winter season 1967/68 (Fig. 8.23) shows that a high-density snow layer was formed at the ground and persisted throughout the winter.

Snow profiles as the one shown in Fig. 8.23 were computed for Kautokeino for every winter over the period 1956–2010. To compare all the winters, the depth of the high-density layers (density > 235 kg/m^3) in the snowpack were summarized for every timestep (Fig. 8.24). Overall, modeling indicates that both the winters of 1966/67 and 1967/68 had a significant element of high-density layers in the snowpack, as compared to all the other years. Furthermore, the modeling results show few high-density layers during the 1970s and the 1980s, but more unstable situations during the 1990s and 2000s. This is consistent with the observed increasing number of days when the temperature crosses 0 °C (Sect. 8.4.1). These modeling results also correspond well with reindeer herders' reports of grazing conditions. Particularly, the winters 1991/92 and 2000/01 are modelled with some high-density layers in the snowpack (Figs. 8.25a and 8.25b).

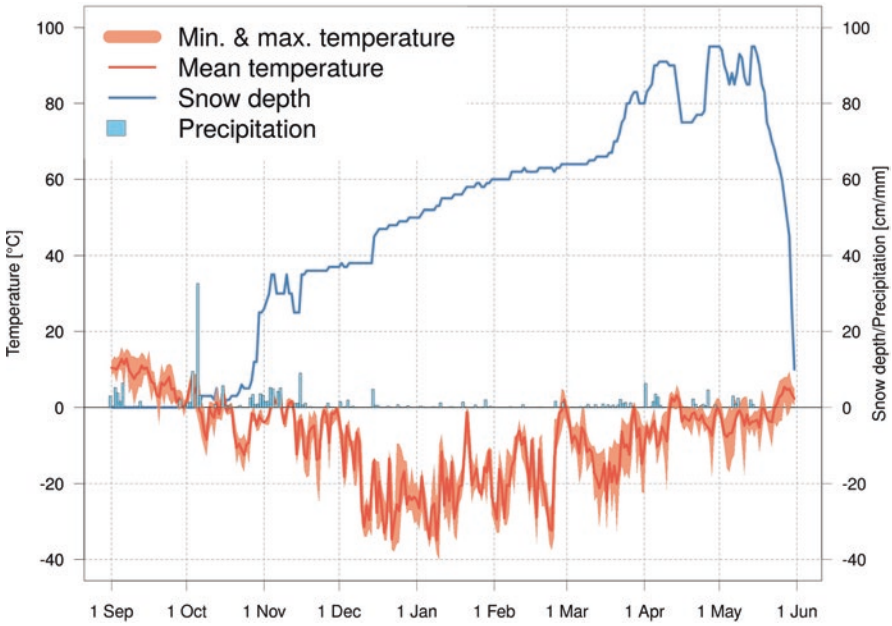

Fig. 8.22 Weather causing ice-layer formation during the autumn and winter 1967/68 in Kautokeino. (Data from the Norwegian Meteorological Institute)

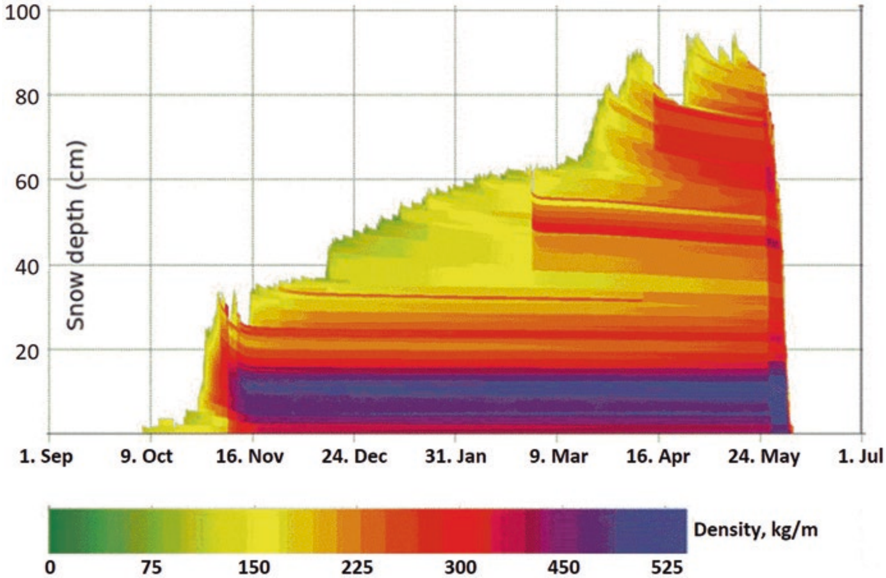

Fig. 8.23 High-density layers formed during autumn 1967 (modeling results). A mild weather event followed by extreme cold in mid-November created a high-density snow layer at the ground surface which persisted throughout the winter and spring. (From: Vikhamar-Schuler et al., 2013)

8.5.2 *Further Perspectives for Modeling Snowpack Structure*

The snow modeling results successfully:

- Reproduced periods with ground-ice conditions causing difficult grazing conditions: The years 1966/67, 1967–1968 and 2000/01, where 1966/67 is known to be a difficult year for the reindeer herding on the Finnmark plateau.
- Reproduced the period between the 1970s and the 1980s with favorable winter grazing conditions and there were no particular high-density layers in the snowpack.

The correspondence between herders' reports and the model results are promising, concerning the model's ability to describe some structures of relevance for reindeer grazing conditions. It should thus be possible to apply the model to produce projections for future *guohtun*.

A study by Rasmus et al. (2016), using the SNOWPACK model with input from four regional climate projections (based on two global models run under two scenarios), indicates on average a shorter snow season and less snow, but more frequent ice layers in northern Finland towards the mid-century. According to Turunen et al. (2016) the shorter snow season might be positive for reindeer herding, while an increased frequency of ice layers definitely will have a negative impact. These results cover a limited area, and the models applied also have a limited spatial resolution (about 50 km). The spatial variability of snow conditions is considerable,

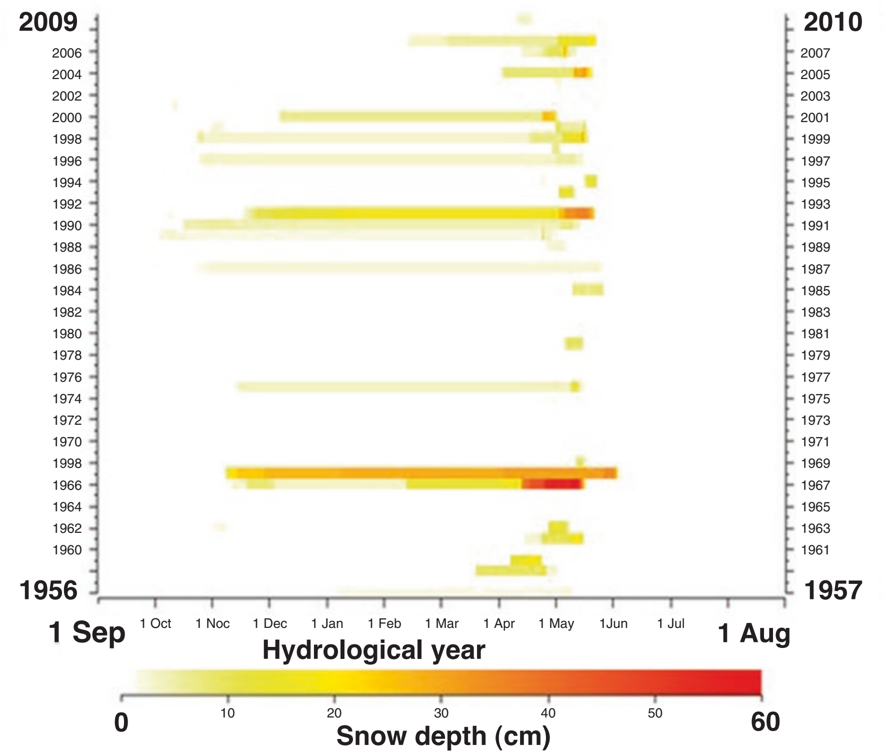

Fig. 8.24 High-density snow layers (density > 235 kg/m^3) at the Kautokeino weather station, modelled with the SNOWPACK model. The white color represents periods without high-density layers present in the snowpack. Orange and red represent increasing thickness of high-density layers. (From: Vikhamar-Schuler et al., 2013)

Fig. 8.25a Spring migration of the Nenets reindeer herders crossing the Ob Bay, Russia on their way to summer pastures in the Yamal Peninsula, Russia (2007). (Photo: E.I. Turi)

Fig. 8.25b Spring migration of the Nenets reindeer herders crossing the Ob Bay, Russia on their way to summer pastures in the Yamal Peninsula, Russia (2007). (Photo: E.I. Turi)

because of small-scale variability of precipitation, as well as temperature variation caused by topography, and redistribution of snow by wind. It would thus be interesting to produce more detailed projections, and to cover a larger area. Forbes et al. (2016) reported a connection between an observed increasing frequency of rain-on-snow events on the Yamal peninsula and the shrinking winter sea-ice cover in the area. Modeling future winter conditions in coastal areas in YNAO may thus be of special interest.

8.6 Conclusions

Climatological data from selected sites in Finnmark, Norway, and the YNAO, Russia, show that the average summer temperatures lie typically between +10 and +15 °C in the inland area, and between +5 and +10 °C along the coast. Typical average winter temperatures range from −20 to −25 °C in the YNAO, while interior Finnmark has winter temperatures of around −15 °C with coastal Finnmark up to −5 °C. Local projections for climate change under a medium high global warming projection show that the average summer temperatures may increase by about 3 °C in 100 years both in Finnmark and the YNAO, while winter temperatures are projected to rise by more than 7 °C in some inland areas, and somewhat less in most coastal areas. This implies that the projected winter temperatures in the inland of the YNAO will be comparable to the present conditions in the interior of Finnmark, while the future winter temperatures in interior Finnmark may be similar to the present conditions in the fjord districts of Finnmark. The risk for warm events with above 0 °C temperatures as well as rain-on-snow events in winter will thus increase in both areas, compared to the present situation. Presently, the average annual precipitation in coastal Finnmark is about 600 mm, with a maximum in autumn and a minimum in spring. In the interior regions of Finnmark as well as the YNAO, precipitation is lower annually (350–500 mm), and also in autumn and especially winter. Summer precipitation, on the other hand, is slightly higher in the interior regions. The coastal zone of the YNAO is presently the driest part of the area, as precipitation is sparse in all seasons. Global climate projections in general project increased precipitation at high latitudes. Local precipitation projections developed for Finnmark under a medium emission scenario indicate an increase of about 10–15% in 100 years, but are regarded as more uncertain than temperature scenarios.

The ground is presently covered by snow from about 6 to 8 months a year in Finnmark and the YNAO. The snow season tends to be longest in the coastal areas of the YNAO, while it is shortest in coastal Finnmark. Typically, the snow depth in early spring is between 0.4 and 0.9 m. A local snow projection for Finnmark indicates a considerable reduction in the snow season (3 months) and maximum snow depth (−60%) along the coast. In the interior, the projected snow season reduction is smaller (about 1 month), and the projected change in maximum snow depth is minor, as increased winter precipitation compensates for the shorter snow season.

Information from reindeer herders indicates that the grazing conditions in winter depend more on the structure of the snowpack than on the amounts of snow. Snow structure is not observed regularly, but a model which calculates snow structure from standard weather observations was tested for interior Finnmark. The model successfully identified winters with serious problems connected to ice layers in the snow in the near past. A study from Finland indicates that the model may also be used for projecting “difficult winters” in the future. More detailed climate projections than those available for the present study will be needed for making similar projections for Finnmark and YNAO.

The projected warming and precipitation changes in Finnmark and the YNAO will probably not by themselves challenge reindeer husbandry, however, the warming and increased precipitation will lead to changes in the hydrological cycle, including snow conditions, which may be important. Further, the warming leads to an increased growing season, which may affect the vegetation and thus pastures.

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Chapter 9
Loss of Reindeer Grazing Land in Finnmark, Norway, and Effects on Biodiversity: GLOBIO3 as Decision Support Tool at Arctic Local Level

Wilbert van Rooij, Iulie Aslaksen, Isak Henrik Eira, Philip Burgess, and Per Arild Garnåsjordet

Abstract Competing land use and climate change are threats to the pasture land of Sámi reindeer herding. Reindeer pastures are exposed to the development of infrastructure, hydropower, mineral exploration, recreational cabin areas, and wind power. Land use conflicts are exacerbated under climate policy with wind power plants in reindeer herding areas. Projected developments and climate change impacts challenge the adaptive capacity of reindeer herders and the resilience of reindeer herding. Analysis of biodiversity loss by the GLOBIO3 model is suggested as tool for decision support, in consultation with Sámi reindeer owners, taking into account traditional knowledge of reindeer herding. GLOBIO3 analysis for Sámi reindeer herding land in Finnmark indicates that in 2011, compared to an intact situation, about 50% of the biodiversity of reindeer calving grounds has been lost, and it is expected to be reduced with another 10% in the scenario for 2030. Reindeer owners in Finnmark told that they expect biodiversity loss will have implications for the quality and extent of suitable grazing areas. Especially the quality of the calving grounds is essential for reindeer herding. An important lesson from dialogue with reindeer owners is that even highly impacted areas should not be considered as lost, and thus be opened to further development, as they are still important for seasonal reindeer migration and grazing at certain times of the year. The chapter presents research on methods development, traditional knowledge in the context of Sámi

W. van Rooij
Plansup, Lochem, the Netherlands

I. Aslaksen (✉) · P. A. Garnåsjordet
Statistics Norway (SSB), Oslo, Norway
e-mail: iulie.aslaksen@ssb.no

I. H. Eira
Protect Sápmi and International Centre for Reindeer Husbandry, Guovdageaidnu, Norway

P. Burgess
Arctic Global Change and University of Lapland, Rovaniemi, Finland

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reindeer herders in Finnmark and highlights innovative tools to engage rightsholders and stakeholders in the Arctic in development planning processes.

Keywords Reindeer herding · GLOBIO3 model · Sámi traditional knowledge

9.1 Introduction

Competing land use and climate change are threats to reindeer herding, as to pastoral livelihoods worldwide (Uboni et al., 2020). Migrations of reindeer, as other ungulates, are disappearing at an alarming rate, and tracking data combined with local and Indigenous knowledge can form the knowledge basis to support conservation action and policy at local, national, and international levels (Kauffman et al., 2021). The biodiversity of reindeer herding land is impacted by loss of land due to development of infrastructure, buildings, and industry, and by changes in species composition due to climate change. The characteristic Arctic biodiversity is threatened as species migrate north under warming climate (Arctic Biodiversity Assessment, 2013). The changes affect livelihoods and cultures of Indigenous communities and challenge the adaptive capacity and resilience of nature-based livelihoods that depend on Arctic biodiversity (Eira et al., 2018; Tyler et al., 2007).

Reindeer herding is livelihood for more than 20 Indigenous Peoples[1] in the circumpolar Arctic. Reindeer husbandry is practiced in Norway, Sweden, Finland, Russia, Mongolia, China, Alaska, Canada and Greenland, with about 3.4 million semi-domesticated reindeer (Magga et al., 2011; Maynard et al., 2011; Turi, 2002; International Centre for Reindeer Husbandry, 2021). For these Indigenous Peoples, reindeer represent their cultural, economic, social and spiritual foundation. Reindeer husbandry represents a connection between people and nature, ancient in origin, and practiced almost identically wherever it is found (United Nations, 2012). Traditional Sámi use and management of land and resources have aimed for a land use that secures livelihoods for future generations (*birgejupmi*) and good environmental management (Sámi Parliament, 2016).

In the past decades, reindeer pastures have been exposed to loss and fragmentation of land, from development of infrastructure, hydropower, mineral exploration, recreational cabin areas, and wind power (Vistnes & Nellemann, 2007; Nellemann et al., 2003; Pape & Löffler, 2012). Loss of land is the largest threat to reindeer herding (Danell, 2005; Pape & Loeffler, 2012). Land use conflicts are exacerbated under climate policy with wind power plants in Sámi reindeer herding areas (Skarin & Åhman, 2014; Skarin & Alam, 2017; Skarin et al., 2018).

Global reports by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES, 2019) on biodiversity loss, and by the climate panel (IPCC, 2019) on climate change and land use, call for land management that

[1] https://www.un.org/development/desa/indigenouspeoples/about-us.html

support both climate mitigation and biodiversity. Land use change, infrastructure development, fragmentation, and climate change are major human-induced impact factors on biodiversity (IPBES, 2019). Both the global studies and the Nature Index for Norway (Jakobsson & Pedersen, 2020) point to land use change as the strongest driver of biodiversity loss. Warming climate in the Arctic and re-growth of forest on the tundra directly impairs reindeer herding as the composition of species on pastureland is changed under forest re-growth (Arctic Biodiversity Assessment, 2013).

Reindeer herders have through their traditional knowledge developed unique management strategies for sustainable use and protection of pastures, and observation of changes. Adaptation to climate change calls for governance practices that take into account Sámi traditional knowledge, including the need for flexibility in the use of reindeer pastures (Eira et al., 2018; Burgess et al., 2018; Johnsen, 2018; Turi, 2016; Tyler et al., 2007). The future for reindeer herders' communities is dependent on use of their traditional knowledge and implementing risk spreading through diversity in social organization, economy, and understanding of biodiversity and flexible use of pastures (Magga et al., 2011).

Traditional knowledge is defined by the Ottawa principles of the Arctic Council as a systematic way of thinking and knowing, "*owned by the holders of that knowledge, often collectively, and is uniquely expressed and transmitted through Indigenous languages. It is a body of knowledge generated through cultural practices, lived experiences including extensive and multigenerational observations, lessons and skills. It has been developed and verified over millennia and is still developing in a living process, including knowledge acquired today and in the future, and it is passed on from generation to generation*" (Arctic Council Permanent Participants, 2015).

Fulfilment of Indigenous Peoples' rights to land and resources includes recognizing the importance of traditional knowledge for management of grazing land. Culturally relevant criteria for land use management need to be identified, aligned with Indigenous practice. There is need for studies on impacts of land-use change and climate change on reindeer herding land. The special rapporteur to the Permanent Forum on Indigenous Issues has proposed to increase transparency in decision-making on land use, develop new criteria for impact assessments, and monitor reindeer pastures (United Nations, 2012).

This chapter addresses how impacts on Sámi reindeer herding land can be assessed with the GLOBIO3 model and applied as decision support for land use planning, in consultations with Sámi reindeer owners. GLOBIO3 is a spatial model, based on GIS methodology, for assessing impacts on biodiversity indirectly, by modelling pressures on biodiversity. GLOBIO3 is based on cause-effect relations between pressures and impact on biodiversity, as reported by Alkemade et al. (2009), and we apply the assumptions made by Alkemade et al. (2009), with some adjustments to Arctic conditions.

GLOBIO3 is designed for implementation at global scale and is used for international biodiversity assessments, including Global Biodiversity Outlook for the Convention on Biological Diversity (CBD), UNEP Global Environment Outlook, and OECD Environmental Outlook. Although used by high level reports, and many national studies, there is need to achieve more experience with downscaling the global assumptions to local conditions. In this chapter an implementation of the GLOBIO3 model is presented and discussed for potential use as decision support tool at local Arctic level, with a study of Finnmark, a core area for Sámi reindeer herding in Norway (van Rooij et al., 2017). As data on biodiversity is limited, and field mapping is costly, GLOBIO3 provides an overview, that in future research, may be supported by ground-truthing or localized plot data to validate the accuracy of the model at local scales. The overview given by GLOBIO3 may be supplemented by other approaches. A case study of consequences of the Nussir mining project applies a method of impact zones and provides an in-depth study of the landscape, reporting a great concern among reindeer owners that cumulative impacts on pastures may cause reindeer herding in their district to collapse (Eira et al., 2020).

The scope of the GLOBIO3 Arctic pilot study allowed assessment of only one Arctic region. With high data availability for Norway, the county of Finnmark (at the time of analysis, merged into Finnmark and Troms county from 2020) was selected for detailed GLOBIO3 analysis (van Rooij et al., 2017). The results presented here are from the follow-up study of the *Adaptation Actions for a Changing Arctic*, for the Barents region (AMAP, 2017). The GLOBIO3 study of Finnmark was made in collaboration with the *Nomadic Herders* project,[2] studying the impacts of land-use change and climate change on nomadic pastoralists, a joint research initiative by UNEP/GRID-Arendal, the Association of World Reindeer Herders, and the University of the Arctic EALAT Institute at the International Centre for Reindeer Husbandry (AMAP, 2017). The study reported in this chapter used the data compiled by the *Nomadic Herders* project from 2011, with map layers in a geographical information system (GIS), both infrastructure data and biodiversity data. The scenarios presented here, based on projected developments, build on these data. By comparing the situation in 2011 and future projections of biodiversity loss, trends can be observed and implications of change in biodiversity can be discussed with Sámi reindeer owners and policy makers.

At the time of completing this chapter, the Supreme Court of Norway ruled that the licenses for wind power development on the Fosen peninsula in the Mid-Norway region were invalid, as construction interfered with reindeer herders' right to enjoy their own culture under Article 27 of the International Covenant on Civil and Political Rights (ICCPR) (Supreme Court of Norway, 2021). While the Supreme Court ruling is an important recognition of Sámi rights, it is not yet known what the ramifications will be for other projects of which there are several in this study area, and thus we have not addressed potential consequences. However, we note in particular that the Supreme Court draws attention to the total (cumulative) impact of the development. The Supreme Court found, also pointing to statements from the UN Human Rights Committee, that although the interference alone may have such serious consequences that it amounts to a violation of Article 27 of ICCPR, it must

[2] https://reindeerherding.org/nomadic-herders/about-nomadic-herders

also be considered in context with other projects, both previous and planned. According to the judgement, the total impact of the development is the determinant as to whether a violation has taken place (Supreme Court of Norway, 2021). A report from the Norwegian National Human Rights Institution (2022) points to the importance of including the total (cumulative) impacts of developments in environmental impact assessments, and of clarifying the relevant themes according to Article 27 to secure human rights considerations in public decision-making.

9.2 Concepts of the GLOBIO3 Model

The GLOBIO3 model is a tool to assess the integrated impact of pressures on terrestrial biodiversity (Alkemade et al., 2009). It incorporates impacts of five types of pressure: land use change, infrastructure development, fragmentation, climate change, and nitrogen deposition. These pressures are included in the model as they are found to have large impact on biodiversity. As nitrogen deposition pressure in general is absent in Arctic areas, this pressure type was excluded from this Arctic pilot study. The model can assess past, present and future biodiversity at different scales. By using local data and local expertise GLOBIO3 can be downscaled for (sub-) national implementation.

The GLOBIO3 model, owned and developed by Netherlands Environmental Assessment Agency (PBL), was built upon the GLOBIO2 model, developed by a consortium of UNEP/GRID-Arendal and other researchers and experts, with impacts expressed as relationships between terrestrial biodiversity and distance to roads and other infrastructure elements (UNEP, 2001a, b). PBL added four more pressure types and updated the cause-effect relationship for infrastructure. GLOBIO3 builds on an integrated environmental model (IMAGE) model. GLOBIO3 can be combined with economic drivers simulated by other models (Verboom et al., 2007).

GLOBIO3 expresses the state of biodiversity by a natural intactness indicator, Mean Species Abundance (MSA), defined as average abundance of species, relative to their abundance in the original (intact) state. Biodiversity loss is measured by reduction in MSA. In general, the intact state refers to pristine or undisturbed ecosystems, but the model can also be used to assess impacts on semi-natural ecosystems, i.e., old cultural-dependent ecosystems like heathland, semi-natural grasslands and grazed tundra, where the intact state refers to the ecosystem sustained by optimal level of maintenance. The distinction between natural and semi-natural reference states is implemented in the Nature Index for Norway (Jakobsson & Pedersen, 2020).

GLOBIO3 is built on cause-effect relationships between pressures and biodiversity, derived from available literature, using meta-analysis for comparable ecosystems, as explained in Alkemade et al. (2009). Each MSA pressure map consists of a grid of cells with a value between 0 (completely disturbed) and 1 (intact biodiversity). The total MSA impact map is calculated by multiplying the MSA raster maps for each of the four pressures, land use, infrastructure, fragmentation and climate change, by applying the cause-effect relationships to the appropriate input map, in a geographical information system (GIS). The calculation of the total MSA map, illustrated in Fig. 9.1, is carried out by a raster calculator of the map layers, where the approach is explained by Alkemade et al. (2009, pp. 379–380): “Little quantitative information exists on the interaction between drivers. To assess possible interactions assumptions can be made, ranging from ‘complete interaction’ (only the worst impact is allocated to each grid cell) to ‘no interaction’ (the impacts of each driver are cumulative).” In the no-interaction case, for each grid cell, GLOBIO3 calculates the overall MSA value by multiplying the MSA maps for each driver:

$$\mathbf{MSA}_{\mathbf{total}} = \mathbf{MSA}_{\mathbf{LandUse}} * \mathbf{MSA}_{\mathbf{Infrastructure}} * \mathbf{MSA}_{\mathbf{Fragmentation}} * \mathbf{MSA}_{\mathbf{ClimateChange}}$$

Figure 9.1 shows the total effect on MSA for Finnmark for 2011. The most intact biodiversity (dark green color) can be observed in the most remote natural and semi-natural areas, in national parks and nature reserves. The highest impact (red color) can be seen in the main urban and industrial areas and in the vicinity of major roads. Note that the red-green color distribution is widely used in biodiversity modelling studies as it is generally (except for color impaired people) perceived as the best color range to differentiate between impacted (red) and intact (green) areas.

9.3 Data and Results at the Local Arctic Level: Finnmark?

9.3.1 Data Sources

For assessment of actual and projected future developments of infrastructure until 2030 data were gathered from national sources, regional plans for Finnmark (county governor’s office), and municipal zoning plans, with information from all municipalities in Finnmark, in publicly available reports and websites. A common map resource for all municipalities is found at https://kommunekart.com The previous municipality Kvalsund is now part of Hammerfest, and planning data for Hammerfest are found at https://hammerfest.kommune.no/tjenester/byggesak-arealplanlegging-og-eiendom/arealplanlegging/kommuneplanens-arealdel-2020-2032/ For Sør-Varanger municipality the data portal is found at https://www.sor-varanger.kommune.no/kommuneplanens-arealdel.364142.no.html Data for Alta municipality are found at https://www.alta.kommune.no/plan-og-regulering.5822190-366621.html.

National infrastructure data are from Norwegian Mapping Authority https://www.kartverket.no/en with common map data base (FKB) available at www.geonorge.no with data for a wide range of elements such as buildings, roads, harbors and other infrastructure, industrial sites, mining, quarrying, sport-grounds, playgrounds and parks, and the National Land Resource Map (AR5), i.e., a land cover map, https://www.nibio.no/en/subjects/soil/national-land-resource-map.

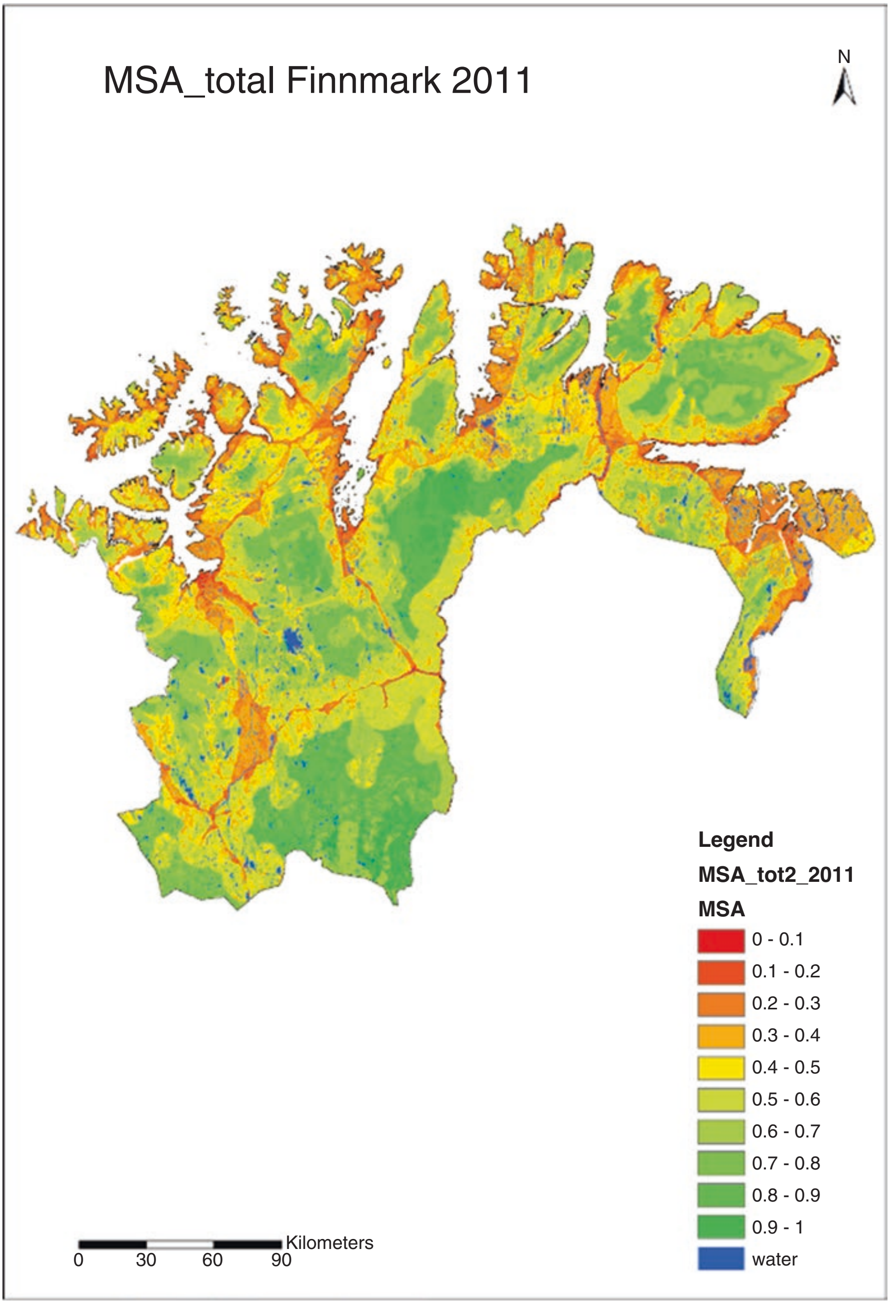

Fig. 9.1 MSA total map for Finnmark, 2011

Hydro power maps are found from https://nedlasting.nve.no/gis/ where all relevant mapping data can be selected – including current, projected and planned. Buildings are found from the cadaster, https://www.kartverket.no/en/property/eiendomsgrenser/matrikkelen-norgeseiendomsregister Roads data are found from National road data bank (NVDB) https://www.vegdata.no, and data on hydropower dams and installations, high voltage power lines, and wind power are from NVE, the Norwegian Water Resources and Energy Directorate.

Data for reindeer herding land, and in particular delineation of calving land and migration routes are retrieved from the Norwegian Agricultural Agency, with publicly available and updated data via www.geonorge.no.

For the climate change scenario, an average temperature increase of +7 °C was assumed to illustrate the expected significant impact of climate change in the long run. Benestad (2016) refers to the intermediate IPCC scenario for Representative Concentration Pathways (RCPs): "Projected temperatures exhibited strongest increase over northern Fennoscandia and the high Arctic, exceeding 7 °C by 2099 for a typical 'warm winter' under the RCP4.5 scenario." We requested advice from Benestad at the outset of this work, and we used the + 7 °C assumption to illustrate the high impact, although this is expected to occur after the projected developments. The adaptive capacity towards climate change impacts will be reduced due to loss of land.

Biodiversity data for Finnmark have been assessed with the national land use/land resource map from Statistics Norway, improved by local data. Information on land use in reindeer herding areas was provided by Sámi reindeer owners. In our discussion of the results during a workshop with Sámi reindeer herders in Kautokeino we achieved additional information from them which later was included in the model. The information was provided informally. The researchers have established cooperation with the reindeer owners in the *Nomadic Herders* project.

9.3.2 Land Use Impacts

The land use /land cover maps of Finnmark (Fig. 9.2) were based on national maps. For the impact analyses, the original land use classes of GLOBIO3 have been aggregated into land use types with a similar use intensity, for which the impact of land use on MSA is known in GLOBIO3. For Finnmark a raster map resolution of 100*100 m was selected. As land use intensity determines the MSA value of each land use class, (Alkemade et al., 2009), it was essential to use additional information from local experts to get a suitable assessment of the intactness or naturalness of the land cover classes.

In order to test the quality of local assessments, compared with assessment at national level, an assessment of impacts on biodiversity for all of Norway was first carried out. This gave the opportunity to discuss, with specialists from Norwegian environmental research institutes, the impacts of different types of land use on the intactness of biodiversity. The MSA land use values for each land use type, based on similarity with the GLOBIO3 land use types, were modified to reflect conditions

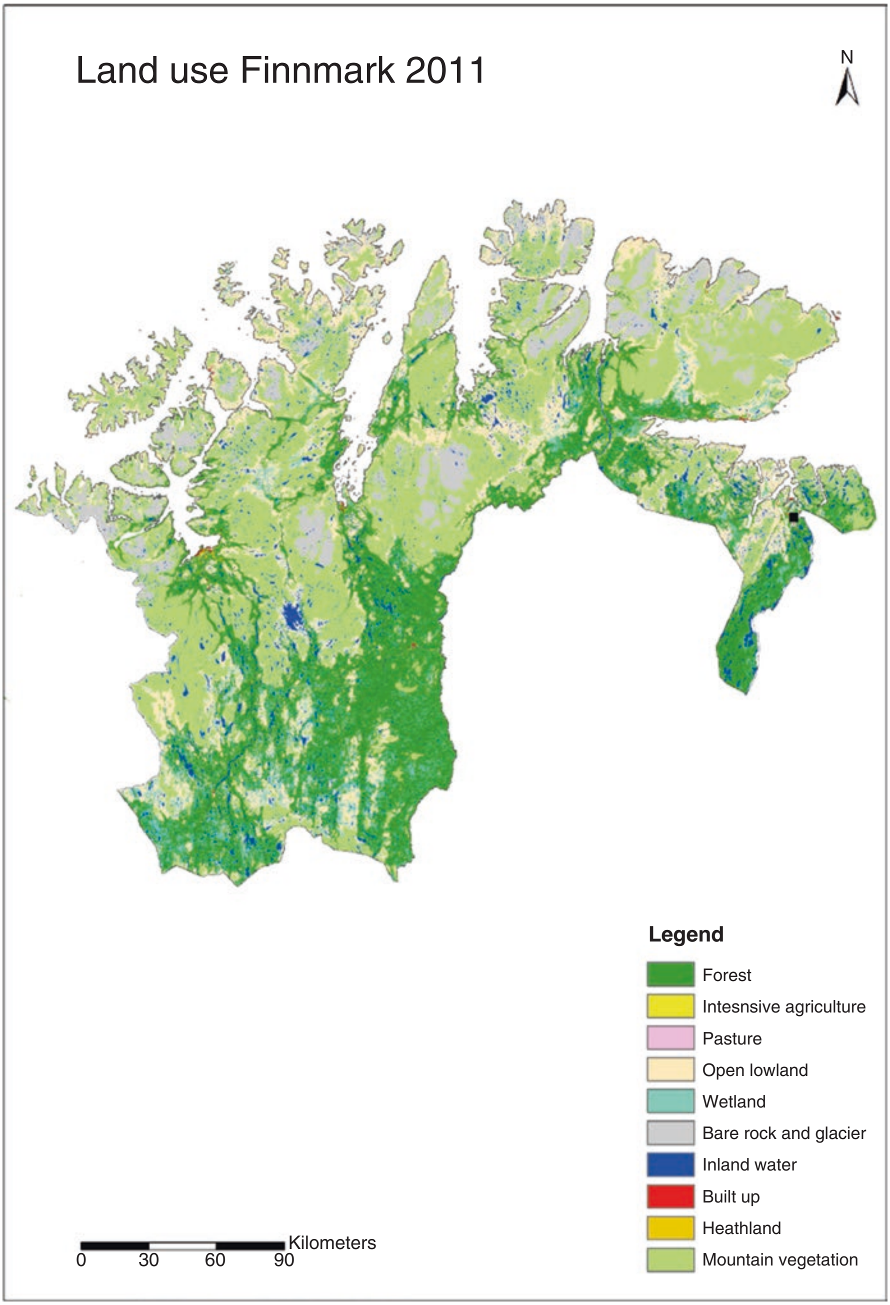

Fig. 9.2 Land use/land cover map of Finnmark, 2011

in Finnmark, after discussions with the experts about the relative land use intensity and intactness of local ecosystems. This provided qualitative information to slightly increase or decrease the MSA value of the closest standard assumptions of MSA value for each land use class (van Rooij et al., 2017; van Rooij, 2017).

In order to test the quality of local assessments, compared with assessment at national level, an assessment of impacts on biodiversity for all of Norway was first carried out.

It is common in biodiversity modelling to use a combined land use and land cover map. For modelling, land use is important as the biodiversity loss is related to human impact, but since there is mostly only limited information available on land use, some classes contain info on land cover only. Since the map in Fig. 9.2 also contains land use classes (intensive agriculture, urban and pastures), it is a combined land use/land cover map.

9.3.3 Infrastructure impacts

While land use affects the entire land cover, the impact caused by infrastructure is limited to a certain distance from the infrastructure elements. The impact of infrastructure on biodiversity in GLOBIO3 is calculated based on cause-effect relations, where linear elements of infrastructure, such as major roads, power lines, and railways, are assumed to have an impact that reaches up to 5 km (Alkemade et al., 2009). The highest impact is measured close to the lines and it decreases to zero at 5 km distance. Small roads and winter roads are not included in the calculation as the traffic on these generally unpaved roads is much less. The impact distance for power lines and pipelines is set to 1 km (Vistnes & Nellemann, 2001). The impact distance from urban, industrial, mining, and agricultural areas is defined as 10 km, adapted from Alkemade et al. (2009).

For recreational cabins there are no separate cause-effect relations in GLOBIO3, and as these houses are not habited all year through it is assumed that their impact will be less than for permanently inhabited buildings. For the analysis of Finnmark, the impact of recreational cabins is considered to be equal to the impact from roads, but with a smaller impact distance of 1 km, adapted from the study by Lie et al. (2006). To avoid double counting of other pressures (e.g., land use), the impact of infrastructure is only calculated for natural and semi-natural areas. We refer to semi natural in case the MSA values of those areas are 0.7 or higher. A complete natural class would have an MSA value of 1. In urban and agricultural areas the impact of land use already includes the presence of roads and other existing pressures. Figure 9.3 shows an overview of existing infrastructure and the corresponding MSA map for impact of infrastructure in Finnmark in 2011.

In future research, more studies are needed on the cumulative impacts of the different types of infrastructure, with roads, power lines, wind power and possibly projected development of railway, and the extent of use.

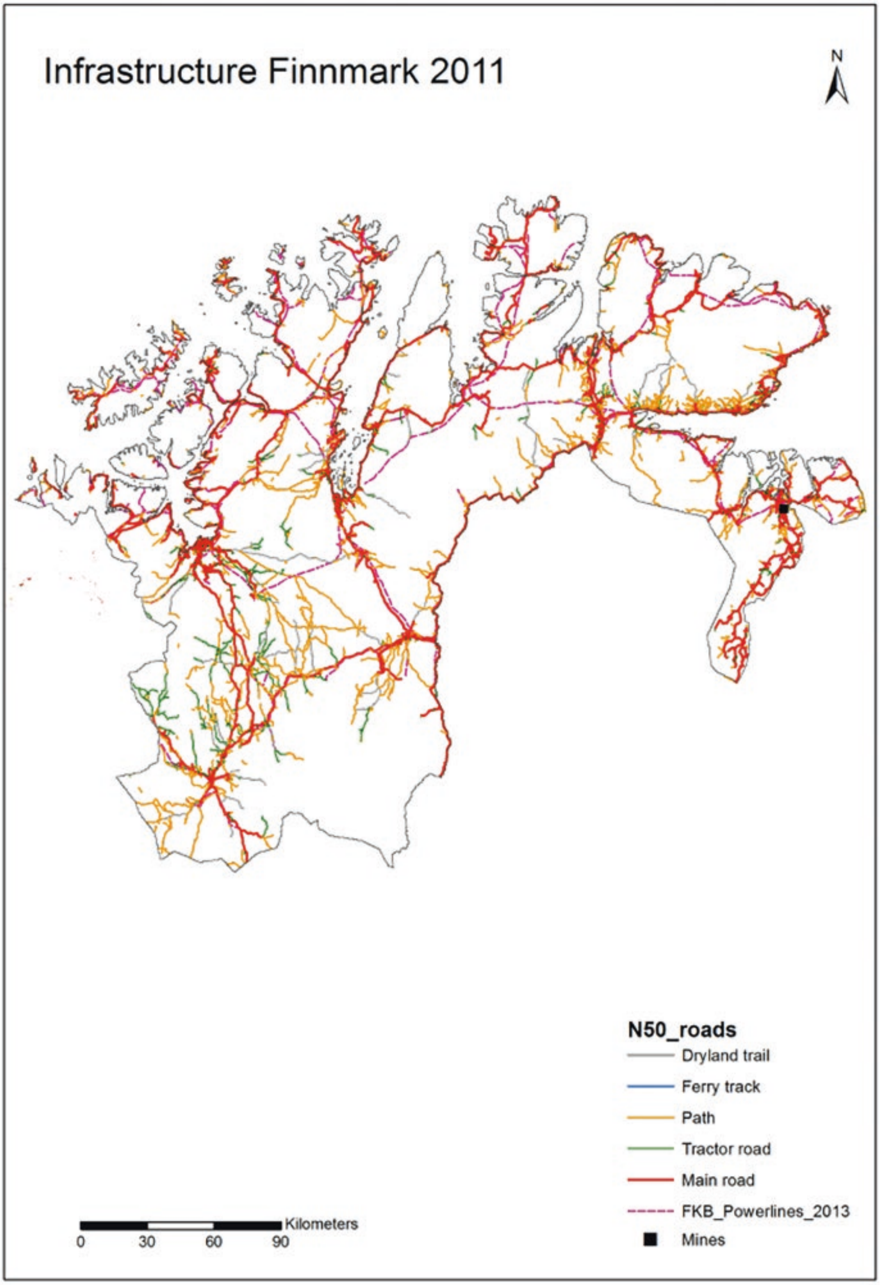

Fig. 9.3 (**a**) Infrastructure in map of Finnmark, 2011. (**b**) Infrastructure and impact on MSA in map of Finnmark, 2011

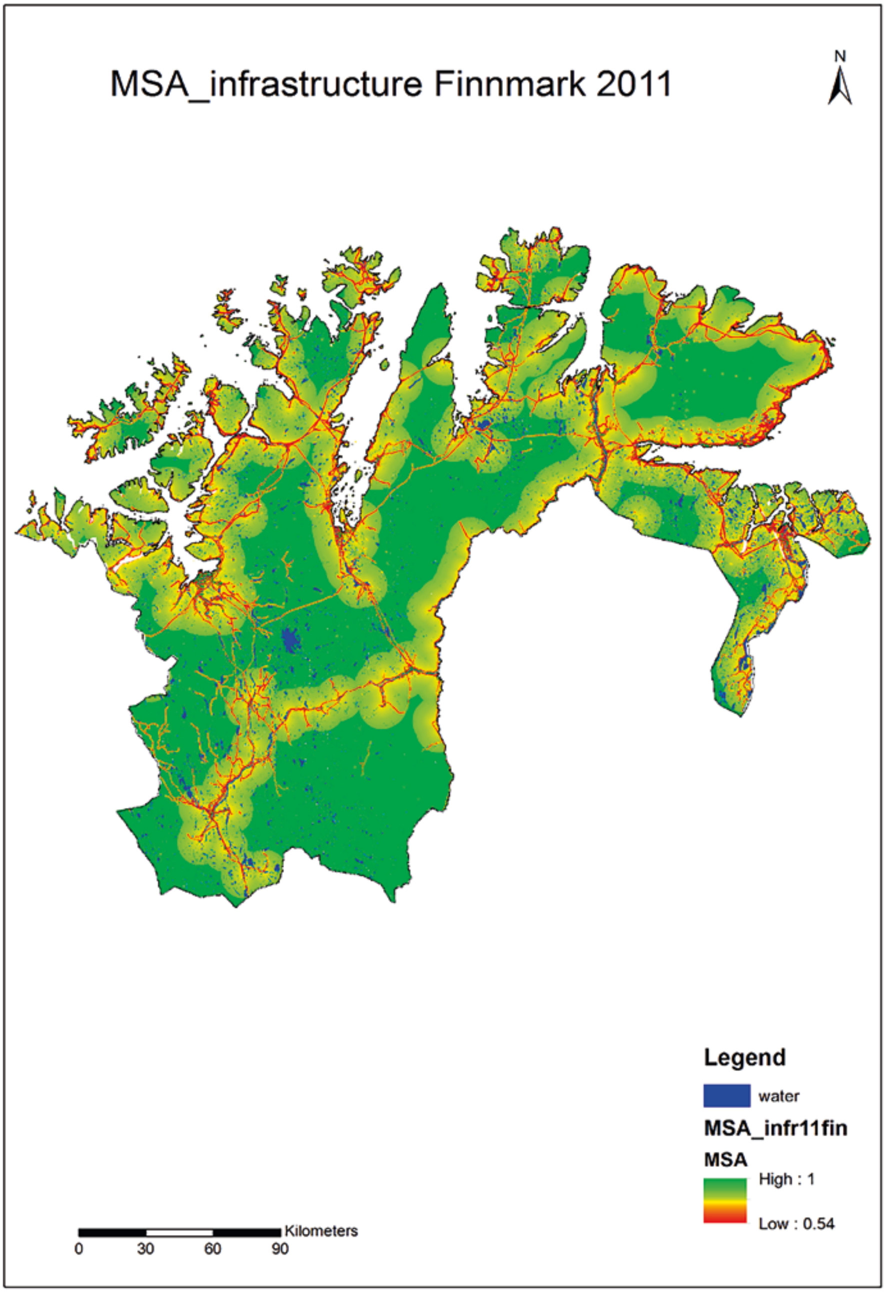

Fig. 9.3 (continued)

9.3.4 Fragmentation Impacts

Fragmentation impact is calculated based on maps with remaining intact areas of non-dissected contiguous nature areas. These contiguous nature areas are derived from the land use and infrastructure maps. The impact of fragmentation in GLOBIO3 is expressed as minimum requirements for intact (semi-) natural areas to sustain viable species populations, based on cause-effect relations between intact area size and biodiversity. The larger an intact area is, the lower is the fragmentation impact. We apply the assumption of Alkemade et al. (2009) that intact areas of more than 10,000 km^2 are considered to have no fragmentation impact. To avoid the error of expressing a fragmentation impact of small islands as a result of their natural small size, islands with area less than 100 km^2 are excluded from the fragmentation impact calculations. Additional cause-effect relations are needed for small islands.

Urban and agricultural land separate natural ecosystems from each other. Major roads, railways and channels that run through a natural area also divide the area into separate parts. Other linear elements of infrastructure such as minor roads, tracks and ski trails are not included in the fragmentation calculations as their impact on fragmentation is expected to be small. Likewise, the impact of electricity lines is not included in the fragmentation calculation, as human presence and physical disturbance along these lines is low and a limited number of species will actually be prevented from crossing the electricity line path. Studies show that reindeer avoid grazing near the electricity lines (Vistnes & Nellemann, 2001), but this effect is already covered by the infrastructure impact calculations, in which the impact of electricity lines are included.

9.3.5 Climate Change Impacts

In GLOBIO3, the assessment of climate change impact is based on a combination of an integrated environmental model (IMAGE) and climate envelope models. The climate envelope (niche) of a species is defined as a relationship between the species' occurrence and bioclimate variables (temperature and precipitation) (Arets et al., 2014; Alkemade et al., 2011). The share of remaining species within a climate envelope is used as an indicator for climate change impacts on biodiversity. Both plants and vertebrate species of Arctic ecosystems show a strong decline in the share of remaining species, relative to the intact situation, with increasing temperature.

Cause-effect relations between temperature change and biodiversity loss in terms of MSA have been developed for a number of biomes (Alkemade et al., 2009). Tundra and birch forest are the predominant biomes in Finnmark. For Finnmark a differentiation can be made between the biomes 'Kola Peninsula Tundra' and 'Scandinavian Montane Birch forest and grasslands'. The climate change impact is rather limited for the study area, as the current temperature increase is still relatively small, but expected to increase considerably in the future. While it can be expected an increase in species number (and MSA) as the average temperature increases meaning the climate is viable for a larger number of animals and plants, the characteristic Arctic biodiversity is threatened with warming climate and disappearance of ecological niches for Arctic species (Arctic Biodiversity Assessment, 2013).

9.3.6 Total Impact

The total impact on MSA, as shown in Fig. 9.1, is disaggregated per pressure type and per municipality in Fig. 9.4. The remaining biodiversity can be expressed as a total MSA value. Figure 9.4 shows that after land use, infrastructure development and land fragmentation have the strongest impact on biodiversity.

Figure 9.4 shows the total remaining biodiversity (MSA) and the share of biodiversity loss per pressure type for Finnmark in 2011. According to this analysis the remaining biodiversity in Finnmark in 2011 was 54% of the intact situation. The largest biodiversity loss is caused by land use (23%), followed by fragmentation (12%), infrastructural developments (8%), and climate change (3%). Although the impact of infrastructure might seem relatively small for the entire Finnmark, the local impact can be very high.

9.3.7 Projected Future Biodiversity Trends in Core Reindeer Areas in Finnmark

In order to explore projected impacts on future biodiversity in Finnmark, a scenario of future developments was constructed as explained. In this scenario it is assumed that all planned developments, where information could be gathered, will be realized by 2030. The projections are strongly dependent on national and regional

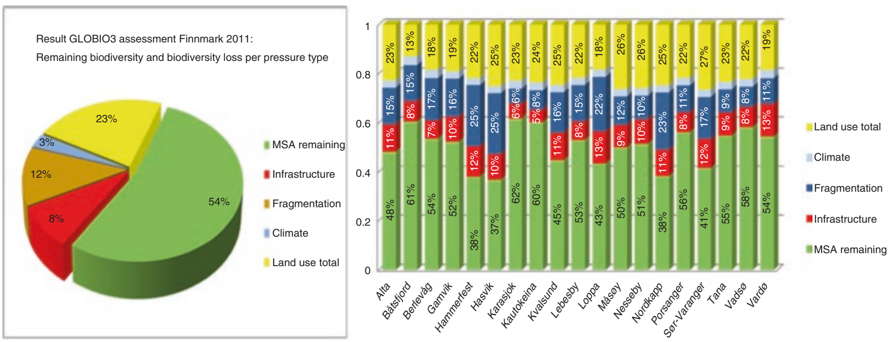

Fig. 9.4 Share of remaining biodiversity and biodiversity loss per pressure type and per municipality for Finnmark, 2011

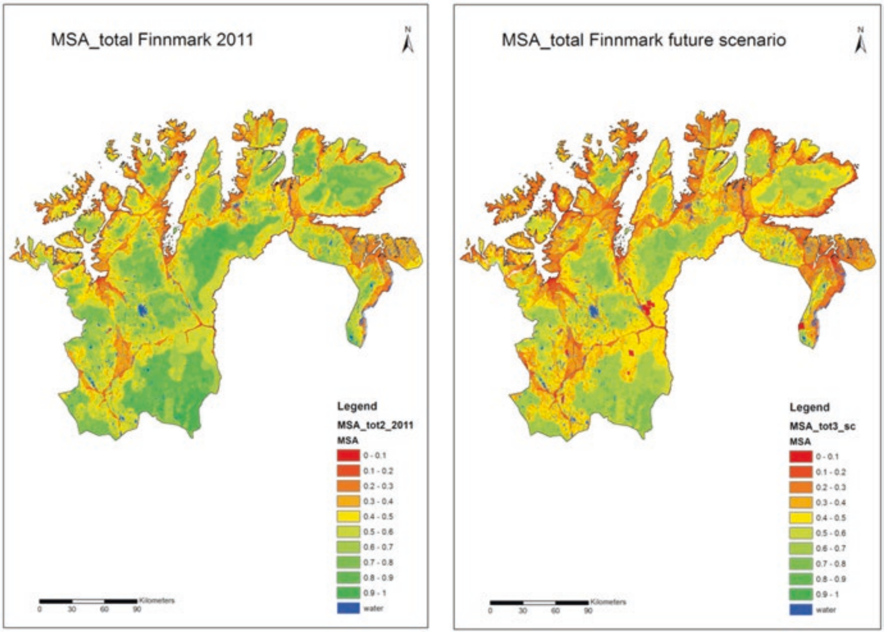

Fig. 9.5 MSA in 2011 (**a**) versus projected MSA in 2030 (**b**) for Finnmark, with overall reduction from 0.54 to 0.43

projections of economic and political drivers for development and assessments of what type of developments are most likely.

Figure 9.5 shows MSA in 2011 (as in Fig. 9.1) and projected future MSA total maps for Finnmark, based on land use/land cover data from 2011 and projected scenarios for 2030 for land use change, infrastructure, fragmentation and climate change. The overall loss of biodiversity from 2011 to the future scenario for Finnmark amounts to about 10%, from 0.54 to 0.43. Climate change is by far the largest contributor to the additional loss, but locally large losses occur as a result of infrastructural, urban and mining development.

9.4 Implications for Reindeer Herding

Indigenous communities worldwide are faced with pressures that affect their traditional use of land and way of living. Reindeer herding in the circumpolar Arctic depends on the availability of large areas of suitable grazing land, and reindeer herds use migration routes to move from one seasonal pasture area to the other. Socio-economic developments, such as urban development, exploration of new mines and building of new infrastructure are causing loss of pastureland, forced changes of reindeer migration routes, and biodiversity loss. Although the GLOBIO3 model is not designed to analyze impacts on a single endemic species such as reindeer, the impacts of infrastructure development and climate change on biodiversity will also affect reindeer husbandry. Loss of biodiversity of grazing areas imply changes of its vegetation, and the warming climate and regrowth of birch forest will have negative impact on reindeer herding.

Infrastructure development near or in the important areas of calving grounds and migration routes will severely disturb the reindeer. In other words, loss of biodiversity is an indication of various threats that negatively affect reindeer husbandry.

Calving land is defined the part of the seasonal spring pasture where most of the female reindeer stay during the time of calving. The most valuable calving land is a gently rolling tundra without steep riverbanks. The migration routes follow the ancient migration routes of the wild reindeer, from time immemorial, and infrastructure development can seriously impair the ability of reindeer to use the seasonal pastures located at large distances from each other.

Figure 9.6 shows the total impact on MSA for 2011 and projected for 2030 biodiversity in Finnmark within calving grounds and migration routes. The average

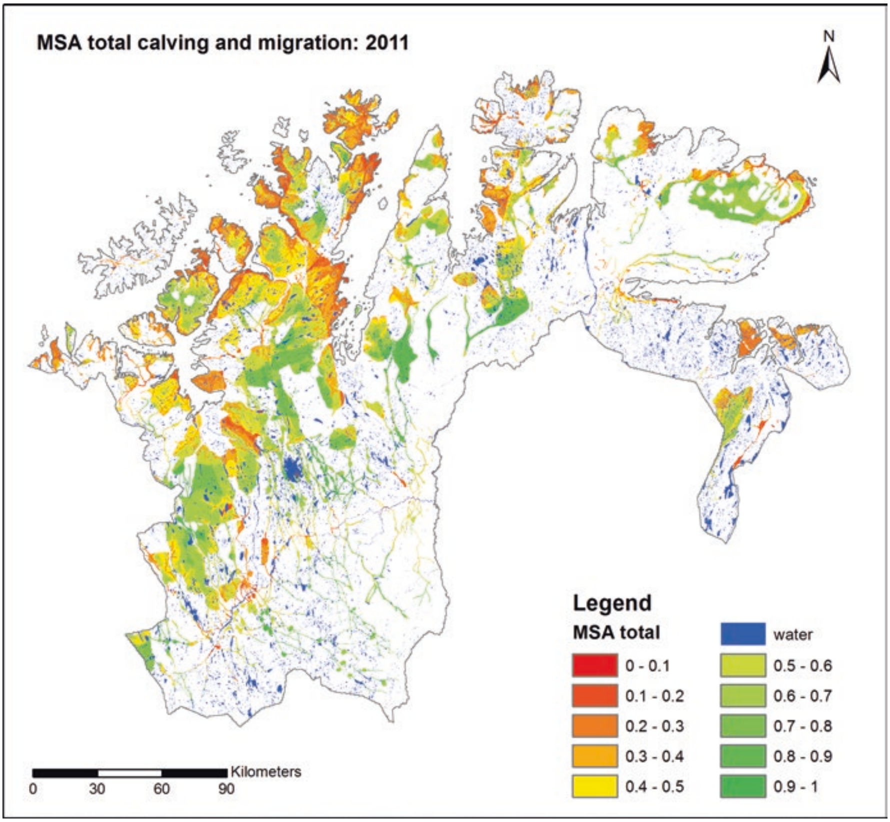

Fig. 9.6 MSA total for calving grounds and migration routes in Finnmark for 2011 (**a**) and projected future scenario (**b**)

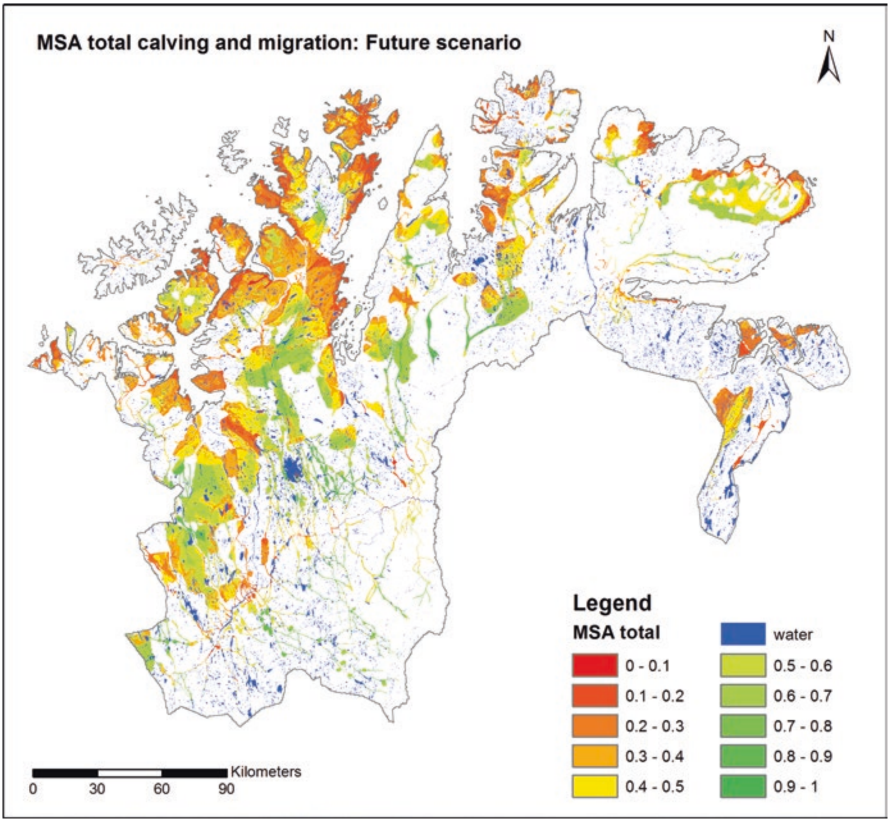

Fig. 9.6 (continued)

MSA value of calving grounds in 2011 is 0.5 with a standard deviation of 0.18. In other words, 50% of the original biodiversity on the calving grounds is already lost. The average MSA of the calving grounds is expected to be reduced with another 10% to 0.4 (standard deviation 0.15) according to the future scenario. The biodiversity loss within the migration routes is somewhat less severe, but still significant with an average MSA of 0.57 (standard deviation 0.15) in 2011 and 0.46 (standard deviation 0.13) according to the future scenario. As these numbers are average biodiversity loss, much higher losses may occur locally. Almost complete losses of biodiversity occur at locations where the original land cover has been removed to make place for urban and infrastructural developments. When a new road crosses a migration route it will create a barrier for the animals, especially when the road is accompanied with guard rails or fences.

Figure 9.7 shows a detail of the projected future total MSA map for three reindeer herding districts in Finnmark: Fálá, Fiettar and Gearretnjárga.

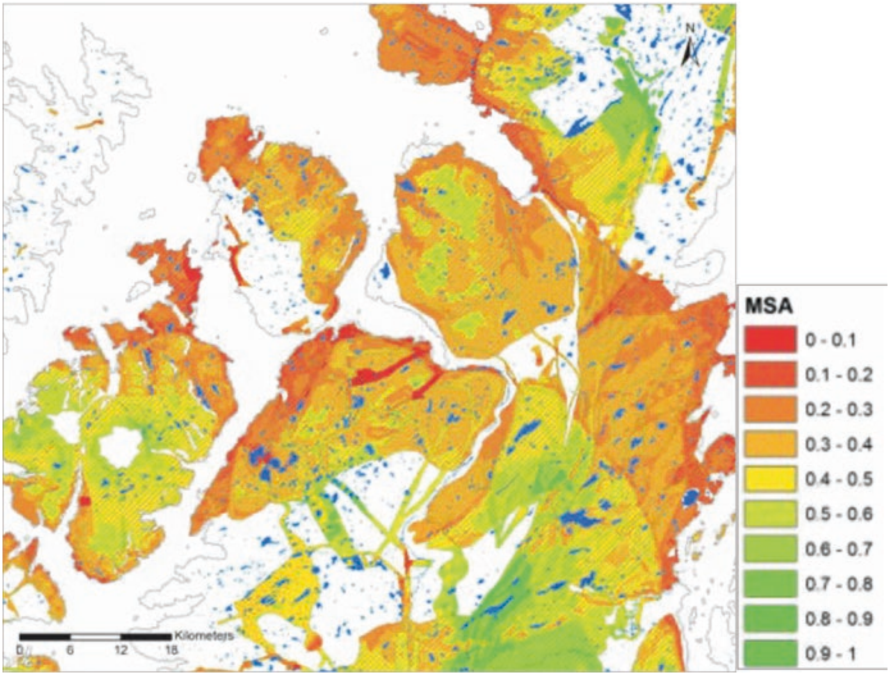

Fig. 9.7 MSA total for Fálá, Fiettar and Gearretnjárga reindeer herding districts in Finnmark for the projected future scenario. Hatched areas are calving grounds. Non-hatched colored areas are reindeer migration routes. Red lines show frequently used reindeer migration routes

Figure 9.7 demonstrates the future challenges that these reindeer herding districts are likely to face should development proceed as projected up to 2030. Lands designated as calving grounds would be strongly impacted.

Figure 9.8 shows the change in biodiversity (MSA) between 2011 and the projected scenario for 2030 for the calving grounds and migration routes, for three reindeer herding districts in Finnmark: Fálá, Fiettar and Gearretnjárga, in case planned projects will be realized. The beige-colored areas show an additional biodiversity loss after 2011 between 0% and 10%. These areas are situated within the impact zones of adjacent urban and infrastructural developments. Among the projected developments are the building of new buildings and industrial complexes, mines and construction of planned roads. Since the data were compiled, the wind power concession area, marked by 1 in Fig. 9.8, has been rejected as result of protests, and the project developer withdraw its plans. Reindeer owners had suggested another location for the site to a less conflicting area, but that seemed to be economically less attractive.

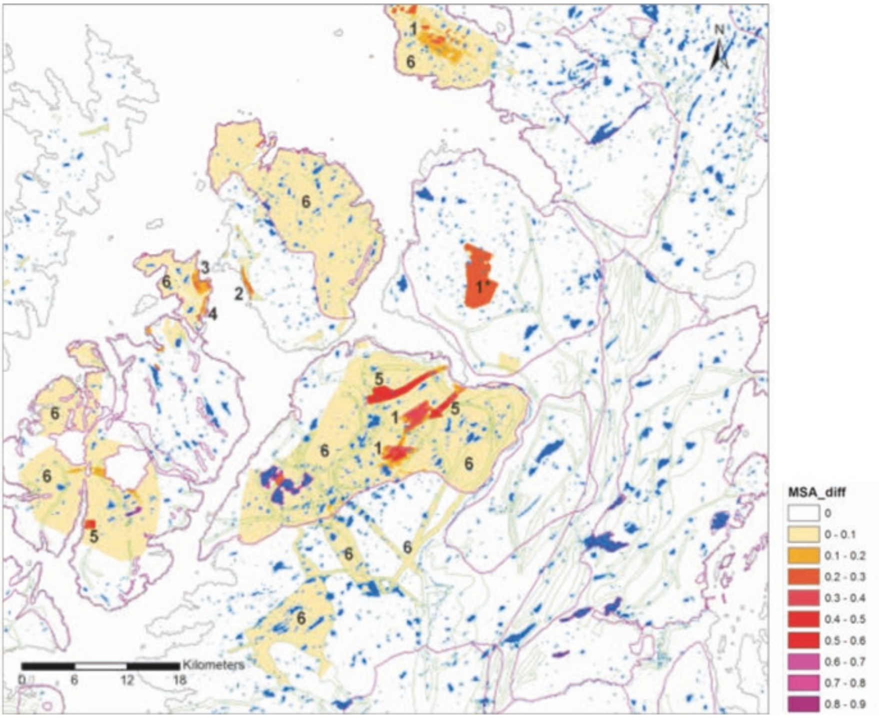

Fig. 9.8 MSA difference between 2011 and projected scenario for 2030 within calving grounds and migration routes, in Fálá, Fiettar and Gearretnjárga reindeer herding districts in Finnmark. Climate change impact is excluded. *1*: previously planned wind power development, *2*: planned airstrip and buildings, *3*: planned industrial area, *4*: planned housing, *5*: mining concession area, *6*: biodiversity loss area due to nearby infrastructural developments

9.5 Using the GLOBIO3 Model as a Decision Support Tool

In this project, as well as the *Nomadic Herders* and related projects, there has established partnerships with Sámi reindeer herders in Finnmark who have been closely involved in the work. The ethical issues of research cooperation with Indigenous Peoples are addressed through the partnership and involvement of the reindeer owners in the research, and their ownership of the traditional knowledge related to use of the reindeer pastures.

The MSA maps for the three reindeer herding districts, Fálá, Fiettar and Gearretnjárga, shown in Figs. 9.7 and 9.8, and other GLOBIO3 output maps, were discussed with reindeer owners from these reindeer herding districts during participatory mapping workshops in Kaitu, Finland, and Skáidi, Finnmark, in 2016. The workshop format consisted of presenting GLOBIO3 maps and discussing the results.

The reindeer owners observed the biodiversity impact in their areas and discussed the pressures behind the impacts and the possible consequences. Serious threats to reindeer herding land can directly be located on the maps by the reindeer owners. As the projected developments are mapped as part of the biodiversity modelling, the maps can be used to facilitate discussions between planners and reindeer owners in consultations and stakeholder workshops.

GLOBIO3 calculations expand the knowledge obtained by mapping the new infrastructure or land use change proposed by the planners relative to the migration routes and calving grounds. The advantage of using GLOBIO3 in this case is to make a comprehensive assessment to see land use chance in connection with climate change. A key point made in previous research with reindeer owners (Tyler et al., 2007) is that the capacity to adapt to climate change requires availability of land that is impaired by the projected infrastructure developments.

The purpose of the dialogue was to test the quality and relevance of the model results in view of the traditional knowledge of the reindeer owners and discuss the potential use of the GLOBIO3 model as decision support tool in land use planning. This process may facilitate discussions about alternatives and may help to reduce conflicts between planners and reindeer herding. It was emphasized by the reindeer herders in the dialogue that the maps are potentially useful tools if they are supplemented with interpretations based on traditional knowledge and success of the dialogues depends on a full engagement and consultation with rights holders and use of their traditional knowledge in discussions about possible consequences.

As expressed in the workshop, reindeer owners were concerned about the projected biodiversity loss and deterioration of seasonal reindeer pastures and the consequences of such developments in their districts for reindeer herding in the future. According to the reindeer owners, low biodiversity along migration routes does not need to be a limitation for migration, as the reindeer sometimes also use roads and railway tracks to move. The threats behind the biodiversity loss cause the largest problems. Fences obstruct passages, cars and trains cause a serious threat to the animals and collisions occur frequently. Herds stay away from wind power turbines, and the animals avoid proximity with people. Expansion of urban and industrial areas, and recreational cabin areas, cause an increase of human disturbances in or near the calving grounds and migration routes. In case disturbances are present on or near calving grounds, the female reindeer try to avoid these.

The increased biodiversity loss is expected to go along with a loss of calving grounds and grazing areas and reduced accessibility of seasonal reindeer migration routes. Therefore, it will be of large importance to discuss consequences of the projected developments well in advance with policy makers and the reindeer herding community. This could be realized in consultations and by participatory scenario planning as part of a wider impact assessment process. During this process reindeer herding will be able to provide planners with traditional knowledge that will increase the understanding of the implications of cumulative impacts. The traditional knowledge of reindeer herding is crucial for sustainable use of grazing land under cumulative impacts, as the capacity to adapt to climate change impacts depends on the availability of a diversity of pastures (Tyler et al., 2007).

An important lesson gained from this dialogue is that biodiversity loss, illustrated in red color on the maps, must be interpreted with caution. While red color on the maps is clearly a warning that planned developments may be detrimental to biodiversity in these grazing areas, it does not mean that the highly impacted areas should be considered as completely lost to reindeer herding, and thus be opened to further development, as they are still important for seasonal reindeer migration and grazing at certain times of the year. There is a risk that people might incorrectly assume red zone areas should be open to development because they perceive them to be of no use to reindeer. This is not an issue of scale, but of the need for continuity in the landscape of reindeer herding, to ensure the passage between the seasonal pastures.

These findings inform guidance for interpreting the maps. The maps are not a good indication of how the reindeer move in the disturbed areas, but rather they are an indication of growing pressure that has detrimental impacts to reindeer. The model can be used to help shift the discussion to reindeer husbandry as both a traditional livelihood and a viable economic sector with potential for growth, and how the reindeer owners' traditional knowledge may enhance the economy of reindeer herding (Reinert, 2006).

One of the workshop participants made a point of asking whether a future in reindeer husbandry could be guaranteed. Another participant asked why the question of how these developments would limit the ability of reindeer owners to sustain their economy was left unasked and, even more pertinently, why the potential for growth in reindeer husbandry was not discussed, neither by the authorities nor by the reindeer husbandry sector itself. Yet another participant raised the issue of calling for more self-governance for reindeer husbandry to increase the protection of remaining areas of reindeer herding land without physical impacts.

Flaws in planning process were brought into the discussion, pointing to the need for improved participation and consultation. A reindeer owner from Fálá reindeer herding district, with summer pastures near Hammerfest, who participated in the GLOBIO3 workshop pointed out what he saw as fundamental flaws in the planning processes: that reindeer owners are included too late, after the area planning has taken place. This is also pointed out in research on impacts of mining in other regions (Herrmann et al., 2014), The area planning (*områderegulering*) sets out broad land use plans for large-scale areas of land and does not require an impact assessment. Input from reindeer owners is only sought at the next stage of zoning plan (*reguleringsplan*), when decisions are taken at a local scale. By that stage, however, people are already envisioning the land in a different way, and their "mental landscapes" – the perception of what is possible – have already shifted. Extending the decision support for consultations, by modelling results and maps, as suggested here by use of the GLOBIO3 model, is a comprehensive approach to model impacts of land use change and climate change on biodiversity, together with use of traditional knowledge to give a broader picture of the need to maintain the adaptive capacity of reindeer herders under these changes.

9.6 Land Use Planning and Traditional Knowledge

The Convention on Biological Diversity (CBD), article 8 (j), calls for application of traditional knowledge of Indigenous Peoples to achieve sustainable use and conservation of biodiversity (CBD, 1993). The Norwegian Nature Diversity Act §8 calls for application of experience-based knowledge on use of nature, throughout the generations, including Sámi use of nature, that can contribute to sustainable use and protection of biodiversity. While Sámi reindeer herding in Norway is framed as the economic basis for carrying Sámi culture, articulation of Indigenous rights at national and local levels is fragmented, and a challenge remains to integrate Sámi traditional knowledge into governance of reindeer husbandry and land-use planning (Turi, 2016).

Traditional knowledge expresses the interrelated issues of managing grazing land and managing the herd. The traditional organization in reindeer herding reflects a knowledge-based adaptation to use of seasonal pastures to build resilience (Sara, 2015). Strategies include flexible use of seasonal pastures and diversity in herd structure, in contrast to current governance of reindeer herding, with focus on number of reindeer as parameter for monitoring pasture pressure. The issues of knowledge and power in governance of reindeer herding are discussed by Benjaminsen et al. (2015). Traditionally, it was the overall condition of the herd that mattered, assessed by whether the herd had good appearance (*čáppa eallu*) (Haldorsen, 2020). Acknowledging traditional knowledge in governance requires an understanding of the landscape, beyond perspectives of agriculture and nature conservation, to reflect relations between nature and people (Joks et al., 2020). There is need to develop institutional approaches to support self-governance and cooperation (Norwegian Agriculture Agency, 2016). Formal recognition by authorities of informal institutions is key for local communities to organize sustainable resource management (Ostrom, 1990).

In Sweden, RenGIS, has been developed as a GIS tool to support dialogue and mitigate conflicts between reindeer herding and other land use and agencies (Sandström, 2015; Sandström et al., 2012). RenGIS[3] is a tool for compiling traditional knowledge of reindeer herding and field measurements of seasonal grazing lands, combined with data on other land use. The RenGIS process combines Indigenous and scientific knowledge in the planning processes, and the experience highlights the importance of working closely together for co-producing knowledge. The use of participatory mapping empowers reindeer herding communities by improving their knowledge base and their dialogue with other land users, seen as a step towards strengthening their capacity to adapt to climate change (Sandström, 2015). New data sets, as those produced by GLOBIO3, can easily be incorporated into RenGIS.

A key feature of the spatial GLOBIO3 model is that its main output is presented in maps, hence allowing to present the complexity of the model structure directly in a visual way. This relates to the idea of participatory mapping, where traditional

[3] https://www.sametinget.se/111684

Indigenous knowledge on use of biodiversity and the landscape can be expressed in participatory mapping to give a deeper understanding of the Indigenous landscape (Bélisle et al., 2021). Traditional knowledge on use of nature can give richer interpretations of model results, with integration of Indigenous and scientific knowledge (Reid et al., 2009). GLOBIO3 results combined with participatory mapping have the potential to become powerful and collaborative tools to assist both rights holders and local and regional decision-makers. These tools improve the understanding of complex spatial issues and may facilitate development of strategies for adaptation and maintaining resilience. Combining spatial mapping with traditional knowledge is a representation of nature as expressed in the boundary object literature (Clark et al., 2016; Leigh Star & Griesemer, 1989; McGreavy et al., 2013).

The Convention on Biological Diversity (CBD) has suggested several approaches to develop indicators of collective action of Indigenous Peoples in land management, including geospatial modeling, to support conservation and use of natural resources under development pressures, institutional analysis, with active involvement of local resource users to develop, monitor and enforce rules for natural resource use, and ecological assessment, documenting how local conservation efforts can improve the condition of the natural resource base (CBD, 2014). A spatial approach to assessment of ecosystem services, in the United Nations System of Environmental-Economic Accounting – Ecosystem Accounting (SEEA EA), is recently adopted as statistical standard by the United Nations (2021).

The special rapporteur to the United Nations Permanent Forum on Indigenous Issues proposed that there is a need to increase reindeer herders' capacity in negotiating with developers competing for the grazing land. Reindeer herders should have the right themselves to determine their own future, based on their own philosophy of life and understanding of the world, and should be consulted, included and accepted as partners when development, research and monitoring takes place on their territories (United Nations, 2012). The Intergovernmental Panel on Climate Change (IPCC) recently concluded that protecting reindeer grazing lands would be the most important adaptation measure for reindeer herders under climate change (Nymand Larsen et al., 2014). It is in the application of the international proposals to national and regional governance that we suggest that GLOBIO3 may provide a mechanism for decision support in the dialogues.

9.7 Projected Impacts of the Nussir Mining Project

This section presents a case study of the proposal for developing the Nussir copper mine in Kvalsund, a previous municipality, now part of Hammerfest, with impacts for the reindeer herding districts Fiettar and Fálá, with location shown in Figs. 9.7 and 9.8. The study is elaborated by the *Foundation Protect Sápmi*[4], a foundation

[4] https://protectsapmi.com/engelsk/about-protect-sapmi/

whose purpose is to maintain and develop the Sami cultural community. The Nussir proposal was approved in 2014 by the Ministry of Local Government and Modernization. It was acknowledged that reindeer husbandry is a livelihood protected by international rights implemented in national law, and that a substantial loss of the material basis of Sámi culture could not be allowed. However, the approval did not address what that might mean in practice and did not consider cumulative effects of mining combined with other encroachments on the pastures and did not consider the question of a 'tipping point' beyond which it would no longer be possible to practice reindeer husbandry, a crucial question put forward by the reindeer herding communities.

The study by *Foundation Protect Sápmi* applied a model for assessing cumulative impacts, through calculation of impact zones, combined with traditional knowledge of reindeer owners, to assess consequences of the planned mining at Nussir and the adjacent area Gumpenjunni for the reindeer herding districts Fiettar and Fálá (Eira et al., 2020). The model of cumulative impacts has been developed in cooperation between mining industry and reindeer herding in Sweden, building on models from Sweden, Canada and USA (Folkesson, 2010; Canadian Environmental Assessment Agency, 2009; National Oceanic & Atmospheric Administration, 2012). The model has been applied in Sámi reindeer herding in Sweden with results that both developers and reindeer owners perceive as realistic and relevant (Leveäniemi, 2014).

The analysis by *Foundation Protect Sápmi* of already existing land use changes shows that 54% of the area of Fiettar reindeer herding district is impacted, within an impact zone of 10 km assumed for mining. A compilation of research results suggested an impact zone of 14 km for mining (Skarin & Åhman, 2014). The analysis shows that the projected future impacted area will increase to 63% of the Fiettar reindeer herding district, impacted by construction of a new high voltage power line, and with the planned mining activities, the impacted area will increase to 70%. Both 63% and 70% impacted land are far above the threshold for reindeer herding, assessed as 65% remaining natural land as limit for when the reindeer population has sufficiently high probability to be sustainable (Eira et al., 2020). In comparison, a study assessed that of all Sámi reindeer herding land in Norway, an average of 89% is impacted within an impact zone of 5 km, however, with geographical variations, and a larger share of impacted land is found south of Finnmark (Engelien & Aslaksen, 2019). These models of impact zones calculation represent the infrastructure module of GLOBIO3, while they do not include the climate change impacts and the impacts on biodiversity that give a broader picture.

Climate change with increased temperature variability around zero degrees will increase challenges for reindeer herding, and more flexibility of land use is needed. Projected impacts of the Nussir mining project will reduce the flexibility and increase the risk for reindeer herding, especially for access to intact spring pastures and calving grounds, which is more critical as the frequency of unpredictable snow and temperature conditions is expected to increase. If the spring pastures are impacted, calves cannot make efficient use of summer pastures and are thus at risk of not surviving the winter if grazing conditions are bad.

The study by *Foundation Protect Sápmi* points out that with use of explosives in Nussir, it is probable that reindeer may sense tremor and instinctively flee with a larger avoidance zone than 10 km. Avoidance effects will be especially high for female reindeer with young calves, leading them to the high mountain areas, with higher death risk for calves. The herd must be forced back to areas they have fled. Calves that survive avoidance must be used for herd renewal and profitability will decrease. For Fálá reindeer herding district, the autumn migration route will in practice be closed, and they need to consider alternative migration routes possible, in cooperation with neighboring reindeer herding district Fiettar. However, in the 1970s, when previous mining took place, Fiettar reindeer herding district had to change calving land to their spring and autumn pasture, and further adaptation to infrastructure development is not possible without ruining the spring and autumn pastures, i.e., the scope for adaptation is used up (Eira et al., 2020).

A study of the impact assessment process of Nussir mining project noted that impact assessments focused mainly on the number of 'square meters on the ground' that would be affected by physical development, while as pointed out by a reindeer owner interviewed, disturbance from mining is far more extensive than the actual area of mineral extraction (Johnsen, 2016). Exploring the question of co-existence between reindeer herding and mineral exploration, Uhre (2020) concluded that co-existence does not seem possible in the Nussir area. In general, it should be emphasized that the consideration for co-existence in certain appropriate circumstances will depend on scale and the presence of cumulative effects.

The report by *Foundation Protect Sápmi* on the Nussir project concluded that disturbances and physical barriers will fragment the landscape and lead to cumulative intermediate effects in Fiettar reindeer herding district and furthermore in the eastern reindeer migration route (*Nuortajohtolat*). This may cause pressure (*doldi*) on pastures to be used later in the seasons, a pressure occurring if different herds reach the migration corridor earlier in the autumn season and may cause a longer and more intense pressure on the pastures during the spring season. The pressure on the spring pastures occurs if mining development takes place in the calving grounds, and calving must take place in inland areas. Altogether, increased pressure on pastures occurs as a result of pastures having to be over-utilized at the wrong time of the season, due to the barriers created by mining development. Pressures also disturb the well-established system of sequential moving along the migration route. Thus, during autumn migration, coastal grassland pastures will be under-utilized, while inland lichen pastures will be over-utilized. The cumulative long-term effect can be disastrous, especially if expected warming climate lead to warmer autumns when dry lichen pastures may be harmed by trampling (*duolmmastuvvon*). The negative consequences include cascading impacts on winter pastures, weight loss for reindeer, and reduced chance of survival through the winter. All together this means weaker economy and higher operational risk in reindeer herding. The report by *Foundation Protect Sápmi* concluded that there is great concern among reindeer owners that regional and intermediate cumulative impacts on vulnerable lichen pastures in the Fiettar reindeer herding district may also cause collapse of reindeer herding in the form that it is known today in the Fálá district (Eira et al., 2020).

9.8 Discussion and Conclusions

As explored in *Adaptation Actions for a Changing Arctic* for the Barents region, processes for impact assessments are found to have flaws, particularly for reindeer herding land, as they do not consider cumulative effects, do not include traditional knowledge in reindeer herding, do not sufficiently take into account societal issues, and assume that what can be counted and measured is more important than what cannot (Degteva et al., 2017). As a result, the role of Indigenous Peoples in impact assessment processes, their knowledge, stewardship of nature, and value perspectives, and the question of land rights are under-communicated. However, more attention has recently been given to how new approaches in impact assessment could assist Indigenous communities to engage in these processes in a meaningful way, in participatory scenario planning that provide multiple perspectives on social-ecological challenges (Degteva et al., 2017). GLOBIO3 scenarios as explored here, combined with traditional knowledge, may be part of this extended approach.

Results of the GLOBIO3 study for Finnmark can contribute to develop the GLOBIO3 model for Arctic conditions, as a tool for assessing cumulative impact of drivers of biodiversity loss. The results reported here show the need for further improvements of the model, to include characteristic elements of Arctic biodiversity and important Arctic socio-ecological systems, such as reindeer herding. GLOBIO3 can be used to quantify and visualize actual and projected future impacts on biodiversity in Arctic regions and is potentially useful for reindeer owners in consultations and to support policy makers in land use planning. The model provides support for enhanced dialogue between reindeer herders and planners on development projects affecting Indigenous Peoples' communities and reindeer pasture. For decisions at local level more detailed data are needed, and the quality of results depends on availability of traditional knowledge and local expertise, for adjustment of land use impacts for local conditions.

There is a limit to the level of detail for which the GLOBIO3 model can be used. The issue of ground-truthing is important to ensure the global model, representing broad trends, is aligned with specific spatial predictions that are meaningful to reindeer owners. The interaction between land use changes, climate change impacts, and biodiversity loss constitutes the broad picture for the resilience of reindeer herding and the adaptive capacity of the reindeer herders.

Detailed land use and infrastructure maps were available for Finnmark. The relations in GLOBIO3 are based on global data with limited information on Arctic species. Future research should include a review of results in available literature to develop GLOBIO3 relations to Arctic environmental conditions. Characteristic elements of Arctic environmental conditions not yet included in GLOBIO3 are impacts of permafrost thawing and the increased occurrence of ice on snow. The latter has a major impact on reindeer pastures. Melting of the permafrost in tundra areas will have huge implications for climate change (increase of emissions) and land use (change of soil and vegetation). Additional research is needed to develop cause-effect relations between characteristic Arctic environmental conditions and biodiversity in GLOBIO3. In the pilot study reported here, some of the parameters in GLOBIO3 were adjusted through advice from ecological researchers, and in follow-up research, elements of traditional knowledge may be integrated in the model if MSA values is adjusted for specific locations.

Future work might illuminate potential connections and specific mechanisms between biodiversity and herding both in terms of ecological systems and in terms of potential policy related solutions to the key issues raised. In existing policies for new developments, a connection could be made to use reindeer herders' traditional knowledge, which would include herders earlier as a part of the development planning process.

GLOBIO3 results for Finnmark were presented to Sámi reindeer owners who recognized the implications of actual and projected future impact of pressures on reindeer husbandry. According to the reindeer owners, maps from the model are expected to support dialogue between the reindeer herding community and policy makers, but they emphasized that the maps should be used during consultations in the area planning process before decisions are made. Reindeer owners in Finnmark told that they expect that biodiversity loss will have implications for the quality and extent of suitable grazing areas. Especially the quality of the calving grounds is essential for reindeer herding. A reduction of biodiversity in the migration routes does not directly impair seasonal reindeer migration, but as biodiversity reduction in GLOBIO3 is partly caused by new developments such as infrastructure, impediments for migration are expected. The study by *Foundation Protect Sápmi* reported great concern among reindeer owners that regional and intermediate cumulative impacts on lichen pastures may cause collapse of reindeer herding in their district (Eira et al., 2020).

A potential improvement of decision support is to develop a specific reindeer model in GLOBIO3, in collaboration with reindeer owners, with focus on calving grounds and migration route impediments, drawing on the experiences from RenGIS developed in Sweden, to localize and describe bottlenecks of planned developments and consequences for reindeer husbandry. This may provide a reindeer pasture land monitoring system as proposed by the special rapporteur to the Permanent Forum on Indigenous Issues (United Nations, 2012). To test the models as decision support tools they should be implemented in policy cases at municipal or county level. Knowledge of cumulative impacts and potential future consequences of climate and socio-economic drivers achieved through modeling, in consultation with and including the traditional knowledge of reindeer owners, may provide a tool to assist in planning future developments and advancing strategies for adaptation and resilience. Experiences from this pilot study from Finnmark may be useful in further research on land use change and impacts on biodiversity in other parts of the Arctic, in research partnerships involving reindeer owners, and other Indigenous communities, with their traditional knowledge, in order to enhance decision support for consultations.

Fig. 9.9 Snow covering the winter pastures in Vuorašvarri, Finnmark, Norway reflects the sunshine and heat. Albedo or reflectivity measures how reflective the surface is: the diffuse reflection of solar radiation out of the total solar radiation. (Photo: I.M.G. Eira)

Supplementary Material

The uploaded report, Technical report biodiversity assessments of pilot areas in the Barents region with GLOBIO3, describes in more detail model equations and base layers, in the form of data and maps, including maps from Statistics Norway, that have been used for each GLOBIO3 map layer. There may be differences between maps in this report and in the chapter, due to differences in selected scenarios.

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Chapter 10
The Phenomenon of Entrepreneurship in Reindeer Husbandry in Yamal: Assessment of the Situation, Paradoxes, and Contradictions

Alexander Nickolaevich Pilyasov and Valeriy Aleksandrovich Kibenko

Abstract The chapter considers the development of domestic reindeer herding in the Yamal-Nenets Autonomous Region over the past 30 years in terms of an entrepreneurial paradigm. Individual reindeer herding families own almost 60% of all domestic reindeer in the region. The chapter describes two types of nomadic entrepreneurs: economically independent and those relying on state support as well as differences in their behavior patterns, cultural values, and nomadic routes. Two reindeer herding models are presented: the 'meat model' of the Yamalsky district and the 'antler model' of the Tazovsky and Priuralsky districts in Yamal. Both models determine the differences in terms of size, dynamics and structure of the herd, length of nomadic routes, structure of production income. Unlike the dominant point of view blaming irresponsible reindeer herders for the depletion of pastures, the authors of the article see the problem as an institutional one – the result of public policies that created wrong incentives for reindeer herding entrepreneurs in recent decades. This policy transferred them to the position of hired herders equal to the state workers. The authors propose reforms in Yamal reindeer herding that will ensure a decisive transition to an entrepreneurial model in reindeer husbandry and an algorithm for the reforms in the state support system.

Keywords Arctic entrepreneurship · Nomad entrepreneurs · Reindeer husbandry development model

A. N. Pilyasov (✉)
Lomonosov Moscow State University, Moscow, Russia

V. A. Kibenko
Arctic Research Center of the Yamal-Nenets Autonomous Region, Salekhard, Russia

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10.1 Introduction

Over the past 30 years, the Yamal-Nenets Autonomous Region has undergone a transition to an entrepreneurial model in reindeer husbandry. The region is the leader not only in Russia, but also globally in terms of the number of private reindeer belonging to nomadic families. Meanwhile, there are practically no studies on Yamal nomadic entrepreneurship (although there are some on private reindeer herding, e.g., for the Sámi (Departament informatsii i obszhestvennyh svyazei Yamalo-Nenetskogo Avtonomnogo Okruga, 2005)). The problems of nomadic entrepreneurship and reindeer herding entrepreneurs themselves (for example, the motives of their behavior), of their state support, are unclear and underexamined. The work by Yuzhakov (2017) is a rare exception. However, reindeer herders consider this area extremely important. Yet these problems are not exclusive to the Russian Arctic. As noted by E. Reinert, the same issues in the structure of scientific research on reindeer husbandry are seen in Norway: harmless topics dominate on the impact of climate change on the productivity of pastures, on the anthropology of reindeer husbandry, on the "tragedy of common property" (depletion of pastures as a result of overgrazing), but the topics of the effectiveness of state support for private reindeer herding units and public-private co-management in reindeer husbandry have been ignored by researchers (Reinert, 2006).

The work on the Yamal reindeer husbandry by our numerous colleagues Golovnev et al. (2014), Detter (2017), Klokov and Khrushchev (2004) and others concentrate on the clash of ways, the traditional reindeer herders and the oil and gas industry, on the economy of reindeer husbandry, on the problems of overgrazing, on the dynamics of Yamal reindeer husbandry against the situation in the whole Russian North and Arctic. Paradoxically, the reindeer herders of Yamal are more often studied as ethnic groups, as nomads, but not as entrepreneurs. The entrepreneurship of the nomadic households of the Autonomous Region is not considered something to be taken seriously, not worthy of separate research attention and study.

Our work is designed to bridge this gap. The object of the study was private reindeer herding in the form of nomadic family households in the Yamal, Tazovsky and Priuralsky districts of the Yamal-Nenets Autonomous Region, where the bulk of the personal livestock of the autonomous region and Russia are concentrated. There are about 3000 indigenous reindeer households here, which concentrate about 60% of the total livestock of the district (Departament informatsii i obszhestvennyh svyazei Yamalo-Nenetskogo Avtonomnogo Okruga, 2005). In the Tazovsky district alone (or in the two Yamalsky and Priuralsky districts taken together), there are more privately-owned reindeer than in the whole of Finland. Yamal has three times as many family-owned reindeer herders as Finland and nearly six times as many as Norway (Heikkinen, 2006; Reinert, 2006). The average size of a personal herd varies from 150 to 200 reindeer.

The informational basis of the work was the materials of our expeditionary surveys of Yamal reindeer herders from 2016 to 2019 at the Scientific Center for the Study of the Arctic, materials from a sociological study of the indigenous small-numbered peoples of the North conducted by the authorities of the Yamal-Nenets Autonomous Region in 2005 and materials from our own field surveys in 2017, data from federal and regional statistics, including the All-Russian Agricultural Census of 2016, laws on reindeer husbandry in ten reindeer herding regions of Russia (in which the main livestock of domestic reindeer is concentrated), materials from the INTEGRUM regional press database. The chapter is based on the article published in the Arctic: ecology and economy journal (Pilyasov & Kibenko, 2020).

10.2 The Phenomenon of Yamal Private Reindeer Husbandry as an Entrepreneurial Activity

A combined comparative analysis of the region's place in terms of the total number of reindeer and the friendliness of the regional law towards nomad entrepreneurs in relation to the nomadic entrepreneur[1] (Table 10.1) did not reveal a direct

Table 10.1 Comparison of regional laws on reindeer husbandry in terms of their friendliness towards entrepreneurs

Region	Characteristics			
	Number of pages of regional law (year of the latest version)	Are entrepreneurs mentioned in the law?	Are the possibilities for granting land plots to (new) units?	Rating by the total number of domesticated reindeer in Russia
Yamal-Nenets Autonomous Region	4 (2016)	Yes	No	1
Nenets Autonomous Region	7 (2019)	Yes	Yes	2
Chukotka Autonomous Region	4 (2018)	No	No	3
Republic of Sakha (Yakutia)	6 (2009)	No	No	4
Krasnoyarsk Krai	5 (2017)	Yes	Yes	5
Republic of Komi	4 (2018)	Yes	Yes	6
Murmansk Oblast	6 (2013)	No	Yes	7
Khanty-Mansiysk Autonomous Region (Yugra)	3 (2013)	No	No	8
Kamchatka Krai	2 (2014)	No	No	9
Magadan Oblast	7 (2016)	No	Yes	10

[1] For the list of regional reindeer husbandry legislation see Appendix 10.1.

correspondence: the most friendly are the laws of the Nenets Autonomous Region (NAR), Krasnoyarsk Krai, and the Komi Republic, in which entrepreneurs are explicitly included in the law and the possibility of allocating land plots to new private units is provided. But among them, only NAR is among the top four in terms of total livestock, and the absolute leader in terms of the number of personal reindeer, the Yamal-Nenets Autonomous Region, has a rather laconic document in terms of the number of pages and is not very friendly towards reindeer herder entrepreneurs. Certainly, the phenomenon of Yamal private reindeer husbandry, where three-quarters of Russian personal reindeer are concentrated, deserves a more thorough – and separate – institutional arrangement.

Private family reindeer husbandry in Yamal should be viewed as a full-fledged small business. Only such a view allows us to understand the new motives of the economic behavior of nomads, which were hidden or did not appear during the period of the dominance of the model of state reindeer husbandry in the last decades of the Soviet era (1960s–1980s). At that time, the viability of Yamal reindeer husbandry as an industry was based on obtaining a scale of economy effect for the herd and the regional livestock as a whole. This made it possible to save costs when carrying out regular vaccinations, fighting wolves, carrying out other veterinary and zootechnical activities and ordering helicopters.

The transition to an entrepreneurial model has radically changed the economic effects that now determine the viability of the industry. These are, first of all, *spatial externaliti*es[2] – the flow of knowledge and experience from one nomadic entrepreneur to another as well as experienced personnel from former public units going to private family households, much greater diversity in the structure of the herd, related activities (traditional crafts like hunting, fishing and wildcrafting); great flexibility and maneuverability (up to daily intuitive improvisations) in grazing routes in terms of pasture conditions and proximity to the sales markets for reindeer meat and antlers; the mobility of the actual organizational structure of the small business itself and temporary coalitions in which it enters daily with neighbors, other relatives and the authorities.

The mobile motivations of individual reindeer herding entrepreneurs are precisely how the new emerging model of Yamal reindeer husbandry radically differs from the much more inertial, former and *frozen* state model. And the current problems of Yamal reindeer husbandry show to how psychologically difficult make it hard for the authorities at all levels to adapt to this extremely mobile new reality of the industry's development.

Within the entrepreneurial community of private reindeer herders, as our surveys have shown, there are two poles: forced, dependent on state support, and frontier, self-sufficient. Simultaneously, there is a third compromising (mixed) type of Yamal private reindeer husbandry within the described poles, which includes the features of the first and the second and therefore is more difficult to diagnose.

[2] In economics, externalities are positive or negative external effects that arise among "third parties" who are not directly involved in a market transaction.

The model of economic behavior of an obedient reindeer entrepreneur receives state support, does not mind becoming a state employee, follows the instructions of the district authorities regarding decisions on the delivery of meat (to which slaughter complexes, to which trading posts, through which community, what price etc.): *We hand over everything to the slaughterhouse, then we do not influence the selling price. If we do not hand it over, we will lose all the benefits*. This entrepreneur does not see the need for a transition to a new organizational model in Yamal reindeer husbandry; in the event of force majeure, he moves closer to the settlements, thinks more about preserving than about increasing the herd. The size of his herd is slightly larger than that needed for the subsistence level of a family (about 250 heads). It is this type of entrepreneur who masterly knows how to adapt to the criteria for obtaining all possible forms of state support, even in the face of constant changes in its rules and regulations.

The *model of a self-sufficient private owner:* does not get state support and does not have a legal status for it; highly values economic independence; has about 500 heads; solely responsible for making major decisions; relies on his experience and intuition; he does not need factories and stalls because he sells all the meat to his friends; receives all the supplies in the village/city; plans to increase livestock. Such entrepreneurs are characterized by regular *spreading onto* the pastures of other herders. It is in him that the denial of the sedentary lifestyle is very maximally strong.

His philosophy was clearly expressed by the head of the reindeer family household, A. Serotetto: "*A nomadic way of life is – you should not ask anyone for firewood or transport. You chose this path. You should roam and not ask anyone anything … This is how the northern ones differ from the southern ones (in Yamalsky district) – the northern ones will never say that we have no firewood, no bread, or any other products. They know that since they have chosen this path, it means they have to work, as no one forbids them to stay at home*" (Departament informatsii i obszhestvennyh svyazei Yamalo-Nenetskogo Avtonomnogo Okruga, 2005: 193).

Within the three district leaders of the Yamal-Nenets Autonomous Region in the development of nomadic entrepreneurship – Yamalsky, Tazovsky and Priuralsky – two economic models are clearly distinguished: where the family business receives most production income from the sale of venison, and from antler production. The first model is typical for the Yamalsky district, the second for the Tazovsky and Priuralsky districts.

What factors determine the choice of a particular model by an entrepreneur? Of course, this is an institutional factor of the nature, scale, forms of state support for the district; the economic factor associated with state pricing policy for reindeer meat, as well as the timeliness of payments for the delivered meat and market dependence on the price of antlers and bone horns on the exchange rate; the infrastructural factor, understood primarily as the specifics of how local sales markets are organized in the form of a settlement system, trading posts, a procurement network; the geographical factor, understood as the proximity or transport distance from large local centers, including the proximity to other regions, which have a more attractive pricing policy regarding reindeer products and basic necessities for an entrepreneur.

Separately, one should note the factor of local anomalies (which directly affects the volume of supply of commercial products of a reindeer enterprise – meat, horns, antlers etc.) in the form of frequently recurring animal diseases here (i.e., brucellosis in the Tazovsky district), climatic epidemics,[3] or, for example, a bright local leader within the entrepreneurial community of reindeer herders etc. It is in the sparse and not always predictable terms of climatic and social dynamics of Arctic spaces that the factor of local anomaly can reverse the influence of all other factors.

The Yamalsky district, due to the tradition that developed back in Soviet times (it was the forge of personnel for managing the agro-industrial complex of the whole region, convenient due to its proximity to the center of the region in the city of Salekhard) has become a kind of experimental platform, a showcase for state support of the industry in recent decades based on former state units and newly created municipal unitary enterprises. Since the Soviet period, the district has been considered a large procurement center in the region with relatively favorable conditions created for this (a network of slaughter complexes, trading posts). In Soviet times, the Yamalsky district served well to achieve the plan for harvesting meat ("meat model"), to comply with export obligations, and this recent history largely determined the existing model of entrepreneurial behavior of reindeer herders focused on a meat market and related fishing (for feeding the family and reindeer herding dogs, for additional income and in some cases for survival in the event of a significant loss of reindeer).

At the other extreme are the Tazovsky and Priuralsky districts, where nomadic entrepreneurs developed their business according to the *antler model*, which determines many of its characteristics. It is no coincidence that the most modest household indicators for venison production are here: reindeer are slaughtered in small quantities for personal consumption and cover the most critical urgent needs of families in the period between the delivery of bone horns and a campaign to collect antlers, when they are collected by land and air transport in exchange for fuels, food, various goods, and veterinary drugs, less often for money.

10.3 Paradoxes of Yamal Reindeer Husbandry: 'Black' Market or 'White' Market?

New market stereotypes for the behavior of private reindeer herders (at least some of them) have revealed numerous paradoxes in private reindeer husbandry in Yamal which are completely absent in other reindeer husbandry regions where private reindeer do not dominate in numbers. For example, Yamal is the only region in which the production of reindeer meat is radically lower than expected when compared with the total reindeer population (Fig. 10.1).

[3] The "climatic" epidemic here means the anthrax outbreak in Yamal provoked by the summer heat of 2016.

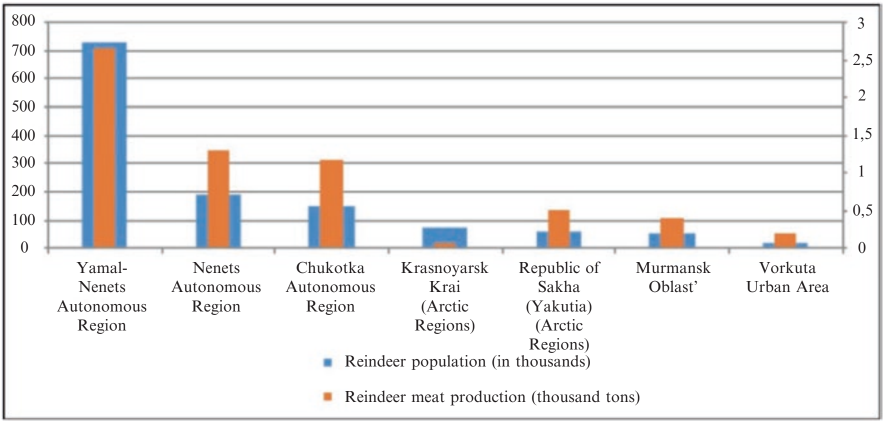

Fig. 10.1 Antlers or meat: black market or white market? Reindeer herding in the Russian Arctic zone, 2016. Source: Data from the Federal State Statistics Office (Rosstat) and internet sites. (By D.A. Sidorova, expert, autonomous non-commercial organization, Institute of Regional Consulting)

What are the reasons for non-compliance with the norms for delivery? Why does a reindeer herder avoid a particular slaughterhouse? The reason lies in the economic incentives formed for private entrepreneurs by the most important ratios of prices for venison and gasoline, venison and antlers. Understandably, within state reindeer husbandry in other regions, these comparative prices do not affect the economic behavior of herders to a great extent. In fact, Fig. 10.1 shows the role of the antlers market in which thousands of Yamal reindeer family households are involved.

Hereditary nomad Ivan Anagurichi from Panaevskaya tundra decided to postpone the slaughter of three hundred reindeer. The animals were saved from inevitable death by … horns!

The buyer for antlers showed up; the man rejoices. Gave a good price. I have more than two thousand heads in my herd, many horns have accumulated; if I sell, I'll get a lot of revenue. And let the reindeer live until next year … Many tundra people adhere to similar tactics nowadays. Reindeer antlers are procured almost everywhere in Yamal.[4] (This is a statement from the electronic media "Myaso-portal", interview with Ivan Anagurichi).

The presence of two markets (the official venison market and the semi-official antlers market with his intermediaries, transport scheme, helicopters, etc.) form a drama within the private Yamal reindeer industry, not comparable with the situation in the state population. The meat market has historical roots while the antler market is more contemporary.

And the fact that both markets make a significant contribution to the incomes of private households in Yamal is confirmed by the data on the structure of herder family incomes (Tables 10.2 and 10.3).

[4] http://www.myaso-portal.ru/news/news-branchs/iz-za-vysokogo-sprosa-na-panty-tundroviki-neokhotno-sdayut-zhivotnykh-na-myaso/

Table 10.2 The structure of income of a family of reindeer herders in the Yamalsky district of the Yamal-Nenets Autonomous Region from the sale of reindeer husbandry products (Zuyev et al., 2017)

Product type	Share, %
Reindeer meat	66.6
Antlers	18.7
Bone horns	14.7
Total	100.0

Table 10.3 Income from the sale of reindeer husbandry products from the families of reindeer herders in the Tazovsky district of the Yamal-Nenets Autonomous Region (Gydanskaya tundra) (Kibenko, 2018)

Reindeer products	Total kg	Income at an average price, rubles	Share, %
Antlers, kg (n = 43)	11,647	14,512,162	67.4
Reindeer meat, heads	29745[a]	4,878,180	22.7
Reindeer meat, carcasses[b]	82	1,230,000	5.7
Bone horns, kg (n = 42)	6184	909,048	4.2
Total		21,529,390	100.0

[a]Total weight is calculated based on an average slaughter weight of 45 kg

[b]Reindeer meat in carcasses – sales to the village or to buyers bypassing official slaughterhouses to get cash. In this case, meat was sold as carcasses by 9 families out of 50. In total, 82 carcasses of reindeer were sold during the year

Everything is different in these two markets: institutions, transport schemes, intermediary structures etc. The meat market set demands for the fat content of reindeer meat, the quality of meat, the presence of important animals for the regular reproduction of the herd; for the antlers market, the livestock of males is important, from which unique raw materials are cut. At the same time, it is wrong, as is customary among journalists, to denounce the greed of private reindeer herders who abandoned the work of their ancestors for the sake of antler gain and, uncontrollably increasing their livestock, and destroying pastures in the process.

Antler harvesting is an important source of additional income for private households. The collection of antlers occurs in the summer, far from settlements, when the herds are in the north, where there are no gas stations or shops and this is the only way to replenish the stocks of food and fuels from buyers at high prices, mainly through barter. *Pantovka* (cutting antlers for the purpose of selling them) does not allow reindeer herders to carry a lot of food and fuel to the north, but to buy on site, to pamper children who come to the tundra for the summer with their families.

This is an important element of insurance (you cannot put all your eggs in one basket, i.e., depend on one source of income like reindeer meat). And for small and medium-sized reindeer herding private households, such diversification of economic activities is critically important. In every district in the tundra there are reindeer-entrepreneurs who buy horns, antlers and *kamus* (deer shin pelt) themselves from close-knit reindeer herders and then resell them in villages at a higher price.

The antler business should not be allowed to develop illegally, predatory, unrestrained, in the format of rent seeking. And there are prerequisites for this. And this is precisely the niche for government regulation, which via long-term subsidies of reindeer herders per *head of deer* or the industry as a whole, without reference to the volume of meat delivered, on the contrary, itself stimulated their hunt for antler rent, and not efficient and eco-friendly sustainable management. That put this market at the mercy of clandestine resellers for sale in China and Korea, not having developed intelligible formats of regulation and certification over time. In one word, regulation is needed.

10.4 The Tragedy of the Commons in Yamal Reindeer Husbandry: Myth or Reality?

It seems very tempting to reduce many of the current problems of private Yamal reindeer herding to the *tragedy of the commons* model. The term was introduced by G. Hardin in 1968 in an article for the journal *Science* (Hardin, 1968). Indeed, the situation in Yamal reindeer husbandry seems to have developed canonically according to this model.

At first, in the state reindeer husbandry, the ecological capacity of pastures corresponded to the number of domesticated reindeer. Then, after the denationalization and privatization of the industry, private reindeer herders emerged with new incentives to make a profit, who, according to the *free-rider effect* at no cost and mercilessly (and with weak and ineffective state regulation of this process) exploited the rapidly growing population of their personal reindeer on public winter and summer pastures as a foraging resource, which caused their rapid depletion (primarily winter pastures). The real facts of the growing competition for pastures (such as young people wanting to separate from their parents and set up their own chum and get reindeer – these are the demographic reasons for overgrazing), satellite images of the lunar landscapes in the place of the formerly civilized reindeer moss in the center of the Yamal Peninsula seem to confirm this theory. The government is blaming the herders for pasture degradation.

However, with all the attractive simplicity of this theory, the real situation in private reindeer husbandry in Yamal is more complex and the interpretation of the problem of overgrazing only from the standpoint of the tragedy of commons (and therefore, the greed of the reindeer herders is to blame) has limitations. Overgrazing also existed in Soviet times, such as in the Chukotka Autonomous Region, when there was no trace of private use of common land ownership of pastures.

First, there is no chaotic system of common property pastures, but an established system of the traditional distribution of plots and regulation of pastures, which most herders adhere to (and only a few violate it). Therefore, the initial premise that these pastures are in *common property* does not correspond to real practice. The idea that private reindeer herders are predators who, in the name of profit, destroy the foundations of their future well-being strongly contradicts all the nature-compatible values that have been asserted for centuries in the folklore of the indigenous peoples of the North.

Second, overgrazing[5] and eroded landscape phenomenon is by no means a homogeneous and total phenomenon. On the contrary, we are talking about a very polarized phenomenon when *dormant* areas are combined with very depleted ones.

Third, it is impossible to unilaterally assume that reindeer herders are to blame for the current situation because *other conditions* have not been equal in recent decades: during this period, gas industry development in the north of Yamal accelerated significantly, even radically, and this caused the economic alienation of a part of the pastures previously used by herders.

Finally, let us state some general considerations on this matter. The direct coupling of *growth in a number of reindeer* to *overgrazing of pastures* greatly simplifies the natural reality of Yamal as a typical Arctic territory. This coupling is inspired by analogies of a totally controlled and predictable conveyor process in the form of standard animal husbandry, a meat factory where cows and bulls are grazed in a completely controlled environment. But the situation in reindeer husbandry is fundamentally different. Here, the environment is non-stationary and poorly controlled by human influence. This is a multifactorial reality in which the condition of pastures is influenced by many other factors than just reindeer grazing, climate cycles, constant changes in weather, and climate work (Reinert, 2006). These Arctic systems (this is their fundamental difference from natural systems of the temperate zone) are in high disequilibrium, and it is simply impossible to find a simple correspondence here between the number of animals and the capacity of pastures in the style of a closed unit.

In the collision of overgrazing, in which the reindeer herders are to blame, one can see a conflict between two polar types of knowledge: formal knowledge of biologists and tacit knowledge of reindeer herders. The knowledge of biologists is a model of ecological balance, when the livestock of domesticated reindeer, after high-amplitude fluctuations, *calms down* to a certain *harmonious* and stable level. The knowledge of reindeer herders is the unpredictability of the environment of rapid change and reliance on intuition. This knowledge has been accumulating for decades within a family of relatives who jointly graze a herd of reindeer. It is difficult to blame only one of them for it (Reinert et al., 2008). And only solutions based on the integration of knowledge will be sustainable and rational from the point of view of further development of Yamal private reindeer husbandry.

But the concept of the tragedy of commons, applied to the situation of Yamal private reindeer husbandry, is correct in one thing: the weak state regulations were the catalyst for the rapidly emerging problem of overgrazing. The laws on reindeer husbandry for the Yamal-Nenets Autonomous Region are the weakest in terms of environmental requirements compared to others (Table 10.4).

[5]The current reindeer population in the Yamal-Nenets Autonomous Region is almost twice the estimated reindeer capacity (Zuyev, 2015).

Table 10.4 Characteristics of regional laws on reindeer husbandry in terms of the environmental criteria

Criteria[a]	Is it possible to withdraw reindeer pastures for the use in the case of rules violation?	Is there a norm on the need to match reindeer capacity of pastures determined by land management?	Is there a norm for restoration of damaged cover and/or compensation for exploration and mining?	Ban on the movement of motor vehicles during the snowless period	Reindeer capacity control (sources)	Total score
Yamal-Nenets Autonomous Region	No	No	No	No	No	***0***
Nenets Autonomous Region	Yes (violation of carrying capacity)	Yes	No	Yes (except for special permits, emergency, etc.)	Yes (projects on pastures land management)	***4***
Chukotka Autonomous Region	No	No	No	No (on the contrary, delivery is important)	No	***0***
Republic of Sakha (Yakutia)	No	No	Yes	Yes (except for dedicated tracks)	No	***2***
Krasnoyarsk Krai	No	No	No	No	No	***0***
Republic of Komi	No	No	No	Yes (except for special government decisions)	No	***1***
Murmansk Oblast	Yes (in case of appropriate use)	Yes	Yes	Yes (except for dedicated tracks)	Yes (land management materials)	***5***
Khanty-Mansiysk Autonomous Region (Yugra)	No (but there are conditions for the provision of pastures)	Yes	No	No	Yes (projects on pastures land management)	***2***
Kamchatka Krai	No	No	No	No	No	***0***
Magadan Oblast	Yes	Yes	Yes	Yes (except for rescue, medical, emergency, etc.)	Yes (established by the regional government)	***5***

[a]Having read all regional laws on reindeer husbandry, we have selected these criteria as the principal ones to distinguish one from the other and therefore to compare them in a more informative way

The Yamal reindeer herding problems associated with overgrazing are not unique to the global Arctic. For example, in the Norwegian province of Finnmark, where three-quarters of all reindeer in the country are grazed (there are about 250,000 domesticated reindeer in Norway), there is also a very high spatial concentration of pastures used by private reindeer family households (especially in winter). Overgrazing problems emerged here as early as the 1980s. State measures aimed at forcing reindeer herders to reduce their personal herd are ineffective; the reindeer population is growing despite the tightening of the regulation (Johnsen, 2014).

As in the Yamal Peninsula, a compelling argument for the tragedy of commons is satellite images of lichens. A time series over 30 years, which scientifically provide the frontal logic of *fewer lichens – more reindeer, which means there are fewer of them because of the reindeer* (Behnke, 2000). However, more in-depth and multifactorial studies show an influence of not one, but a whole range of factors: climate change, government pricing policy, sanitary regulation of reindeer husbandry, etc. The combined effect of these factors leads to the fact that the reindeer herders themselves have very little influence on the development of their industry, that they not only cannot fully realize their malicious intent to snatch profit from their business but, on the contrary, are themselves hostages of significant changes in natural conditions and government tightening of the regulation (Reinert, 2006).

10.5 What Is to Be Done: Entrepreneurial Model, Adaptive Co-management, Polycentric Governance

Many features of the tragedy of common property that manifested itself in Yamal reindeer husbandry, with amendments to the specifics, have long been known and described in scientific literature. But the solutions to these problems, which go beyond the purely market or purely state-centralized, were also described in detail by the Nobel Laureate in Economics E. Ostrom in her book Governing the Commons (Ostrom, 1990). This book elucidates on self-governing institutions that allocate shared resources like communal land tenure, coastal fisheries, groundwater, water resources, and irrigation projects which have been successful for a long time. They may well be used to solve the problems in Yamal reindeer husbandry. It is important that these mechanisms are based on the already established reality of personal, family reindeer husbandry (and the reliance on personal interest inherent in this model, i.e., they do not require a return to public ownership of reindeer in one form or another), including algorithms for the collective use of limited pasture resources based on the regulation of this process by the participants themselves with the support of the State.

This system has three cornerstones: initial clarity and certainty in the formulation of the problem of pasture depletion; reliance on communication between all parties of the conflict – these are reindeer herders, resource corporations, and the state; a course toward the creation by reindeer herders of their own restrictive institutions.

The *first block*, in turn, is specified in the requirements for the accuracy and reliability of information (today, even the initial indicator of the number of domesticated reindeer in different information sources of the Autonomous Region differs by 25–30%; personal reindeer family households in all senses are *invisible*, absent from official registries and regulations) within clearly defined boundaries of the problem area; it will be important to determine whether the problem of overgrazing is being solved within the area where it is acutely identified (i.e., in the Tazovsky, Yamal and Priuralsky districts or within the outline of the entire autonomous region). An effective solution is obviously possible only with the utmost adequacy of local conditions, that is, via ways of recognizing the colossal heterogeneity of the tundra of Yamal and the need to develop a solution to the crisis for each of its sectors. Practice shows that if there are general recipes for well-being, then the ways out of the crisis are specific for each local entity.

The *second block* of effective and trusting communication puts the success of solving the problem in the hands of intermediaries of the authorities and the private reindeer herders, who can understand and hear both. In different countries, such intermediaries are lawyers, former reindeer herders who have become officials or national leaders, expert scientific consultants, etc. No less important are such intermediaries among the herders themselves, between the owners of large and small reindeer family households, and between social activists and personalities. After all, they need to impose voluntary systemic constraints on themselves. The experience of Norway shows that it was not possible to find such effective intermediaries among the Sámi herders and for communication between the Sámi and the State, which was the reason for the failure of government measures to regulate the number of reindeer. In establishing trust and open communication between all participants, the establishment and maintenance of permanent forums play a huge role as effective platforms for exchanging opinions and coordinating positions.

The *third block* of gradual institutional changes involving the reindeer herders themselves in creating norms and rules for themselves means the emergence of a new type of institutional entrepreneurship in their environment; these are people, who can propose their own or change the existing institutions of supervision and sanctions to control livestock, for the subsequent formalization by state bodies.

The ideal scheme for Yamal reindeer husbandry is the transition to the principles of adaptive self-governing co-management (Armitage et al., 2014) by granting the reindeer herders themselves the right to make key decisions, considering the existing restrictions. This is somewhat closer to the Finnish-Swedish model of private reindeer husbandry. However, of course, it is much easier to switch to such a model when the cost of the issue is lower when the total number of reindeer is small, and the significance of the issue is relatively limited against the background of other social problems. But, in Northern Norway, where the number of private reindeer is significantly higher, it has not yet been possible to switch to these principles due to influential political interests.

10.6 Mistake: Supporting Reindeer Husbandry as an Industry, Not as a Reindeer Entrepreneur

The problems faced by Yamal reindeer husbandry have risen to their full extent in recent years: anthrax, overgrazing of pastures, unsuccessful attempts to stabilize the number of domestic reindeer by directives, and the ineffectiveness of the system of economic support for reindeer husbandry are honestly acknowledged by the regional government itself:

"The legal norms for regulating the number of domesticated reindeer, established by the legislation of the autonomous region, regulating relations in the field of reindeer husbandry, do not work. There are no mechanisms for their implementation".[6]

Why, despite the significant budgetary resources that are annually allocated to support reindeer husbandry in the Yamal-Nenets Autonomous Region (and the region has budget funds for this, unlike other reindeer herding regions, and this even plays a cruel joke on him because there is an illusion that a simple distribution of budgetary resources in various areas of development of reindeer husbandry can solve all its problems), the problems of the industry are aggravated, and it is not possible to come up with solutions that satisfy the herders themselves?

State support ignores the realities of the emerging new model of private, small, and medium entrepreneurial husbandry, which dominates the number of livestock in the region. Meanwhile, support is being given as if reindeer husbandry is still formed by a few large state units: there is no understanding of the new nature of a small business enterprise, which fundamentally differs from a large one in the motivation of the owners, in their economic behavior, interests, aspirations, super mobility etc. They are supported as if they were wage earners in the brigades of large state units.

This would not be frightening if private herding was a tiny fraction of total livestock, as it is in many other regions of the Russian North. But the Yamal challenge for state support is that private reindeer husbandry dominates here, and support is still focused on the industry, a large unit, where there is no entrepreneur as the leading agent of changes in the regional reindeer husbandry. There is a type of activity called reindeer herding that is eligible for state support; the animal (reindeer) is recognized, but there is recognition of the entrepreneur.

This is manifested, for example, in the ultimate unification of support as if all units were the same. But it is not so. There are strong and rapidly growing units; there are weak and even dependent private households. There is no encouragement to support strong entrepreneurs who are ready and willing to grow; state support deprives of any incentives for strong units which at best shun support or go into the shadows (black market), naturally fostering many weak and small units, which

[6] Resolution of the Government of the Yamal-Nenets Autonomous Region on the approval of the state program of the Yamal-Nenets Autonomous Region «District property management for 2014–2018» dated March 13, 2017, No. 171-P.

undermines the constructive dynamics of the industry. The system rewards obedient subsidy recipients and punishes herders with genuine entrepreneurial ambitions.

In Yamal, the failure of state policy is especially noticeable because the industry is dominated by a private herd, and the forms and measures of support are essentially old. State support is aimed at maintaining an inertial trajectory in which large state units are the main ones, but not at the formation of an entrepreneurial model of reindeer husbandry (paradox: there are personal reindeer, but there is no market-oriented system of state support for private reindeer herders).

Meanwhile, entrepreneurs differ from large state enterprises in that they react very quickly and flexibly to the changes of institutions. What is *digested* at state units in months and years is instantly reflected in the behavior of the entrepreneur and his business: going into the "shadow" (black market), switching to other markets, changing grazing routes etc. The regional government does not take into account the super mobility of the private nomadic business in response to institutional changes set by the measures of state support. In these new conditions, by quickly initiating and then gradually improving the institutions of state support, it is possible to ensure that reindeer herders will accept these state institutions and comply with the restrictions that they impose.

The most important instrument of economic support is always the price, the pricing strategy. There are special requirements for the specific conditions of Arctic domestic reindeer husbandry: Arctic areas and Arctic reindeer husbandry are subject to the strongest annual cyclical fluctuations. This distinguishes it from conventional, "conveyor" livestock herding.

A key element of the reindeer husbandry economy is the two different types of economic crises that these fluctuations create at the top and bottom of this cycle: crises of underproduction and overproduction. The crisis of underproduction arises partly with difficult accessibility and lack of food on winter and autumn-spring pastures, and the crisis of overproduction occurs under extremely favorable grazing conditions. The pricing policy must consider this inherent feature of the industry: ideally, when the price of venison rises during periods of underproduction and decreases during periods of overproduction. In reality, the purchase price is set without regard to these natural and climatic cycles. As a result, pricing policy exacerbates rather than diminishes the impact of negative climate fluctuations. The principle of price stability, e.g., for beef or pork, is transferred to domestic reindeer husbandry which has an essentially different, highly cyclic nature of production (Reinert, 2006).

Instead of a normal economic institution in the form of a price for meat, the response to underproduction is the constancy or increase in social subsidies for reindeer herders, while the price remains the same: the livestock has decreased sharply, the price is the same, less meat was sold, less income was received, but the subsidies were the same or more. As a result, the problems and instability within the nomadic business only increase.

But the price for venison contains another paradox that provokes instability in business. Normal entrepreneurship is impossible if the herder does not have the right to direct (legal) supply of products to the market. But this is precisely what many, especially the poor and state-dependent reindeer herding entrepreneurs, are deprived of.

Under the conditions of state support, they are obliged to supply meat to *authorized* trading posts and slaughter complexes, where they are offered a reduced price against the conditions of a normal market. The State partially compensates for low purchase prices and, accordingly, the economic impoverishment of reindeer herders with social benefits. But this has nothing to do with the sustainability of their entrepreneurial activities. It is formed only at a fair price.

A paradox arises: wealthy reindeer herders, who already have relative financial security, strengthen it even more because they can sell meat in normal city markets at a fair price, and poor reindeer herders, tied to state support, must donate meat at slaughter complexes and get poorer due to the low purchase price. Formally, private reindeer herders resemble hired workers of public units who also do not own the product they produce and do not have control over key processes in the venison market: the procurement of reindeer meat and the sale and marketing of reindeer meat in the food markets.

For many decades, the main support measure for private reindeer herding in Yamal was subsidizing the head or branch, not produced reindeer meat. On the one hand, this ensured ease of reporting. On the other hand, it created the wrong incentives to increase livestock to work in the "shadow" antler market. It turns out that the State by its own hands encouraged entrepreneurs to leave the legal local meat market for the illegal Asian antlers market. At the same time, the State did not have an official price for the surrendered antlers, i.e., initially, this entire market became clandestine and was left at the mercy of various intermediaries.

Given the multiplicity of activities carried out by a private family in reindeer husbandry, it would be more correct to set the main subsidy per ruble on value-added from any legal type of activity (production of meat, antlers, fishing, fur trade, tourism, etc.), or attach the support to kilograms of meat being handed over for the first time.

The veterinary services critical to reindeer husbandry do not consider the modern capillary organizational structure of the industry, woven from thousands of private households. It is much easier to work with large state units and get the effect of the economy of scale here to save costs. But, as the case of anthrax showed, the fact that the veterinary services do not cover small units affects both small private and large state units when the epidemic begins.

Over the past 20 years, the average weight of a Yamal reindeer has decreased by one and a half times. But it is impossible to carry out pedigree work only at state units, and how to organize it among thousands of private households is not determined by any normative acts of the Yamal-Nenets Autonomous Region.

Many measures of state support for private reindeer husbandry, to be successful, should provide for the possibility of general, collective actions on the part of nomadic entrepreneurs (not only government agencies), for example, in case of fires in pastures or when wolves attack, during veterinary work, in support of pedigree reindeer husbandry, etc. Today, support for the industry, which in its implicit inertial form retains the previous approaches directed at large state units, by default proceeds from the premise of the internal unity of all enterprises, a single labor market in the industry, a single personnel policy, etc. Yet this unity does not exist. It is needed to provide it. Establishing collective action means encouraging the cooperation of private households in the general need for sales, services, etc.

Compared with failures in the economic stimulation of private reindeer households by the *right* new institutions, the social side of supporting the families of reindeer herders looks very good. For example, in the overall structure of incomes of families of entrepreneurs-reindeer herders of the Yamal region, the share of social support of all types is more than 45% (Table 10.5). In accordance with the legislation on guarantees and rights of the peoples of the North, reindeer herder families enjoy all types of state support and even more generously than in other reindeer herding regions. There is *nomadic* money in the region, which is a monthly allowance for indigenous people leading a nomadic lifestyle; compensation payments for children who do not attend kindergarten; district governments provide non-material assistance to the tundra people in the form of non-food items (stoves, cloth, tarpaulin, generators, etc.), bring in scarce firewood, etc.

It is interesting to compare the support of private Yamal reindeer herding with the Scandinavian experience (Sweden, Finland, and Norway). Within the three Scandinavian countries of Sámi private reindeer husbandry, it is easy to distinguish Finland and Sweden on the one hand from Norway on the other, which has the largest livestock of Sámi domesticated reindeer.

Support for self-regulation and self-government, decentralization in decision-making on priorities and specific measures are not found in the country with the most numerous livestock, but, on the contrary, in Finland and Sweden (there is a kind of inverse relationship where reindeer herding entrepreneurs have more control in the development of the industry where there is less livestock). In Norway, the industry is characterized by extreme overregulation and a complete lack of control from below, from the reindeer herders themselves (Reinert, 2006; Reinert et al., 2008).

Table 10.5 The general structure of income of the family of reindeer herders in the Yamalsky district of the Yamal-Nenets Autonomous Region, % (Kibenko et al., 2017)

Income type	Share, %
From economic activities:	*54.2*
Reindeer meat	22.1
Subsidiary activity	16.3
Realization of antlers	9.5
Bone horns	6.3
Social support of all kinds:	*45.8*
Pension payments	17.0
Social benefit («nomadic» money)	11.8
Inventory assistance	8.5
Social payment (for children who do not attend a preschool institution)	7.0
Social payment (child and other benefits)	1.5

The Finnish-Swedish support model is characterized by a minimum threshold in terms of numbers from which assistance is provided (300 reindeer in the south and 500 in the north). In Sweden, the price support for a slaughtered animal can be up to 20% of the net income from the sale of venison. Reindeer herders here receive compensation for grazing animals for kills by wolves and other predators, for losses from vehicles and the contamination of pastures due to the attributes of industrial activities. Reindeer herders themselves own the corals (slaughter); that is, they have control over critical elements of the value chain (Dana & Riseth, 2010).

On the other hand, the Norwegian support model is larger, but the degree of regulation of the private reindeer herder – the recipient of assistance there – is much higher. Unlike Finland and Sweden, Norway does not set a limit on the population from which support is provided, rather a *ceiling* where it stops (to stimulate a decrease in the number of livestock as a way to combat overgrazing). Since 1977, annual negotiations have been held on the level and conditions of subsidies which are constantly changing (therefore, the very adjustment of the entrepreneur-reindeer herder to the new rules becomes a profitable business).

There are various structures for the *care* of private reindeer herders; for example, special firms that are engaged in slaughtering reindeer and receive subsidies for this, a reindeer husbandry development fund for R & D in the industry, and reindeer herders' associations. However, these organizations do not reflect the voice and interests of independent entrepreneurs-reindeer herders, but in fact, are just a subdivision of the Ministry of Agriculture (Reinert, 2006).

10.7 A New Model of Reindeer Husbandry in Yamal: Small Business as the Key Agents for Change

In the winter of 2017, reindeer herders on private and community units in the Yamal, Priuralsky, Nadym, and Purovsky districts were asked to answer a questionnaire in which the question was: In your opinion, how should the new model of organizing Yamal reindeer husbandry look like? (To set priority on a five-point scale). Scored options included the widely discussed solutions for reindeer husbandry in the Yamal Autonomous Region. Among the responses of 20 heads of reindeer herding units, two positions can be clearly distinguished: hopes for a return to the Soviet state-controlled model (minority) and a course for the further development of the entrepreneurial model, the potential of private small and medium-sized businesses in Yamal reindeer husbandry (Table 10.6).

Along with this, there are general proposals that can be incorporated into any economic model (introduce new technologies, take a course towards intensifying the development of the industry, take voluntary commitments to reduce the herd etc.).

The radical changes in the internal structure of Yamal reindeer husbandry, which led to the emergence of thousands of small and medium-sized private reindeer family households instead of the previously existing dozen large state units, are still far

Table 10.6 Key proposals that received the highest number of points for the new model of Yamal reindeer husbandry

<table>
<tr><th>'Soviet' model</th><th>Entrepreneurial model</th></tr>
<tr><td>More large state units and fewer private ones</td><td>More private reindeer units and fewer state ones</td></tr>
<tr><td>More experienced herding units, with medium-sized number of reindeer, in which the standard is maintained</td><td>Strengthening insurance institutions in private reindeer husbandry</td></tr>
<tr><td rowspan="3">Focus on the community as the core of private reindeer husbandry in the district, which, as a network, consolidates private family units in one district</td><td>Differentiated system of state support: Considering the life cycle of a particular private reindeer herding business (growth, stabilization, decline), as well as the size of the individual unit (large or small)</td></tr>
<tr><td>The freedom to sell reindeer meat and its marketing is completely in the hands of the reindeer herders themselves</td></tr>
<tr><td>More pressure on income for traditional industries (fish, fur), tourism, to diversify sources of income and reduce the risks of reindeer husbandry</td></tr>
<tr><td colspan="2">Both groups agree on the necessity of:
The voluntary commitment of each unit to reduce the livestock in overgrazing areas.
Increasing the grazing area range with access to the forest-tundra zone.
Replacement of the quantitative livestock increase with a qualitative improvement in herd structure and productivity.
Purchasing and installing mobile meat processing plants along the grazing routes to reduce the number of reindeer in Yamal.</td></tr>
</table>

from complete, and a real change of models has not yet taken place because support does not yet encourage the development of entrepreneurship in the industry, does not take into account the phenomenon of the emergence of hundreds and thousands of nomad entrepreneurs. Yamal so far ignores the new effects and opportunities that the industry is providing with the emergence of a new private model for organizing domestic reindeer herding with the inclusion of entrepreneurial energy, new dynamics, and new incentives for the economic behavior of herders (when it is better to provide shepherds-entrepreneurs with a fishing rod rather than fish).

The potential of the former radically socialized model has been exhausted and the resources of the new entrepreneurial model are not mobilized. The industry has frozen in the worst intermediate state.

The new entrepreneurial model for the development of domestic reindeer husbandry in Yamal should be based primarily on small family businesses. It organically corresponds to the new configurations of the main resource of reindeer husbandry like pastures, which in recent decades, under the influence of a sharp increase in livestock and an increase in the scale of economic activity, the advance of forest landscapes to the north, to tundra territories, have become more small-contoured. The monotonous landscape of pastures turns into a patchy one. The recognition of the correctness of small- and medium- herd reindeer husbandry is supported not only by the institutional transformations that have taken place but also by the landscape and climatic dynamics.

The former *vertically integrated* model of the organization of the state industry is being replaced by a networked, decentralized one, with a huge role not of directive orders from the center, which, as a Communist party line, should certainly be implemented, but horizontal flows of knowledge, experience, implementing best practices from each other, collective training of neighboring private households which jointly face the challenges of the strongest temperature amplitudes and fast landscape dynamics (changes in the structure and areas of lichens).

To fully liberate the new effects that the entrepreneurial model for organizing reindeer husbandry brings, it must be recognized as a full-fledged, real business and not a leisure activity. This means that you need to rely on entrepreneurial energy. And this means decentralization of the right to make key decisions down to the private family households themselves.

If everything is already clear enough about the entrepreneurs themselves, their motivations, economic behavior, and incentives to which they react sharply and quickly, then regarding the position of the State we can say that it has not yet been formed, except for an acute declared desire to reduce the number of domesticated private reindeer and through this to reach a solution to the problem of the industry. But there will be no solution on this path; on the contrary, such measures will provoke a further crisis in the regional reindeer husbandry: a rigidly regulated *roller* can lead either to a massive departure into illegality (which is already happening) or refusal to engage in private business, which has become the object of strong administrative pressure. And this (at least initially) will exacerbate the already dramatic problems of the industry.

As for overgrazing, there is not one linear solution. It should be a systematic package of measures in which each participant (resource corporations, reindeer herders, state land administration, and reindeer husbandry regulation services) bears its own risks and responsibilities. It would be immoral to assign the solution to the problem of overgrazing only to the most politically weak participant in the conflict – the private reindeer herder.

10.8 Conclusion

The situation in Yamal domestic reindeer herding is difficult. It is itself an experiment on a global scale in terms of the scope of developed private reindeer husbandry (neither Norwegian, Finnish nor Swedish private Sámi reindeer husbandry can compete with the Yamal in terms of size and spatial coverage; and there are no close analogs in Russia either).

So far, all the main attempts at optimal solutions go beyond recognizing it as typical Arctic entrepreneurship. It will be constructive and correct, on the contrary, to return to the discussion of searching for solutions via the channel of an entrepreneurial model and its opportunities and limitations.

Government support and regulation do not consider the realities of the transition to an entrepreneurial model of reindeer husbandry, they are still focused on helping all units as if they were state-run and large. But the motivation in a private household is completely different from that of a state unit. The existing support, without considering these realities and new incentives for private households, is not able to solve the problems of the industry. On the contrary, it provokes their occurrence, such as an increase in livestock and problems of overgrazing.

Instead of the former centralized bureaucratic management of the industry, the emphasis should be on the self-organization of reindeer households from below, on feedback in response to decisions from above, on the decentralization of the practice of making key decisions with significantly greater access to them by the reindeer herders themselves and greater trust in the tacit knowledge of herders, which has in recent years been actively replaced by the knowledge of biologists and officials from the regional administration. In fact, this knowledge should enhance, complement, and not substitute one another in competition.

Instead of annually providing *fish* with social support to private reindeer herders, it is much more effective to train them to master the *fishing rod* skills of nomadic business and Arctic entrepreneurship. Yamal reindeer husbandry should be built from below, from the sole business economy and its strengthening as the basis, a new backbone for the development of the whole industry.

It is necessary to give reindeer herders the right to independently sell their products on the nearest markets, so they have incentives for responsible entrepreneurship and not the attitude of a hired worker of the state unit type. It is necessary to look for solutions along the lines of not suppressing but strengthening the impulses of entrepreneurship in family nomadic reindeer husbandry (Figs. 10.2 and 10.3).

Fig. 10.2 Selection of sled reindeer, Yamalsky district, Yamal-Nenets Autonomous Region, Russia (2017). (Photo: V. Kibenko)

Fig. 10.3 Setting up a dwelling, Yamalsky district, Yamal-Nenets Autonomous Region, Russia (2016). (Photo: V. Kibenko)

Appendix 10.1: Reindeer Husbandry Legislation

The chapter operates the latest editions of the regional laws on reindeer husbandry from the normative legal database "Consultant +":

- the law of the Yamal-Nenets Autonomous Region "On reindeer herding in the Yamal-Nenets Autonomous Region" dated June 6, 2016, No. 34-ZAO,
- the law of the Nenets Autonomous Region "On reindeer husbandry in the Nenets Autonomous Region" dated December 6, 2016, No. 275-OZ (as amended on April 23, 2019, No. 73-OZ),
- the law of the Chukotka Autonomous Region (ChAR) "On state regulation and state support for the development of northern reindeer husbandry in Chukotka Autonomous Region" of June 8, 2007, No. 57-OZ (as amended on May 7, 2018, No. 24-OZ),
- the law of the Republic of Sakha (Yakutia) "On northern domestic reindeer herding" of June 25, 1997, No. 179- I (as amended on October 15, 2009, No. 736-З No. 363-IV),
- the law of the Krasnoyarsk Krai "On state support of reindeer husbandry in the Krasnoyarsk Krai" dated December 11, 2012, No. 3-868 (as amended on 8 June 2017 No. 3-663),
- the Law of the Komi Republic "On reindeer husbandry in the Komi Republic" dated March 1, 201 1, No. 18-RZ (as amended by dated November 29, 2018, No. 109-RZ),
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