Managing mountains, past and present conditions for traditional summer farming and Sami reindeer husbandry in northern Scandinavia

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Abstract

Traditional land use and conditions for maintenance of biodiversity are often interlinked. When land use changes and ecosystems change as a result, there is a risk to loose both the traditional ecological knowledge and the biodiversity connected to this land use.

This thesis focuses on traditional land use, summer farming and Sami reindeer husbandry, in the mountain areas of northern Scandinavia (mainly Sweden), in a historical and contemporary perspective. The overall aim is to contribute to the understanding of the conditions for the traditional land use in the Scandinavian (mainly Swedish) mountains, using the concepts of traditional ecological knowledge (TEK) and a historical-ecological perspective. Both summer farming and reindeer husbandry are under strong external pressure and face large challenges today. Some of these challenges are shared and some differ between the two types of northern pastoralism. Scandinavian summer farmers experience that different views on their land use from different authorities affect them negatively. The increasing populations of large carnivores also worry the summer farmers. Recent depredation rates are in fact of the same level as historically (around 1900). Interviews showed that traditional knowledge about protective measures had eroded during years without carnivores, but also that farming practices have changed recently and that new knowledge developed. Sami plant use has been studied historically, but information about Sami plant management of *Angelica archangelica* was not documented. We argue that Sami ecological knowledge should be used to ensure sustainable harvest methods. Today traditional reindeer husbandry faces severe problems due to the reduction of winter grazing land by different encroachments, most importantly from modern forestry. The negative effects are even larger since increasingly difficult winter conditions create a need for a wider range of good grazing areas. Traditional knowledge is essential in the herders´ daily work, but the usability of the knowledge is severely constrained by recent changes. In the future planning of an ecologically and socially sustainable mountain management it is necessary to work with traditional land users and integrate their traditional knowledge.

Keywords: Traditional ecological knowledge, historical perspective, forest grazing, pastoralism, transhumance, boreal forests, carnivores, land use changes

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Dedication

Till alla fäbodbrukare och renskötare som fortsätter förvalta sina arv.

”Vem vördar daggmasken, odlaren djupt under gräsen i jordens mull. Han håller jorden i förvandling. Han arbetar helt fylld av mull, stum av mull och blind. Han är den undre, den nedre bonde där åkrarna klädas till skörd. Vem vördar honom, den djupe, den lugne odlaren, den evige grå lille bonden i jordens mull.”

Harry Martinsson, ”Daggmasken”, ur diktsamlingen Passad, 1945

Contents

List of publications

This thesis is based on the work contained in the following papers, referred to by Roman numerals in the text:

I Tunón, H., Axelsson Linkowski, W., Kvarnström, M., Bele, B., Norderhaug. A. & J. Wissman. (2013). To view a landscape: reflections upon the governance of Scandinavian transhumance. *Baltic World,* vol. VI (3-4), pp. 53-60.

II Axelsson Linkowski, W.*, Kvarnström, M., Westin, A., Moen, J. & Östlund, L. Wolf and bear depredation on livestock in northern Sweden 1827–2014: combining history, ecology and interviews. (*submitted*).

III Rautio, A.-M., Axelsson Linkowski, W.* & Östlund, L. (2016). "They followed the power of the plant": Historical Sami harvest and traditional ecological knowledge (TEK) of *Angelica archangelica* in northern Fennoscandia. *Journal of Ethnobiology,* 36(3), pp. 617-636.

IV Axelsson Linkowski, W., Fjellström, A.-M., Sandström, C., Westin, A., Östlund, L. & Moen, J. Strategies to handle loss and disturbances of winter pastures: the role of traditional ecological knowledge in Sami reindeer husbandry (*manuscript*).

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The contribution of Weronika Axelsson Linkowski to the papers included in this thesis was as follows:

I HT initiated the study. WAL participated in workshops and fieldtrips. WAL wrote the parts of the manuscript about biodiversity effects of boreal forest grazing and effects of increasing carnivores. WAL commented on the manuscript together with the other co-authors.

II WAL and MK initiated the interview study. WAL together with LÖ and JM developed the ideas for the manuscript. AW contributed with an agri-historical perspective. WAL wrote the manuscript with support from the co-authors. WAL acted as corresponding author towards the journal.

III AMR initiated the study. AMR and LÖ designed the study. AMR did the fieldwork and statistical analysis of the expected lifespan of *Angelica archangelica*. WAL contributed with knowledge about traditional ecological knowledge. AMR and WAL wrote the manuscript together with support from LÖ. WAL acted as corresponding author towards the journal.

IV JM initiated the study. WAL and AMF designed the study and performed the interviews. WAL, AMF and CS discussed the analysis and results. WAL compiled the results and wrote the manuscript with support from the co-authors.

1 Introduction

Sonfjället in the evening of August 10, 2016. Sonfjället is winter grazing area for Mittådalens reindeer herding community and summer grazing area for, among others, Östvallen and Nyvallen summer farms. Photo by the author.

Historic human land use and conditions for maintenance of biodiversity are often interlinked. Long term traditional land use change ecosystems and create conditions for specific species and species assemblages. This is true for both agrarian land use and in hunter-gatherer societies. This long-term land use has also created and is dependent on, a rich body of traditional ecological knowledge. When ecosystems undergo rapid changes in land use, there is a risk

to loose both the traditional ecological knowledge and the biodiversity connected to this land use.

In northern Fennoscandia, due to climatic and other biophysical conditions, subsistence has for a long time been focused on animal husbandry (Hultblad 1968, Lundmark 1982, Manker 1947, Myrdal and Morell 2011, Ruong, 1969) combined with fishing, hunting and plant gathering (Bergman et al. 2004, Norstedt et al. 2014, Norstedt and Östlund 2016, Päiviö 2017, Rautio 2014). Crop production has been of limited importance and is a rather recent phenomenon. In focus of my thesis, summer farmers and Sami reindeer herders represent traditional land users that move their animals after the seasons in this area. The conditions for livestock and reindeer husbandry are to a large extent set by the physical landscape (mountains, rivers, forests etc.) but also biophysical factors such as soil fertility, insolation and access to water. This land use that has been practiced for many centuries has also altered the environment. There are for instance traces of intense livestock grazing in the mountains of western Norway, that date from 500 BC, but archaeological and vegetation analyses show that this extensive land use probably originated even earlier (Norderhaug et al. 1999). Although the methods and intensity of the utilization of low productive land has varied with human population density, extensive livestock grazing has shaped the Scandinavian landscapes over several millennia (Butleig et al. 2003). Summer farming created a characteristic and complex anthropogenic landscape in the mountains and mountain forest areas in northern Scandinavia (Norderhaug et al. 1999). In Sweden summer farming is today primarily practiced in the counties Dalarna, Gästrikland, Hälsingland and Jämtland (Figure 1A), and thus partly overlaps with the geographical distribution of Sami reindeer husbandry (in Jämtland and to a smaller degree in Dalarna), which spans large parts of northern Sweden (Figure 1B and C). Like summer farming, continued Sami land use during many centuries changed the land on which Sami livelihood relies (Josefsson 2009, Karlsson et al. 2007, 2009, Rautio 2014, Östlund et al. 2015). There are for example subtle but visible changes in the vegetation from this ancient use, such as luxurious grass and herbs in ancient reindeer pens (Tömmervik et al. 2010). Austrheim and Eriksson (2001) conclude that grazing by reindeer and livestock is a key process for maintaining biodiversity in alpine and sub-alpine habitats in the Scandinavian mountains. Altogether this emphasizes that the mountains and mountain forests are influenced to varying degrees by people throughout history and are not uninhabited wilderness areas. Despite this knowledge, historical management practices and land uses have in many places been underestimated and considered as “light footprint” management and the resulting landscapes have been regarded as untouched wilderness (Fowler and

Lepofsky 2011). This has been the case in the Scandinavian mountain landscapes, and nature conservation organizations as well as tourism enterprises have often promoted the idea of "the last wilderness of Europe". While the human influence is much less apparent in this region, both today and historically, compared to in more densely populated regions, the legacy of human land use is definitely there, which is also shown in biodiversity patterns.

Since the Convention on Biological Diversity (CBD) entered into force in 1993, much research has focused on how to stop the loss of biodiversity and how to obtain sustainable use of biodiversity (CBD). In this context, more and more attention has recently been drawn to the understanding of how traditional land uses may have created niches for biodiversity (see article 8(j) and 10 (c) in CBD) and how continued traditional land use may halt biodiversity losses.

1.1 Traditional ecological knowledge

Knowledge and practices of indigenous and local communities are key elements in my thesis. I address these using the term traditional ecological knowledge (TEK), often described as:

> *"…a cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment"*. (Berkes et al. 2000)

The use of the term *traditional* ecological knowledge is not unproblematic. Despite the fact that traditional ecological knowledge is adaptive and complex, it has been interpreted to refer to "simple, savage and static knowledge" (Warren 1995). Because of this, some scholars have favored the term "indigenous knowledge" (Warren 1995). This term has however in turn been interpreted to include only indigenous peoples' knowledge and consequently leaves out knowledge that has been developed in non-indigenous communities with traditional lifestyles. Instead, the term indigenous and local knowledge (ILK) has come into use describing "traditional knowledge within indigenous peoples as well as within local communities". Nevertheless, the use of the term "traditional ecological knowledge" has become well established (Berkes et al. 2000) and often used (Roué and Molnár 2016). TEK has recently been acknowledged as a knowledge system that differs from the western scientific system that has been prevailing for a long time. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services was

established in 2012 (IPBES) in order to identify potential impacts of different policy options on ecosystem services and biodiversity. In the IPBES network, scientists and knowledge holders work together to bring indigenous and local knowledge systems and scientific knowledge systems together in order to move towards sustainable use and management of biodiversity in traditional land use systems (Tengö et al. 2017).

I have chosen to use the term "traditional ecological knowledge" throughout my thesis in which I include knowledge from both indigenous and local communities, including practices (which is the concrete expression of knowledge in use) and innovations (because the knowledge is constantly adapting to changing conditions). The part of TEK concerning customs and beliefs is not directly dealt with in my thesis.

1.2 Traditional land uses in northern Scandinavia

My thesis focuses on traditional land use and knowledge in the mountain areas of northern Scandinavia, and the summer farmers and Sami reindeer herders that are the traditional land users in this area (see Table 1 for comparisons). The geographic focus lies in Sweden, but Paper I deals with summer farming also in Norway.

Animal husbandry has been a part of the farming systems in Scandinavia since five or six thousand years ago, first in southern and middle of Sweden, (Welinder et al. 1998) and then in the mountains (Myhre and Øye 2002). As far as we know, grazed forests were widespread since the middle ages. A transhumance system (Sw. fäbodbruk) where livestock were moved between the home farms and summer farms (Bele and Norderhaug 2013, Kardell 2016, Larsson 2012, Lidman 1963, Montelius 1975, Myrdal 2012, Myrdal and Morell 2011), is documented in some regions since the sixteenth century (Larsson 2012), but may have a much longer history (Myhre and Øye 2002, Welinder et al. 1998). The Swedish transhumance system persisted for centuries and reached its height around the 1850´s after which the number of livestock brought to summer farms started to decrease (Larsson 2012). There are, however, no estimates of the total number of summer farms in Scandinavia at its peak. Summer farmers that today continue to move their livestock seasonally to summer grazing areas represent pockets of local and traditional knowledge in the sense that they have kept central traditional elements, such as seasonal movement of livestock and production of milk products at the summer farms. This continuation of traditions is especially pronounced for summer farming since large parts of Swedish livestock husbandry has been rationalized and many farmers stopped using the pastures at the summer farms a hundred

years ago (Myrdal and Morell 2011, Larsson 2012). The summer farmers´ understanding of the environments at the grazing grounds, free-ranging livestock behavior and livestock wellbeing is the result of a long-term adaptive process to the environment surrounding the summer farms, as summer farms are usually inherited (Hedén 2014).

Reindeer husbandry is an extensive land use that has been conducted for centuries in northern Sweden (Allard 2011, Bergman et al. 2008, Lundmark 1982). Reindeer husbandry requires large grazing areas as the reindeer move seasonally (Beach 1981, Brännlund and Axelsson 2011): for example, in mountain based reindeer husbandry, herds of semi-domesticated reindeer migrate between the summer pastures in the mountains and winter pastures in the interior and coastal forests (Moen and Danell 2003, Moen 2008).

Reindeer husbandry is an important and traditional part of the indigenous Sami livelihood and culture (Beach 1981, Lundmark 1982, 2008) and the awareness of Sami traditional knowledge, *Àrbediehtu*, is strong within the reindeer herding community (Nordin- Jonsson 2010a, b). The trade is inherited within families on their traditional lands and the knowledge and practices are transmitted through the daily work with the reindeer and associated languages (Roturier and Roué 2009, Ryd 2001). For example, whereas the Western use of the word pasture is often associated with grazed plant communities, the Sami herders´ understanding of winter pastures is holistic and also includes the effects of snow conditions on the accessibility of grazing (Roturier and Roué 2009, Roturier 2011).

Summer farmers and Sami reindeer herders have continuously used the same land as did their ancestors, thereby creating strong land-use knowledge about sustainable use and living in the boreal forests and Scandinavian mountains. This long land-use has in turn also created environments for grazing dependent biodiversity that declines when grazing is decreasing (Austrheim and Eriksson 2001, 2003, Bele and Norderhaug 2013, Olofsson and Oksanen 2005, Olofsson et al. 2010). The practices are based on seasonal migration of livestock and reindeer between ecological regions following peaks in pasture productivity in order to fully take advantage of the available resources. Such transhumance or pastoralism exists in other parts of the world and examples from Europe are the Spanish pastoralism described by Oteros-Rozas et al. (2013), pastoralists in the Pyrenees described by Fernández-Giménez and Estaque (2012), and from Hungary described by Molnár (2012), Molnár et al. (2016).

Summer farming and reindeer husbandry are livelihoods based on a customary right to use also land beyond their proprietary right, thus making them especially vulnerable to changes in other forms of land use such as

forestry, infrastructure, industries, tourism and carnivore management policies. The accumulated land use knowledge is important for continued and sustainable future management in the summer farming areas in the same way as the reindeer herders´ knowledge about their land and historic land use are essential to the sustained survival of traditional reindeer husbandry. Their knowledge might also be important for the sustainable management of mountain biodiversity and ecosystem services (Pascual et al. 2017).

Table 1. Comparison between the systems studied: summer farming and Sami reindeer husbandry in Sweden.

Summer farming	Sami reindeer husbandry
• Traditional low intense land use of spatially broad resources with long history (at least since the 16th century).	• Traditional low intense land use of spatially broad resources with long history (since centuries).
• Livestock-based agrarian livelihood.	• Pre-history as hunter gatherers which have developed into reindeer pastoralists.
• Seasonal movements to take advantage of resources – transhumance.	• Seasonal movements to take advantage of resources – transhumance.
• Based on customary right to use land beyond their proprietary right.	• Based on customary right to use land beyond their proprietary right.
• Local people.	• Indigenous people.
• Traditional and local knowledge.	• Traditional, local and indigenous knowledge.
• Free ranging livestock; cows, sheep and goats used for meat and milk products (historically mainly milk).	• Free ranging semi-domesticated reindeer used for meat products (historically also for milk).
• Positive effects on biodiversity of summer grazing. Today grazing effects on vegetation more visible near summer farms, less visible in the gradients away from the summer farms.	• Positive effects on biodiversity of summer grazing, however summer grazing effect on mountain slopes and mountain birch forest often unrecognized.
• Steadily decreasing number of summer farmers since the mid-19th century. Today approximately 200 summer farmers.	• Declining number of reindeer owners. Today approximately 4,600 reindeer owners.
• Declining number of livestock and area grazed at summer farms.	• Constant number of reindeer and constant area used for grazing.
• Today alternative grazing areas often available at villages.	• Today available grazing areas reduced by other land uses.
• Primarily associated with the counties Dalarna, Jämtland, Hälsingland and Gästrikland.	• Today in the same area as traditionally but previously able to cross national borders.
• Culturally important but also of great value to tourism.	• Culturally important but also of great value to tourism.
• Negatively affected by increasing carnivore populations.	• Negatively affected by increasing carnivore populations.
• Traditional land use in conflict with	• Traditional land use often in conflict

other land use such as increasing populations of carnivores.	with other land users, specifically forestry, hydro power, wind farms and to some extent tourism.
• Summer farming today uses relatively small areas in a few specific localities surrounded by forest that has a grazing history. • Today minor food production but important as producers of cultural and biological values.	• Reindeer husbandry use very large areas with low intensity both in summer and winter, across most of the boreal part of Sweden. • Continue to be important food producers and maintaining cultural heritage and increasing understanding of importance to preserve biodiversity.
• Livestock stay in barns during winter and eat hay harvested by the farmers.	• Reindeer are outdoors and eat available ground and arboreal lichens, otherwise supplementary food.

2 Objectives

The overall aim of this thesis is to contribute to the understanding of conditions for the traditional land use in the Scandinavian (mainly Swedish) mountains using the concepts of traditional ecological knowledge (TEK) and a historical-ecological perspective. The thesis focuses on summer farming and Sami plant use, including reindeer husbandry during the last 200 years. The specific aims are the following:

- What are the most important challenges to continued traditional land use by summer farmers and Sami reindeer herders?
- How can TEK and a historical-ecological perspective contribute to handle these challenges?
- To what extent is TEK used today in Scandinavian summer farming and reindeer husbandry?

Throughout the papers I will use knowledge from different sources such as historical records, current data on carnivores and interviews with a particular emphasis on TEK.

In **paper I**, we draw attention to the conceptual gaps concerning the perspectives on the summer farming landscape in Sweden and Norway, between and within academia, government officials and the farmers using the landscape for food production. We show what factors cause the main problems for summer farmers today in Sweden and Norway.

In **paper II**, we focus on the effects of carnivores on summer farmers and their livestock, since the mid-19th century until today. The aim is to give an environmental-historical perspective on the recent livestock–carnivore conflict in boreal Sweden. Central questions are how the risk of depredation (livestock killed by carnivores) has changed since the second half of the nineteenth

century, and if the knowledge on how to protect livestock from predation has survived through a period with no or little carnivores until present days?

In **paper III**, we focus on the Sami use of a single plant, *Angelica archangelica*. We explore the Sami people's interaction with this plant and whether their use went beyond opportunistic harvest and also included management. We study the Sami use of Angelica, using historical ethnographic information, a field experiment and discussions with a Sami woman with extended knowledge and experience in Sami plant use. We also evaluate if the use of different methods can strengthen our understanding of traditional Sami plant use and management.

In **paper IV** we focus on reindeer husbandry and the changing extent and availability of winter grazing pastures. Specifically we want to investigate *i*) if and how reindeer herding strategies today differ from the strategies used by the earlier generation and *ii*) if these changes in strategies can compensate for the changed availability of winter grazing pastures and *iii*) what encroachments on winter grazing areas causes the most problems for the herders today compared to in past times. Finally, we want to investigate if it is possible to save winters pastures in order for the lichens to regrow.

Based on the objectives for the thesis and the results from the papers I furthermore want to broaden the perspective and discuss the importance and use of TEK in designing future mountain management.

3 Research context

Studies of TEK and historical land use in the Scandinavian mountains have previously focused on a number of different topics, such as historical Sami land use (Brännlund 2015) and ecosystem change after that use (Josefsson 2009, Karlsson 2008), Sami plant use and management over a landscape scale (Rautio 2014), and the historical development of summer farming (Larsson 2012). There are also studies about the effects of forestry on reindeer husbandry (Berg 2010, Roturier 2009), as well as about the interactions between forestry and reindeer husbandry (Horstkotte 2013, Sandström 2015). Social studies include the history of reindeer husbandry resilience (Brännlund 2015), space for indigenous agency in protected areas (Reimerson 2015), what it is like to be a summer farmer in the common agricultural policy (Eriksson 2013), and the role of TEK in reindeer-herding governance (Turi 2016).

In my work I use TEK as a source of knowledge about living conditions in the present and recent past, but in my opinion it is not enough to use only TEK as a source, it is also important to find a longer historical dimension using additional sources. TEK is adaptive, meaning that practices that are no longer in use are gradually being lost. Knowledge about past practices can be remembered for some time if there is continuity in the land use, finally, however, "unused" knowledge will be forgotten (Oteros-Rozas et al. 2013). Although a rich body of traditional ecological knowledge persisted among transhumance shepherds on the Conquense Drove Road, a major active transhumant network in Spain, rapid deterioration of traditional knowledge was observed among young shepherds in this area (Oteros-Rozas et al. 2013). The most important factor influencing knowledge preservation here was the maintenance of transhumance on foot. The Spanish study emphasizes the importance of time on the amount of traditional ecological knowledge remaining. Thus TEK and memories of past practices may not reach back far enough in time in order to inform about the more distant past, especially in

land use systems that have gone through large changes in a relatively short time, such as summer farming and reindeer husbandry (se section 1).

A historical perspective on land use systems gives context to short-term studies and expands the time-frame beyond the living memory and can therefore contribute with a longer time perspective, and bring back knowledge necessary to understand the current situation. A longer time perspective is also necessary to understand the effects of past and current land use on biodiversity, which can be studied within the field of historical ecology (Bürgi et al. 2017 b, Szabo 2015). There is a legacy of past land use on today's ecosystems e.g. reflected in species composition (Gustavsson et al. 2007) and details in past land use regimes can be necessary to use in current management regimes in order to get desired results for biodiversity conservation (Dahlström et al. 2008, Gustavsson et al. 2011, Eriksson et al. 2015).

A further benefit of a historical perspective in ecological studies is that it provides a possibility to distinguish important internal and external drivers of change, thus answering why things happen (Bürgi et al. 2017 a). In the context of this thesis, it has been important to understand how much TEK is available but also what historical conditions prevailed before the studies, thus asking about shaping circumstances, such as small-scale economy, efforts to kill carnivores, encounters with carnivores and memories of previous land use from earlier generations. By studying historical records and relate these findings to changes in traditional use, the understanding of what is essential to the continued land use is improved. Gómez-Baggethun et al. (2012) found that the collective memory to cope with environmental extremes was coded into religious rituals. Traditional ecological knowledge was thus stored between drought episodes and this contributed to the maintenance of long-term resilience of social-ecological systems in southwestern Spain.

An inherent property in traditional knowledge systems is also that the absorption of new knowledge leads to higher resilience against changing environmental and socio-economic conditions (Gómez- Baggethun et al. 2013, Reyes-Garcia et al. 2014). But, a change may be too rapid or too large, and at some point the traditional knowledge will lose its importance, get lost or become abandoned. The time perspectives in this thesis varies, the summer farming and reindeer husbandry have long history in the mountains, and have always gone through changes. But today the changes are very rapid, including the increase of carnivores since the 1990´s (Kaartinen et al. 2009, Sand et al. 2014, Wabakken et al. 2001), markedly changed tree composition and ground lichen amounts caused by forestry in the reindeer winter grazing areas during the last 50 years (Kivinen et al. 2012, Sandström et al. 2016) and increasing

effects of climate change (Putkonen and Roe 2003, Rasmus et al. 2016, Riseth et al. 2009, 2011, Turunen et al. 2016).

Several studies argue that an enriched picture involving also local and traditional knowledge can be used as a starting point to improve future management planning (Hernández-Morcillo et al. 2014, Kis et al. 2016. Sutherland et al. 2013). Consequently, in my thesis I aim to combine oral ethnographic information from current land users with written historical sources in order to draw conclusions on what factors are vital for continued traditional use in the Scandinavian mountain area.

4 Methods

4.1 Study systems

4.1.1 Summer farming

Nyckelbergs summer farm in Malung, Dalarna, people among cows year 1901. Unknown photographer Nordiska museet NMA.0048268.

Summer farming was developed in order to access remote grazing grounds, increase the total available grazing grounds and enable pastures close to the

home farm to regrow before late summer when the herders returned with the livestock. Grazing livestock was consequently moved from the home farms and to summer farms during the summer months where, primarily female herders, took care of the livestock and processed the milk into butter (Bele and Norderhaug 2013, Kardell 2016, Larsson 2012, Myrdal 2012, Myrdal and Morell 2011). The traditional summer farming area in Sweden extends primarily over an area north of the river Dalälven and roughly covers the counties of Dalarna, Gästrikland, Hälsingland and Jämtland. However the practice of taking livestock to summer pastures (with or without milk processing) has occurred over a much wider area in Sweden historically (for example see Frödin 1954).

The biophysical conditions in Norway with large mountainous areas cause restricted possibilities of large-scale agriculture, but instead good conditions for livestock production. Summer farming has been common all over the mountainous parts of Norway. In the mid-19th century there were 70,000 to 100,000 active summer farms in Norway, today 1,100 of them are still in use (Bryn and Daugstad 2001, Bye et al. 2012, Dragstad 2005). From the 1870´s, summer farming in Sweden decreased rapidly due to agricultural change, including cultivation of fodder on arable land in the villages (Larsson 2012), and the Swedish forest companies also worked hard to reduce livestock grazing in forest land, which was considered a great threat to forestry (Kardell 2016). Today grazed forests are one of the habitats that have declined the most during the last 100 years (Andersson et al. 1993, Aronsson 2006). Although more and more livestock was raised on cultivated fodder during the 20th century (Myrdal and Morell 2011), forest grazing remained in some regions. In 2012, there were 201 registered summer farmers, eighty of them in the county Dalarna, and another eighty in the county Jämtland (neighboring north of the county Dalarna, Hedén 2014). Hides and milk products, such as butter and cheese, were important sources of income for the farmers (Larsson 2012). Historically, in the Swedish summer farming area, all villagers had to take the livestock to the summer farm at a decided date, in order to save grazing grounds in the village. The returning date was in the same way coordinated so that no one could take the advantage of going down to the village earlier. Each village usually had access to several summer farms, and at each summer farm there could be livestock belonging to several villages (Larsson 2012). Although grazing has decreased, the ownership of a share in a summer farm has been inherited until present times. Swedish summer farmers of today are either owners of a share that has been inherited, or they hire the grazing right from a summer farming community (Sw: fäbodlag). In Sweden many summer farmers have taken over from their parents but there are also those who started anew

without previous belonging. In Norway summer farming has a stronger hold. Even though it has decreased, mountains and forests are still important for grazing and food production, since 85 % (in 2011) of the livestock graze these areas during summer (Hegernes and Norderhaug 2013). Today, summer farmers produce milk, butter, cheese meat, wool, pelts, eco-tourism, courses, bio-cultural values, biological values (in paper I, II) and can in Sweden receive agri-environmental payments through the Swedish Rural Development Program for 2014–2020, with the aim of supporting summer farming that "strengthens and preserves the character of the landscape and its biological diversity" (Eriksson 2011, Government Offices of Sweden 2016). In Norway, summer farmers are financially supported by various payment schemes at the national, regional and local level. The subsidies aim to preserve the cultural landscape as well as maintaining rural settlements and the capacity for independent food production. The pastures surrounding the summer farms have high conservation values, both in terms of species richness and occurrence of vulnerable species and call for maintenance of land uses that have created these semi-natural sub-alpine grasslands in Norwegian mountains (Austrheim et al. 1999) as well as in Sweden. Without grazing and trampling from livestock, biodiversity dependent on this activity declines in Scandinavian mountains (Austrheim and Eriksson 2001, 2003). Serious threats to biodiversity of semi-natural grasslands are identified due to the decline in agricultural use and changes in where and when livestock grazing occurs, resulting in that semi-natural grasslands in the mountain are changed into woodlands by forest succession (Olsson et al. 2000, 2004), and associated grazing dependent bio-cultural values disappear (Bele and Norderhaug 2013, Ljung 2011, Norderhaug et al. 1999). In Sweden, the decline has already gone very far and only small fragments of grazed forests remain around the summer farms although the traces of ceased summer farming may still remain for some time (Ljung 2011).

4.1.2 Sami reindeer husbandry

Grazing reindeer belonging to Sirges reindeer herding community, on Lulep Gierkav, between the lakes Bietsávrre and Langas, by Sáltoluokta and Stora Sjöfallet. Photo Tommy Lennartsson.

In Sweden the right to own and herd reindeer (*Rangifer tarandus tarandus* L.) exclusively belongs to the indigenous Sami people (SFS 1971.437). Sami reindeer husbandry is divided in 51 reindeer herding districts, of which 33 are mountain-based, 10 are forest-herding communities and eight are concession-herding communities. The total number of reindeer is approximately 225,000 animals during the winter (fluctuating between 150,000 and 300,000; Sametinget 2017, Moen and Danell 2003) and have been more or less stable since 1945 (Bårdsen et al. 2017). There are about 4,600 reindeer owners in 1,000 reindeer herding companies (Sametinget 2017). Today Sami reindeer husbandry is a spatially broad, but usually low intense form of land use practiced on approximately 50% of the Swedish land area (SFS, 1971.437).

Most studies of historical Sami subsistence have focused on the role and importance of the reindeer (Hultblad 1968, Lundmark 1982, Manker 1947, Ruong, 1969), and to some extent on fishing (Norstedt et al. 2014, Norstedt and Östlund 2016), but Sami subsistence was more diverse and also differed between mountain and forest Sami groups (Päiviö 2017). For example, the Sami also gathered plants for both food and medicine (Bergman et al. 2004,

Päiviö 2017, Rautio 2014), but the scale of this use has not received much attention (but see Rautio 2014). Garden Angelica (*Angelica archangelica* ssp. *archangelica*, hereafter referred to as Angelica) is considered one of the most important plants within the historical Sami diet; Angelica was used for food, medicine and most importantly as a preservative for reindeer milk (Fjellström 2000, Linné and Fries [1732] 1905, Qvarnström 2006, Svanberg and Tunón 2000).

Although reindeer herding practices have changed over time, the overall practice has remained basically the same over time, including seasonal movement with free-ranging reindeer. The reindeer move for longer or shorter distances between traditional summer and winter pastures. The summer grazing areas are shared with other herders from the same herding district. The grazing area is usually restricted by geographical borders, such as rivers or mountains. When winter is approaching, the herders divide the reindeer by ownership into smaller winter groups, in order to steer their reindeer to the best available grazing pastures in the forest. During the migrations, the reindeer (and herders) use traditional migration trails. In areas where the trails have been cut off by industry activities, roads and railroads, the reindeer are transported by trucks to their seasonal grazing land (Sametinget 2017). The winter is a critical period in reindeer husbandry. The reindeer diet consists of terrestrial lichens (mainly *Cladonia* spp.) and arboreal lichens (mainly *Bryoria* spp.), which make up 80% of the total diet (Heggberget et al. 2002), and the rest consists of wintergreen herbs and grasses (Inga 2007, 2008). Today the composition and configuration of the forest landscape mosaic has become less suitable for sustainable reindeer husbandry (Kivinen et al. 2012), and the area of winter grazing pastures are decreasing rapidly (Korosuo et al. 2014, Sandström et al. 2016), due to conflicting land uses (Kivinen 2015, Kløcker Larsen et al. 2016, Kumpula et al. 2007, Löf 2013, Öhman 2016, Össmo 2014), forest pasture degradation (Berg et al. 2008, 2011a, 2011b, Sandström et al. 2016, Horstkotte et al. 2011, Östlund et al. 1997), disturbance caused by infrastructure development (Beland Lindahl et al. 2016, Kivinen et al. 2015, Kumpula et al. 2007, Skarin et al. 2015, Skarin and Åhman 2014), and increasing carnivore populations (Hobbs et al. 2012, Åhman et al. 2014). The reindeer herders require diversity in the landscape throughout the winter in order to be able to respond to weather variations and resulting impacts on grazing conditions, such that good grazing conditions can be provided for the reindeers throughout the winter (Rasmus et al. 2016, Turunen et al. 2016), hence these changes cause considerable challenges to Sami reindeer husbandry (Kløcker Larsen et al. 2016, Pape and Löffler 2012). In addition, there has also been considerable climate change (Putkonen and Roe 2003, Riseth et al. 2009,

Turunen et al. 2016), including increasing weather unpredictability in the fall and early winter, and there is also an increased frequency of "rain-on-snow" and ground icing events that reduce access to the lichen pastures (Putkonen and Roe 2003, Rasmus et al. 2016, Riseth el al. 2011, Turunen et al. 2016).

The land use itself has shaped the environment on which reindeer husbandry relies (Aronsson 1993, Freschet et al. 2014, Josefsson et al. 2009, Karlsson et al. 2007, 2009, Östlund et al. 2015). Reindeer grazing has, like the grazing of livestock, been shown to uphold biodiversity in the mountain area. In Finland, reindeer grazing positively affected the density of red-listed plants outside a reserve. The reserve was first fenced from reindeer grazing in the belief that this would protect the red-listed species inside. Olofsson and Oksanen (2005) later recommended the reserve to be opened to reindeer grazing in order to increase red-listed plant densities. Eilertsen et al. (1999, 2000) also recommend to use reindeer grazing to open up and restore shrubified meadows in northern Norway. In line with this idea, reindeer grazing has in several studies been shown to lower the tree limit, via its negative effect on the spread of young mountain birches (Cairns and Moen 2004, Oksanen et al. 1995, Väisänen 1998). A recent study also showed that herbivory and nutrient limitation protects warming tundra from lowland species invasion and diversity loss (Eskelinen et al. 2017). Although convincing, a systematic review on the impacts of reindeer/caribou on arctic and alpine vegetation could not determine a general pattern and called for more systematic studies to give more general conclusions about grazing impacts (Bernes et al. 2015). However, despite this current uncertainty on the biodiversity effects, the impact on bio-cultural values of traditional reindeer grazing are clear (Josefsson et al. 2009, Karlsson et al. 2007, 2009, Östlund et al. 2015).

4.2 Environmental setting

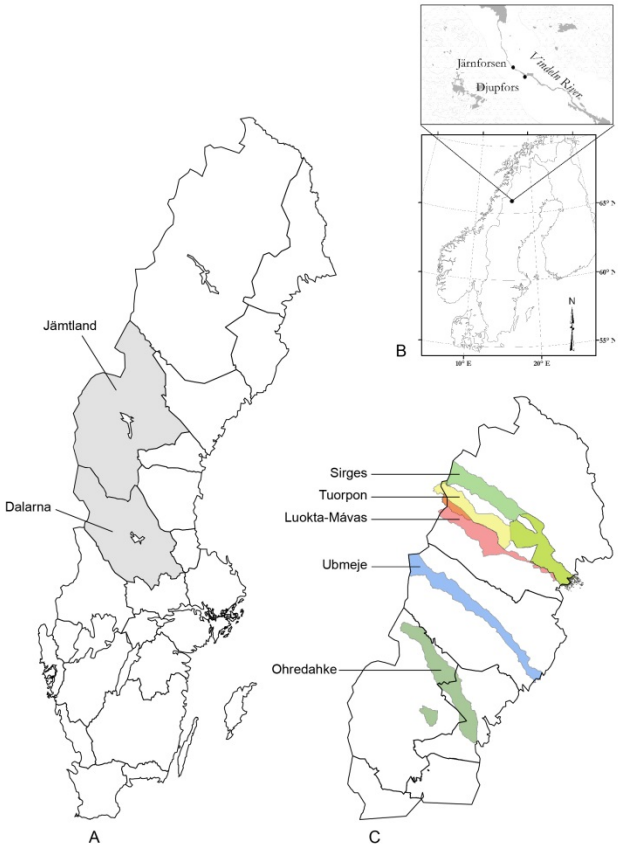

Figure 1. Environmental settings of the studies. A. Sweden with the counties of Jämtland and Dalarna (marked in grey), where comparison were carried out in paper II and interviews were conducted in paper I and II. The Norwegian area studied in paper I is situated in the area to the west of Dalarna and Jämtland. The county of Jämtland is also part of northern Sweden where reindeer husbandry is of national interest. B. Scandinavia, with the location of the study area in northern Sweden used for the field experiment in paper III. C. Map of Northern Sweden showing the five Sami reindeer herding districts taking part in the study for paper IV.

In **paper I** and **II** we focus on summer farming in the northern and central parts of Sweden and Norway that are part of the coniferous Western Taiga, the boreal region, which is a primarily forested landscape (Figure 1A).

In **paper II** we make a closer comparison between summer farmers from two adjacent counties; Dalarna and Jämtland in Sweden (Figure 1A).

In **paper III** the study area for the field experiment lies within Sorsele municipality, in the county Västerbotten. The harvest experiment was

conducted at two forest meadows, Järnforsen and Djupfors both sites lie right next to the river Vindeln, spaced approximately 1 km apart (Figure 1 B and Figure 1 in paper III).

In **paper IV** the study includes herders from the reindeer herding districts Sirges, Tuorpon, Luokta Mavas in the county Norrbotten, Ubmeje in the county Västerbotten and Ohredahke in the county Jämtland (Figure 1C).

The studied region exhibits typical inland north Swedish climate with long cold winters with long lasting snow cover and short vegetation periods (SMHI).

4.3 Analysis of historical records in paper II and III

Historical sources were used for studying summer farming in paper II and Sami plant use in paper III.

In **paper II** the written records on the number of livestock, yearly bounty statistics and yearly livestock depredation were obtained from: ”Bidrag till Sveriges officiella statistic: Jordbruk och boskap – Hushållningssällskapens årsberättelser 1865–1911”, ”Sveriges officiella statistic: Jordbruk och boskapsskötsel 1913–1964”, ”Jordbruksstatistisk årsbok 1965–2000”, ”Jordbruksstatistisk årsbok 2001–2014”, ”Domänstyrelsens officiella statistik 1870-1910”, and ”Kungliga domänstyrelsens förvaltning 1911-1965”. We obtained data on recovering wolf populations from Viltskadecenter (Wildlife Damage Centre) (1998-2014), and the county administration boards of Dalarna and Jämtland provided data on bear populations for recent years. Yearly statistics on bears and wolves killed do not only serve to indicate historical carnivore population sizes, but also the historical effort in killing them. When combining older statistics with more recent, it is important to be aware of differences in sampling strategies and purposes of the statistics. In the case of historical records of yearly depredation statistics on livestock, the purpose of the records are the same as the more recent statistics from Viltskadecenter (2003-2014), that is to measure the damage farmers suffer from carnivores.

In **paper III** we explored ethnographic written information and modern scientific papers on Angelica. We found that most of the later ethnographic descriptions available about Sami use of Angelica actually originated from the same earlier source: the travelogue of the Swedish botanist Carl von Linné’s travels through Lapland in 1732 (Linné and Fries 1905). The travelogue is the earliest, systematically collected information on Sami plant use. We therefore used this original source of information, focused on finding out what parts of the plant were harvested and when. We then designed the field harvest

experiments based on this information. Other important sources of information are Lindahl, Öhrling and Ihre's *Lexicon Lapponicum* (1780) and Drake (1918).

4.4 Interviews in paper I, II, III and IV

Oral information, primarily in the form of interviews, has been used in all four papers.

In **paper I** the results were obtained throughout several years with multiple workshops, in field meetings and semi-structured interviews at several occasions while working with the *National program on local and traditional knowledge concerning the conservation and sustainable use of biological diversity*, called Naptek, an Interreg Sweden-Norway project – *Grazing of outlying land: a biological cultural heritage as resource for a sustainable future 2011–2014* and work with the Swedish National Heritage Board about bio-cultural heritage of summer farms (summarized in Ljung 2011), thus regular meetings with summer farmers in Sweden and Norway compiled the material for this paper.

In **paper II** we conducted semi-structured interviews with active or recently active summer farmers who were known to us from previous work (paper I). In all, twelve farmers, four from Jämtland and eight from Dalarna, were interviewed via phone or at their summer farms. Five of the farmers were female, seven were male. The interviewed summer farmers were selected because of their early and/or frequent experience of encounters with carnivores, i.e. we searched for farmers who were among the first to experience the relatively recent increase in carnivores.

We used open-ended questions about carnivore attacks, livestock, experiences and knowledge about how to protect the livestock. We specifically asked for knowledge passed on from previously active farmers in order to document transmitted knowledge about carnivore and livestock encounters. The interviews were analyzed focusing on: what carnivore that was responsible for the attacks, what livestock were attacked, the behavior of the livestock and carnivores, the farmers' knowledge of how to protect their livestock, and where the knowledge came from.

In **paper III** we made a semi structured interview with Greta Huuva, a Sami woman with extended knowledge about Sami plant use. Greta Huuva was born in 1946, in the village Liehittäjä, in northernmost Sweden. In her twenties she moved to Jokkmokk, 250 km northeast from our study site, where she has lived since. Greta has documented Sami plant use and also learned about Sami plant use from many Sami elders in different parts of northern Fennoscandia (Huuva 2009, 2010). She has been teaching field documentation and Sami food culture

at the Sami Education Centre, and has also written cookbooks about Sami food (Huuva 2014a, 2014b). It was her mission to inform and spread not only the knowledge from her area but also the knowledge acquired during her travels. In that sense, Greta extended her role as "cultural refugia" (Turner 2006) for her area and transferred Sami knowledge from other parts of Sapmi as well. For her efforts to recover and reclaim knowledge about Sami traditional food and plant use, Greta was appointed to be Sami food ambassador by the Swedish government. Her role was to inform the general public about Sami food culture and to work with Sami food enterprises.

We used open-ended questions such as, "How and when did the Sami harvest Angelica?" The discussion was aimed at deepening our understanding of Sami use of Angelica and we wanted specially discuss the outcomes of our field experiment.

The empirical material for **paper IV** is based on five semi-structured paired interviews (one older and one younger reindeer herder). The interviewed herders were related and both from the same winter group. Both have or have had a leading position in their winter group and have experienced planning as well as taking the strategic decisions necessary to utilize the grazing pastures in the most efficient ways. The informants were all in winter groups with 5-15 different reindeer owners. The interviews were conducted at two occasions during the spring 2016 and lasted between 60 and 120 min. They were conducted in Swedish (with the necessary Sami expressions translated to the Swedish interviewer). Communication was facilitated by the fact that one of the interviewers was a reindeer herder and Sami speaking.

The questions were focused on traditional knowledge in relation to winter herding strategies: How does a reindeer herder learn the trade; what strategies are used; how does the winter land look compared to earlier; and how have winter planning strategies changed accordingly? We in particular asked about strategies to save pastures for the late winter period (short-term savings) or pasture rotational schemes where land is left un-grazed in order for the lichens to regrow (long-term savings). The herders described their winter pasture land, their understanding of how different encroachments affect reindeer grazing and their pool of strategies to control and steer the reindeers.

4.5 Harvest experiment of *Angelica archangelica* in paper III

The aim of the field experiment in **paper III** was to *i*) estimate the quantities which can potentially be harvested from wild growing Angelica populations, *ii*) to find out whether it is possible to prolong the life-span of Angelica by

continuous harvest of infertile petioles, and *iii*) to provide an overall understanding of Sami harvest practices of Angelica. The design included the harvest of roots, harvest of infertile petioles, and harvest of flowering plants. The experiment began with harvesting of roots in June 2011, as the Sami preferably obtained the roots in spring/early summer. The roots were dug using a small spade and a broach, as the soil was compacted it was time-consuming. Harvesting of infertile petioles and flowering plants took place in the middle of summer; i.e., July 12–16, when infertile and flowering plants could easily be distinguished from one another. The stalks and petioles were cut off near the ground with a knife. All the different plant parts were weighed in the field and brought back to the laboratory for further drying and weighing. Each treatment included harvest of 30 plants in each of the two study sites. In addition, 30 control plants were randomly selected to pair with each treatment. In total, the entire experiment included digging up 60 roots, harvesting 60 infertile petioles, 60 flowering plants, and 60 control plants. All plants were randomly selected and marked with numbered plastic-sticks so that the survival/death of each individual plant could be monitored. During the summer of 2012 and 2013, the harvested infertile plants and the control plants were visited again to monitor the survival rates. The infertile plants that survived harvest were harvested again in July 2012 and July 2013.

5 Results and Discussion

5.1 Paper I. Views of landscape. Reflections on the governance of Scandinavian transhumance.

Bräckvallen summer farm in Jämtland, July 2012. The cows graze outside the fence and the grass inside is harvested for the winter. Photo Håkan Tunón.

When managing, governing or studying the landscape, governmental agencies and researchers often concentrate on one or a few aspects and fail to see the

landscape as a whole, thereby creating different perspectives on the landscape. In paper I we draw attention to these conceptual gaps concerning perspectives on the summer farming landscapes (Daugstad 1999). We focus on gaps between and within academia and government officials on the one hand and the farmers using the summer farming landscape for traditional food production in Sweden and Norway on the other. Central in paper I are the perceptions of the farmers who strive to run viable farms while trying to manage the interests of the other groups that value other aspects of the summer farming landscape, such as tourism, biodiversity, cultural heritage, etc.

We find that the compartmentalization (Rouzel 2011) of the management of the landscape and its resources results from the lack of coherence among governmental institutions. This has negative effects on biodiversity and cultural heritage values and also increases the costs for the affected farmers, due to more administrative work with numerous applications and repeated reporting (see also Eriksson and Wagenfors 2012).

In paper I we conclude that the obstacles for the continuation of the summer farming trade are rather similar in Sweden and Norway. There are indeed large resemblances but also a few notable differences between the colleges in the two neighboring countries, partly because of topography but mainly due to political reasons. The political decision in Norway to promote rural settlements and food production all over the country has no equivalent in Sweden. This difference is mirrored in the remaining number of summer farmers, the aim of economic support and the level of payments. The economy of small-scale farming both in Sweden and Norway is dependent on agri-environment compensations for conservation of ecological and cultural functions at the summer farms (in Sweden by Jordbruksverket 2016). The Norwegian government promotes grazing through various payment schemes, but it is evident that the subsidies are generally too modest to make summer farming attractive to the next generation (Hegernes and Norderhaug 2013). Adequate compensation for the extra costs associated with continued management of summer farms and the grazing of outlying land, such as longer transport and longer time searching for free-ranging livestock, is crucial if this customary practice is to continue in the future. This compensation for costs is particularly important with regard to the increasing populations of carnivores (Sand et al. 2014, Wabakken et al. 2001) and livestock killed (see Paper II), which result in extra work and costs and hence threaten the livelihood of today´s summer farmers as well as the biodiversity that is dependent on continued grazing.

The summer farms and surrounding fields and mountain forests represent a meeting point for different interest and business ventures. For the long-term viability of summer farms in Sweden and Norway, it is essential to establish a

genuine dialogue between the administrative authorities and the different stakeholders, particularly the farmers, because the farmers´ management, which is often based on generations of local and traditional knowledge, is the very basis for upholding the characteristics connected to the summer farming landscape, biodiversity, cultural and bio-cultural heritages (Bele and Norderhaug 2013, Ljung 2011, Norderhaug et al. 1999). To be able to make a living on their summer farms, the farmers need regulations and subsidies that support them, are well designed and stable over time.

Given the fact that there are only approximately 200 active summer farmers in Sweden today, their land use has attracted an impressive complex of conflicts. There are two main reasons for this: Firstly they are in fact keepers of a national heritage in terms of buildings, traditional knowledge and biocultural heritage. Summer farmers are emblematic symbols of a Swedish folkloristic stronghold, with many traditions around music and clothes etc. They also serve tourists with qualitative experiences in terms of scenic landscapes, landraces of livestock, a living countryside etc. Given their vital role for preserving such common goods, I find it surprising that there is not more societal and economic support for the few remaining summer farms. The second area of conflict is that the summer farmers´ grazing grounds coincide with the core area of the increasing carnivores, especially the wolves. There is a strong societal support for the returning wolf and increasing bear populations, due to their protected status (see paper II). Whereas farmers and hunters are generally opposed, the support for increasing carnivores is divided among conservation biologists, as the increase of carnivores is associated with a risk of losing a large number of species of vascular plants, lichens etc. that are dependent on continued grazing practices in these regions.

In conclusion there is a need for a holistic and long-term perspective on governance and management of the summer farming landscape. There is a need for increased dialogue between and within authorities and research intuitions, to help identify and evaluate conflicting targets that may subsequently be reconciled through further dialogue. Furthermore, there is also a need of more focus on the farmers´ situation and increased dialogue with authorities as well as increased participation of local farmers and communities in decision making processes.

Since our study on livestock depredation (in 2011 to 2014 in paper II), half of the farmers interviewed have stopped practicing summer farming, and refer to the increased levels of carnivores as the main reason for this decision. This clearly shows how important it is to adjust current regulations and support systems in Sweden, as well as in other countries, based on the experiences of the farmers (Karlsson and Sjöström 2011, Rondinini and Boitani 2007). An

example of such an adjustment in Sweden is that since 2016 it is now possible for the farmers to withdraw livestock from summer farms during times of increased risk of carnivore attacks, (with permission from the county administration,) without risk of losing subsidies for an entire 5-year period (Jordbruksverket 2016). Whether this adjustment is enough to manage the carnivore conflict, or if other measures will be needed, remains to be confirmed by the summer farmers concerned.

5.2 Paper II. Wolf and bear depredation on livestock in northern Sweden 1827–2014: combining history, ecology and interviews.

Bear hunt in Dalarna in the beginning of the 20th century. Unknown photographer. Nordiska Museet NMA.0052736.

In paper I we identified the increasing numbers of carnivores as a severe challenge to the livelihood of today´s summer farmers as well as to the biodiversity that is dependent on continued grazing in these ecosystems. In paper II, we focus on the effects of increasing carnivore populations on summer farmers and their livestock in two adjacent counties, Dalarna and Jämtland, in Sweden.

During the twenty-first century, large carnivores have recolonized and/or increased in human-dominated landscapes throughout Europe in which they were previously absent or rare. This has resulted in a significant rise in the numbers of livestock killed (Bisi et al. 2007, Chapron et al. 2014, Dorresteijn

et al. 2014, Kojola et al. 2006, Zlatanova et al. 2014). The aim of paper II is to give an environmental-historical perspective on the recent livestock–carnivore conflict in boreal Sweden, by quantifying how the risk of depredation (livestock killed by carnivores) has changed since the second half of the nineteenth century, and by asking if the knowledge on how to protect livestock from predation has survived until present days?

To these ends, in paper II we assemble historical and recent quantitative data on carnivore, livestock and depredation levels (Figure 2 and 3), as well as interview based information regarding livestock protection measures, and then use both quantitative and qualitative methods to contrast two time periods.

In Scandinavia, the process of carnivore recolonization has been especially pronounced since the 1990´s (Kaartinen et al. 2009, Sand et al. 2014, Wabakken et al. 2001). By combining different sources of numerical data, we can, for the first time, compare recent (since 1998) and historical depredation rates (1876-1930) in the two Swedish counties (Figures 2 and 3).

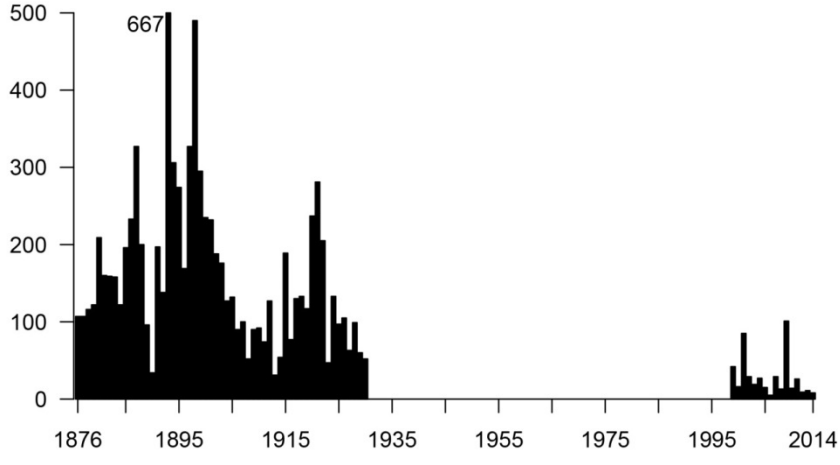

Figure 2. (Figure 7 from paper II). Total number of livestock (including cow, goat and primarily sheep) depredated by carnivores per year, 1876–1930 and 1998–2014, in the county of Jämtland. Sources: Domänstyrelsens officiella statistic and Viltskadecenter. Note that there are no records of livestock killed for the years 1931 to 1998.

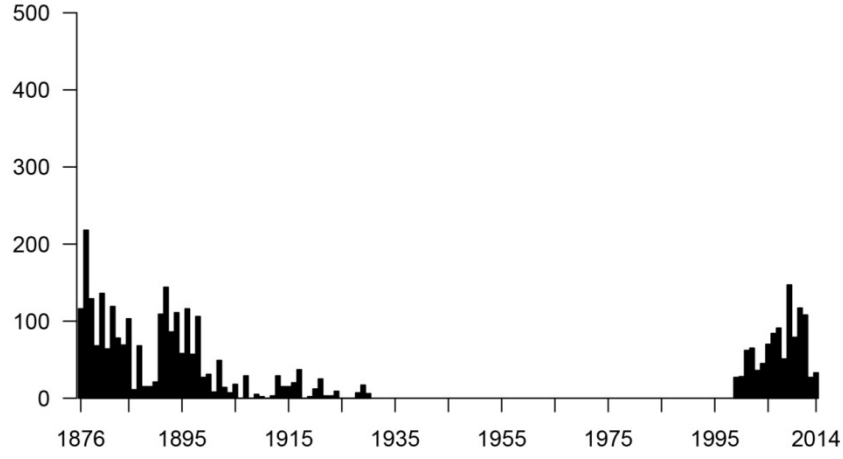

Figure 3. (Figure 8 from paper II). Total number of livestock (including cow, goat and primarily sheep) depredated by carnivores per year, 1876–1930 and 1998–2014, in the county of Dalarna. Sources: Domänstyrelsens officiella statistic and Viltskadecenter. Note that there are no records of livestock killed for the years 1931 to 1998.

Figure 4. Cow killed and eaten by wolves 26th of August 2012 in Dalarna. The cow "Sara" was born at the Klövsjö summer farm in 1996 and belonged to the protected mountain cow breed of the line Klövsjö Z. The owner recounts that Sara was a good dairy cow and also leader of the herd. Photo Hans Lind, Sälen.

We find that recent depredation rates in Dalarna were higher than at the end of the nineteenth century while the opposite pattern is observed in Jämtland (Table 2). Another clear difference between the counties is that recent depredation rates in Dalarna were twice the recent rates in Jämtland, which is contrary to the historical situation in which depredation rates were lower in Dalarna compared to Jämtland. Over all it is noticeable that recent and historical depredation rates in fact are of the same order of magnitude, despite many conditions for livestock husbandry having changed during the time separating these periods (Larson 2012, Myrdal and Morell 2011).

Table 2. Number of doctoral theses and licentiate theses in Epsilon Open Archive published in the years 2011-2015

County	Jämtland		Dalarna	
Year	Cattle	Sheep	Cattle	Sheep
1876-1891	0,009%	0,21%	0,003%	0,098%
1999-2014	0,004%	0,28%	0,008%	0,430%

As noted previously, based on both depredation statistics and information given by the farmers (Figure 4), we find that sheep have been, and are still, more vulnerable than other livestock to depredation (Liberg et al. 2010, Lidberg 2007).

While there are no estimates of past carnivore population sizes available, the numbers of wolves and bears killed indicate that the historical period, 1876–1891, represents a time when large carnivores were present in numbers that warranted killing, although the trend clearly indicates diminishing populations (Figures 1 and 2 in paper II). Our records of the numbers of carnivores killed are furthermore in accordance with early studies warning that offering bounties would cause a drastic decrease and possible extinction of wolves (Lönnberg 1934) and bears (Lönnberg 1929). The effectiveness of the bounties was later confirmed for wolves by Wabakken et al. (2001), as well as for the near extinction of bears in Sweden (Swenson et al. 1995). Although the historical number of carnivores killed cannot be compared directly with the recovering bear and wolf populations from 1999 to 2014, for which we have absolute numbers, the fact that the historical number of wolves killed year after year in Jämtland exceeded the total population numbers today clearly shows that the historical wolf population in Jämtland was larger than at present. In our data, a decline in the number of bears and wolves killed from 1876 onwards is accompanied by a simultaneous drop in the number of livestock killed, indicating that the kill statistics indeed reflect a decreasing carnivore population.

The few summer farmers that still move their livestock seasonally to remote summer grazing areas can be seen as pockets of local and traditional knowledge, in the sense that they remain true to their traditional ways, in manners comparable to the Spanish pastoralists described by Oteros-Rozas et al. (2013) and to pastoralists using traditional pastoral knowledge in the Pyrenees (described by Fernández-Giménez and Estaque 2012) as well as in Hungary (described by Molnár 2012 and Molnár et al. 2016). Our indirect comparisons of number of carnivores killed and recent carnivore numbers presents a clearly indicate that conditions at the summer farms have gone through substantial environmental changes throughout history. While past summer-farmers (before the carnivore extinction/reduction) had experience of a long-term relationship with carnivores and likely had adopted strategies to minimize the risks of their presence (Kardell 2008), we found that the long period with no or low numbers of carnivores meant that potential protection strategies that were no longer in use, had been lost. The recent increase in carnivores is a relatively new element that has a great negative impact on livestock husbandry and the summer farmers did not have preparedness for the returning threat in terms of knowledge of protection strategies. Similar degradation of knowledge has been observed in other parts of Europe, during the time when carnivores decreased, only to increase again (Dorrestein et al. 2014, Kikvidze and Tevzadze 2015, Rigg et al. 2011, Zlatanova et al. 2014).

The deterioration of knowledge about carnivore protection at Swedish summer farms can be compared with studies on Spanish pastoralists, in which it was shown that when local and traditional knowledge of a particular task was not applied, it disappeared quickly (Gómez-Baggethun and Reyes-García 2013, Oteros-Rozas et al. 2013, Rodrigez-Ortega et al. 2014). Differences found between our two studied Swedish counties also highlight the effect of time on knowledge erosion. Summer farmers in Jämtland were still aware of bears and had heard stories about livestock being attacked by bears nearby, reflecting the fact that the bear never went extinct here (Kindberg and Swenson 2014). In contrast, summer farmers in Dalarna, where carnivores were absent for about 100 years, had no reference to carnivore encounters in their areas from earlier generations.

As carnivores increased, we note that the summer farmers started to learn how to protect their livestock. For instance, they learned to interpret livestock behavior indicating carnivore presence, and created new local knowledge that may help to reduce future depredation risks by sharing experiences with other summer farmers. They learned about differences between breeds of livestock in, for example, their ability to detect carnivores and to defend themselves, and as a consequence several of the farmers changed the breeds of cattle but also

stopped bringing sheep to summer farms. We also find that summer farmers have gained knowledge about carnivore behavior, including how they move and in what environment they preferably hide. For example, bears prefer to hide in thicket of shrubs close to the farms, where they lie in wait for the livestock. This agrees with the observation of the Sami reindeer herders, that the only animal that prefer the dense *Pinus contorta* plantations are bears (from interviews in paper IV). Some of the old practices are however difficult to employ again. For example, protective hunting is today only permitted under certain conditions and herding is no longer an option for most summer farmers for economic reasons. All these changes will with time change the environment around the summer farms that in turn will impact the conditions for future summer farmers.

In conclusion, our study shows that the scale of the current carnivore-livestock conflict, as measured using depredation rates, is similar to that during the decades around 1900´s. There are however several differences between the two time periods studied. For example, the numbers of summer farms have declined drastically and consequently also the numbers of livestock grazing in the forests and the farmers nowadays receive support for producing bio-cultural values more so than having their income only from food production. The most notable difference of relevance to our study is however the shift in the societal management policy from hunting to protecting the carnivores. Historically, the killing of carnivores was the common way to protect livestock, and this was not only allowed but even encouraged by society via bounties. The positive effect of hunting (for livestock husbandry) was at least two: First, the numbers of carnivores were reduced. Second, it made carnivores fear humans. There are today examples that carnivores do not fear humans and that this lack of fear is associated with a lack of repeated threatening from humans (Frank 2016, Karlsson et al. 2001). Another important difference is that the summer farming area historically was more densely populated compared to today. More people enabled a closer watch on the livestock and constant herding. Even if the herders were not armed, they could be attentive of approaching carnivores, possibly scare the carnivores off and call for help (Kardell 2008). Increasing carnivore populations currently put the summer farmers in a complex position both in economic terms but also as guardians of livestock grazing dependent diversity. The interviews also showed that farming practices have changed as a result of increased carnivore populations during recent years, such as changing breeds and not bringing sheep to the summer farms. Our study can thus contribute to the discussion about effects of increasing carnivores on the conditions for free-ranging livestock husbandry. A systematic review showed that there is limited evidence for the effectiveness of

interventions used to reduce livestock depredation of large carnivores and call for more evidence-based management practices (Eklund et al. 2017). Furthermore, interdisciplinary and retrospective studies on livestock–carnivore conflicts can contribute to more sustainable solutions for future carnivore management and successful livestock husbandry in areas with increasing numbers of carnivores and complement studies focused on the effectiveness of preventive interventions (Eklund et al. 2017). There is also a need to work with the livestock producers to more consistently and qualitatively measure and report what mitigation techniques are effective (Miller et al. 2016). The importance to include the reindeer herders in the planning and implementing of a study on reindeer calf depredation by brown bears in Udtja and Gällivare reindeer herding community was also stressed by the authors (Karlsson et al. 2012).

Previous Scandinavian studies have looked into historical (Kardell and Dahlström 2013, Nyrén 2012) and current depredation separately (Lidberg 2007, Liberg et al. 2010), but we combined the two. This provided us with information on the variation and the range of the depredation over a long time-period and an opportunity to contextualize the current situation (cf. Keane et al. 2009, Swetnam et al. 1999). A next step would be to compare the combination of factors contributing to the current and historical levels of depredation respectively, such as the society's efforts to reduce depredation, the importance of forest pasture and livestock husbandry in peoples livelihood and for national food production, the influence of landscape openness and the amount of people in the vicinity of the summer farms.

5.3 Paper III. “They followed the power of the plant”: Historical Sami harvest and traditional ecological knowledge (TEK) of *Angelica archangelica* in northern Fennoscandia.

The Djupfors study-site in the year 2013, displaying an abundance of flowering *Angelica archangelica*. Photo Anna-Maria Rautio.

In paper III we show that garden Angelica (*Angelica archangelica* ssp. *archangelica*, hereafter referred to as Angelica) was harvested by the Sami for many different purposes throughout the growing season. Our study contributes information of practical harvest techniques, times of harvest, fields of uses of different plant parts and quantitative aspects of harvest. Based on our results, we argue that the Sami actively managed Angelica gardens and even spread the plant to desired places. Further, our study indicate that the traditional Sami harvest practices were sustainable and we argue that traditional ecological knowledge of this particular plant species should be used to ensure sustainable harvest and use even today.

Angelica is a large herb belonging to the Apiaceae family, can reach impressive heights of 2 meters, and has a distinct and strong perfumed odor. It has large olive-green flowering umbels and a taproot (Jonsell and Karlsson 2010). The natural habitat range of Angelica extends from northern

Fennoscandia to Eastern Siberia and a population in the Himalayas (Ojala 1986). The plant is monocarpic, meaning that it wilts and dies after flowering, usually in its second growing season (Fjellström 1997, 2000). The plant is self-pollinated, a good strategy in low density populations. The seeds are large with low germination (Ojala 1986), which makes Angelica a difficult plant to cultivate.

To evaluate both the importance of a specific plant resource as well as to understand the ecological impacts of harvest practices, quantitative estimations of harvest levels are needed. However, there is no quantitative data available from ethnographic accounts regarding Sami harvest of Angelica. We weighed all harvested plant parts to obtain quantitative measures. On the basis of our practical experience of the logistics of drying of plants, the major problem we encountered was to dry the green biomass quickly enough so that the plants did not rot. We air-dried the harvested plants for two to three days in the field and continued drying in drying cabinets upon returning from the field. Even so, some of our plants had started to become moldy. We suggest that a maximum of 15 plants from each maturation stage could have been harvested at one single occasion. Our estimates are probably higher than reality as indicated by historical photographs showing amounts corresponding to one armful (Figure 4a-c in paper III).

Our field experiment shows that it is possible to prolong the lifespan of Angelica by selective harvest in the infertile stage. According to our results of harvest of infertile plants, fewer plants will go into a reproductive phase. The survival rate of infertile plants after harvest was very high during the first year. However, the rate was lowered in the following year. Our informant explains that we should not have harvested all the green parts because then "*all the power*" is removed from the plant and also that cutting the petioles with a knife will cause the root to rot from water coming in. This is supported by ethnographic descriptions by Drake (1918). Both our informant´s and Drake's (1918) narration of how to harvest the plant are in contrast to that of Linné (Linné and Fries [1732] 1905), which we used for designing our harvest experiment. According to our informant, it is possible also for the fertile plant (sami: *båskå*) to re-sprout in the coming year if the flower stalk is harvested before flowering, but then the rest of the green petioles must be left standing for the plant to survive harvest. Dragland (2000) supports this information and stresses the importance of harvesting early in the plants maturation process, otherwise the plant will wilt and die back anyway. The possibility of prolonging the lifespan of Angelica is further supported by Hansson (1973), which describes how Angelica gardens on Iceland were kept from flowering up to eight years. Population studies of giant hogweed (*Heracleum*

mantegazzianum) in central Europe give important information about reproductive behavior of another monocarpic Apiaceae (Pergl et al. 2006). By comparing age structure and reproductive behavior between plants growing in grazed and un-grazed areas, this study showed that the effect of grazing and trampling significantly prolonging the life span of giant hogweed because it needed more time to accumulate sufficient resources to flower. We can conclude that the removal of biomass, whether it is the result of selective harvest by people or livestock grazing, may act in favor of maintaining stable plant populations.

The ethnographic records in conjunction with the informant´s narration (Table 3) show that the Sami harvested Angelica for different purposes throughout the growing season. According to our informant, Sami elders speak about how Angelica plants were spread to areas where they do not occur naturally to secure availability of this valuable resource. Today such isolated populations of Angelica exist and are described as relics of early agrarian cultivation (Almark 2006; Ericsson, 1984), and this is also suggested by the reference to urtes garde, root gardens in Lindahl, Öhrling and Ihre's *Lexicon Lapponicum* (1780). We suspect that the isolated populations of Angelica are a legacy of old Sami settlements preceding the agrarian settlements (Hörnberg et al. 2015). Considering the low germination rate of Angelica seeds (Ojala 1986), we assume that such populations were managed sustainably to ensure continued access to the resource. Also, management and continuous harvest might have created perennial herb gardens and thus have prolonged the life span of the plants.

Table 3. Matrix showing the multiple lines of evidence we used in order to understand the traditional management and use of Angelica by the Sami people (modified from the table used in paper III).

	Method		
Contributes to understanding of:	Ethnographic records	Field experiment	Discussing with Greta Huuva
Fields of uses	Sami diet, medicine and milk preservation.	-	Sami diet, medicine and milk preservation.

Times of harvest	Information about when to harvest the different plant parts	-	The Sami follow the power in the plant. Harvest of root in spring, leaves in summer.
Practical techniques	Drake (1918) mentions that it is harmful to use knives.	Experience of root and leaf harvest. Difficult to dry harvested Angelica.	To dig for roots near water where the ground is soft and what soils to avoid. Not to harvest the whole plant and not to use knives when harvesting.
Quantities harvested	-	Roots weigh and leaf mass	-
Sami management of plants	Icelandic source, possible to pro-long the life-cycle of Angelica.	Positive effects on survival of plants from harvest.	Possible to pro-long the life-cycle by careful harvest and removal of flower buds. Seed dispersal.
Sustainability	-	Lethal to harvest whole plants. Reduced survival when many leaves harvested.	Respect and care about how to harvest Angelica, and when collecting seeds.

Our results place Sami plant use in a new light, suggesting that plants were not only harvested opportunistically, but also tended/selectively harvested and spread to new areas. Management of wild plants, especially perennials, is also known from other indigenous peoples, for example on the northwest coast in North America (Peacock 1998). A further reflection is that plant use has generally been neglected in studies of Scandinavian Sami subsistence. One reason for this is the lack of historical records of this form of land use. Fish, game, furs and reindeers have all been important tax items, while plants such as Angelica have only been used for local consumption. Our findings are in accordance with studies showing that historical ethnographic information on vegetal resource management and plant exploitation strategies in traditional hunter-gathering groups often are missing (Berihuete-Azorin 2013, Gottesfeld 1994), due to scarcity of archeological findings of vegetal resources but also possibly since the gathering of vegetal resources mainly were the women's work (Turner 2006), that might not have attracted the interest of (often) male ethnobotanist at the time.

Sami plant use of scots pine inner bark (*Pinus sylvestris*) is clearly visible by the bark peeling scars remaining in the historical landscape studied by Rautio (2014). The thesis excellently illustrates the long time landscape scale

of Sami plant use and that the Sami returned to "good" places over centuries. But to study the culturally modified trees in the Sami landscape (Östlund et al. 2002, Östlund et al. 2003) and around the summer farms (Bryn and Daugstad 2001, Moe and Botnen 1997, 2000) it is necessary to have access to forests that are not subjected to "modern" forestry that effectively obliterates the traces of human land use in the boreal forest (Östlund et al. 2002). Almost all old-growth pines in boreal Sweden have been cut for timber during the last 100 years and only a very small fraction of the original bark peeled trees remain (Östlund et al. 2002, Rautio et al. 2016).

The amount of traditional plant knowledge available is connected to if a plant is an important resource or hinders the utilization of another resource (Biro et al. 2014). This was also shown in the work on reindeer herders´ knowledge of reindeer food plants. The herders had precise and detailed knowledge of the ground lichen species and their requirements, since this knowledge is essential to the winter survival of the reindeer. But they have less knowledge of the abundant summer grazing plants, as summer grazing is plentiful (Inga 2007, 2008).

Taken together, our study also shows that in order to understand complex patterns of traditional land/ plant uses different methods must be combined. Such multi-faceted approaches to understanding traditional management practices have been effective also in other parts of the world (Barthel et al. 2013; Fowler and Lepofsky 2011; Lepofsky and Lertzman 2008). The ethnographic information addresses when and what to harvest and also how the different plant stages were used for different purposes. The information obtained from our informant covers details about Sami traditional ecological knowledge, such as harvesting and plant use from all of Northern Scandinavia. The field experiment complements our study by providing unique knowledge on quantitative and practical aspects of Sami Angelica harvest. When designing the harvest experiment, our knowledge was limited to information from ethnographic records and general plant biology, without the TEK information given by our informant; we would have reached to the wrong conclusion that Sami plant use was unsustainable. Thus the TEK documented in this study can contribute to protection against commercial harvest of wild growing Angelica populations and lead to more sustainable harvest techniques based on Sami traditional ecological plant knowledge.

The traditional ecological knowledge about the use of Angelica was as in the case of preventive methods about carnivores (in paper II), sensitive to time. Since Angelica is not commonly used today, the knowledge remained in the memories of the elders and was fortunately carefully gathered by our informant. This clearly shows how vulnerable TEK is to time, as shown in

several studies (Gómez-Baggethun et al. 2012, Oteros-Rozas et al. 2013), but also how important it is to document TEK in general. The knowledges used in the past might be of great significance to future management.

5.4 Paper IV. Strategies to handle loss and disturbances of winter pastures: the role of traditional ecological knowledge in Sami reindeer husbandry.

Reindeer feeding in deep snow in Nääkäla paliskunta (Finnish: Nääkälä herding community), Photo Tim Horstkotte.

In paper IV we investigate how herding strategies have changed during the recent past and whether these changes can compensate for land losses and increasing disturbances. Traditional knowledge is critical for reindeer husbandry and here we focus on interpreting the strategies used to overcome the changing extent and availability of winter grazing pastures. Encroachments are affecting the way that reindeer husbandry operates, as pastures become more fragmented, spatially disconnected and forage resources decline (Kivinen et al. 2012, Korosuo et al. 2014, Sandström et al. 2016), but also cause problems for herders by disturbing and dispersing the reindeers (Skarin and Åhman 2014). It is unclear if traditional strategies of pasture use can still be utilized in this rapidly changing environment. Specifically, we ask what are the encroachments on winter grazing areas that cause the most problems for the

herders today compared to the earlier generation? What reindeer herding strategies are used today compared to earlier generations? How do they differ? Finally we want to know if there are any possibilities to save and manage pastures currently so that lichens can recover from grazing?

In paper IV, we used paired interviews with reindeer herders from different generations to identify and characterize encroachments and strategy shifts..

5.4.1 Encroachments

We identified eight main encroachments that affect the extent and availability of winter grazing pastures: *wind-power, mining, forestry, roads, railways, hydro-power, tourism* and *carnivores*. To compare their current relevance and relative impact, we characterized these encroachments as old or new, and reversible or irreversible, respectively. Wind-power and mining were characterized as new encroachments as they are relatively new developments in the study area. Mining in fact existed in the area as far back as the 17th century, but the herders were referring to new mining developments that are affecting their herding. Railway and hydro-power developments mainly took place in the first half of the 20th century and were thus characterized as old encroachments. Wind-power, mining, railway and hydro-power developments all have more or less irreversible effects on winter grazing (Figure 5). Roads were also considered to have irreversible effects, but can be of both old and new origin. Tourism and carnivores represent new reversible effects, whereas forestry fits all categories.

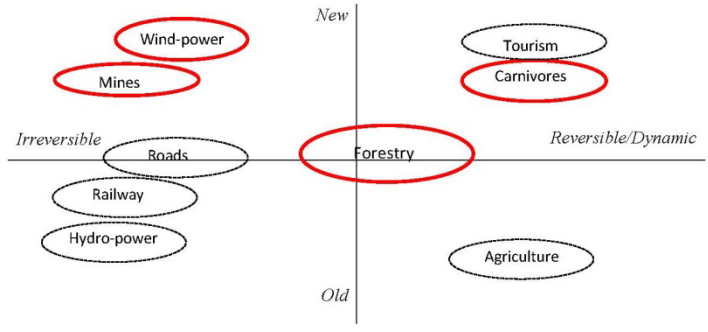

Figure 5. (figure 2 from paper IV). Schematic illustration of the effects of encroachments experienced by the reindeer herders. Whether an encroachment is old or new is in relation to the informants´ age; old encroachments relate to the older herders' youth or active time. New encroachments are happening now or are planned in the near future. Reversible encroachments are encroachment whose effects decrease as soon as the intrusion decreases, whereas irreversible encroachments leave a long-lasting effect. Forestry, mines, wind power and increasing numbers of carnivores (emphasized by solid circles) are of great concern for the young herders.

Within the limits of encroachments mentioned above, the reduction in available lichen-rich pastures caused by forestry is the main concern for all the interviewed herders. The loss of both ground lichen areas and areas rich in arboreal lichens is clearly evident in all interviews. Herders describe how the available lichen pastures are much smaller, more fragmented, and that the quality has deteriorated compared to the previous generation. Old-growth forests with arboreal lichens are nowadays scarce due to modern forestry (Figure 6). Reindeer, furthermore, avoid certain forest areas, for example new clear-cuts with lots of residues and *Pinus contorta* plantations, as these act as barriers to reindeer movement.

Figure 6. Clear cutting in Östra Kikkejaur reindeer herding community near Moskosel, with soil scarification in order to regenerate the forest. Clear-cuttings and soil scarification decrease the amount of ground lichens and logging slash makes it difficult for the reindeer to move and graze Photo Tim Horstkotte.

This is in accordance with forest studies showing how the area of lichen-rich forests have decreased (Berg et al. 2008, 2011a, 2011b, Sandström et al. 2016, Horstkotte et al. 2011) and become more fragmented (Essen et al. 1997, Kivinen et al. 2010, 2012, Moen and Keskitalo 2010) and also that the average age of the forest is lower. For example, old-growth forests older than 60 years have declined from 84% to 34% since 1926 (Horstkotte et al. 2011), consequently changing the structure of the forests (Berg et al. 2008, Östlund et al. 1997).

5.4.2 Strategies used during the winter grazing season

When the older herders refer to how the forests used to be when they started reindeer herding, the younger cannot believe it: nowadays the forest have changed so much that the older herders do not recognize the forests nor the behavior of the reindeers. The fragmenting effects of modern forestry on the boreal forests increase the herder's efforts to keep the reindeer together, resulting in an increased workload, and more difficult winter planning (Table 4). This also mean that the area of available grazing is actually smaller than the

area of available ground lichens (as shown by a vegetation map) because it is hard for the reindeer to access the small and isolated lichen patches.

Table 4. Matrix showing the multiple lines of evidence we used in order to understand the Winter planning strategies used by the herders in chronological order following the winter season. The strategies are either intended to maintain control over the reindeer and the available grazing resources per season (proactive), or to meet the unforeseen, a response to events (reactive). Strategies are characterized as past (in the youth of the older generation) or present and presented chronologically following recurrent events during the winter season.

Proactive strategies	
In the past	In the present
• Grazing while slowly migrating towards the winter pastures.	• Stay for longer periods in the low mountains in response to increased weather uncertainties.
• Reindeer migrate by foot.	• Reindeer migrate by foot or are driven by trucks.
• Use the low quality areas* first, i.e. those that will be unavailable later in winter due to heavy snow.	• Try to use the low quality areas* first, but sometimes this is not possible due to transport costs. The reindeer are transported to the main winter pastures at once.
• Keep the edges around the herd tight. Skiing around the herd.	• Keep the edges wider. Go by snowmobiles around the herd.
Reactive strategies	
In the past	In the present
• Change grazing pastures within the same winter grazing area.	• Decide on what grazing area to use, and whether to use trucks or not. To change grazing pastures within the same area is often hard due to fragmented forests. Supplementary feeding is used instead.
• Use gathered ground and arboreal lichens as fodder when grazing conditions are bad.	• Supplementary feeding with hay and pellets, or to transport the reindeer with trucks to a new area.
• Let the reindeer wander wide to find arboreal lichens (when ground lichens are locked due to ice-crusts).	• Supplementary feeding is used. Letting the reindeer wander wide after arboreal lichens in old forests is today combined with large depredation risks.

*Low quality areas = a combination of areas of lower grazing value and areas that will be unavailable later in the winter due to large amounts of snow, often at higher altitude.

The decision on exactly where to start the winter grazing period is very much dependent on the first cold snow and surrounding weather conditions, and in agreement with the other herders in the same reindeer herding community. In the past, there were more reliable weather patterns and the older herders always anticipated a thaw in the end of November, after which they started to descend into the forests. However, increasingly unpredictable weather conditions make it impossible to decide in advance when and where to go. In the past, on their way down from the mountains to the winter pastures in the boreal forest, the herd moved through low mountain pastures that were only grazed while

passing. In contrast, the young herders have remained in these low altitude mountain areas for up to a month during the last decade. The attractiveness of low mountain pastures is further increased by the deteriorating qualities and reduced sizes of forest pastures. Today these pastures are considered as good, or at least acceptable, pastures. This shows how the quality of the forest pastures has deteriorated during one generation (see Sandström et al. 2016 and Kivinen et al. 2010 for more details on the effects of forestry on winter pastures).

Before motorization, the older herders accompanied the reindeer down from the summer pastures on skies. Nowadays it is necessary to use snowmobiles, helicopters or trucks for transportation. The advantages of transportation using trucks are that all reindeer manage the move and no animals are left behind. The disadvantages are the costs and that the reindeer get disorientated and do not find their way back to their summer mountains. Another drawback is that the reindeer come down to the winter pastures directly, without grazing on the way down. This increase the grazing pressure on the actual winter pastures. The possibility of staying in the low mountains for prolonged periods saves winter pastures in the forests for later in winter, whereas the transportation of reindeer with trucks counteract such saving strategies.

All, both old and young, herders interviewed confirm that to learn reindeer husbandry it is essential to be out in the reindeer forest together with more experienced herders (see also Turunen &Vuojala-Magga 2014). Traditional reindeer herding strategies are constantly evolving in interaction with the reindeer and the traditional landscape. The same traditional strategies are used throughout the study area although with adjustments to the prevailing circumstances and constraints imposed by the encroachments and rapidly changing weather.

Several of the interviewed older herders state that the increased use of snowmobiles results in that the children of the herders have to be at least 16 years old until they can participate in working with the reindeer, this is later than when the older herders started. Increasing weather uncertainties also results in that their older relatives have little previous experience to share. The circumstances have changed so rapidly in just one generation, resulting in incomplete TEK transmission. To follow the knowledge of the older can sometimes feel as a constraint but it is also a security. In Laevas reindeer herding community, the lack of knowledge about the effects of climate change was found to severely concern the younger herders, since they could not ask their older about advice what to do (Liljemalm 2017). The changed climate has severely changed the situation also for Finnish reindeer herders (Turunen et al. 2016 Rasmus et al. 2016).

Effects of bad weather were traditionally avoided by changing grazing areas (Rasmus et al. 2016), and especially in late winter traditionally compensated by letting the reindeer go after arboreal lichens facilitated by cutting down lichen-rich trees (Berg et al. 2011a, b). The herders stress the need to have a range of forests to choose among as the effects of snow differs between forests of different ages (see also Roturier and Roué 2009). Ground ice rarely forms simultaneously in variable forests (Rasmus et al. 2016) and forest canopies of different ages have different effects on the snow beneath (Horstkotte and Roturier 2013). But the young herders in our study have no alternative pastures to go to and most of the winter groups interviewed lack sufficient areas with arboreal lichens (see also Berg et al. 2008, Horstkotte et al. 2011). Those who nevertheless have some amounts of old growth forests are reluctant to use these areas as they present an increased risk of carnivore attacks, in the end leaving only remaining supplementary feeding as a real alternative.

The general situation described in this study is not unique. Many traditional pastoralist systems in the world are strongly affected by both climate change (e.g. Oteros-Rozas et al. 2013, Ims et al. 2013) and encroachment by other land users (Galvin 2009, Dong et al. 2011, López-i-Gelats et al. 2016). This tends to lead to fragmentation of earlier "open", large-scale landscapes, which causes major problems as pastoral systems are usually dependent on animal movements over distances or migrations to sustain the herds over the seasons (Naess 2013, Horstkotte et al. 2014). However, some authors have also suggested that pastoralist systems tend to be flexible and have been able to adapt to various changes in the past (e.g. Galvin 2009, Moen and Keskitalo 2010). A study focusing on risks associated with traditional subsidence harvesting activities in Ikpiarjuk (Arctic bay), Nunavut, was repeated after 11 years. During this time many of the observed environmental changes had accelerated increasing the vulnerability of the society. Modern techniques could to a degree help the land users to manage the changing conditions, but also lead to incomplete transmission of environmental knowledge that increased the sensitivity and limited the adaptive capacity of the community (Archer et al. 2017). Nevertheless, pastoralists must adopt strategies to handle changes that they cannot control.

Indigenous peoples´ observations of ecological impacts due to unusual climate events has proven valuable and is becoming accepted as a valid source of information for local environments over a relatively short time frame (Cuerrier et al. 2015, Golden et al. 2015, Turner and Spadling 2013). So far this has not been the case in Sweden (but se Riseth et al. 2011).

Sami reindeer herders, like summer farmers, are holders of traditional knowledge, in the sense that their daily work is based on their traditional ways

in the same land areas as their ancestors. Thus, the understanding of the grazing grounds and animal behavior is the result of a long-term adaptive process. In the interviews the reindeer herders refer to “easy land” and “hard land”. This knowledge is hard to communicate to outsiders (Roturier and Roué 2009). In “easy land” the reindeer and herders move together and the daily work of the herders is easy. As one of the herders put it, “*The land is so easy that you don’t have to have experience, even the youngest herder will see what is needed to be done*”. It could be interesting, in future research, to try to quantify the cumulative effects of the encroachments, by using the amount of extra time herders use to gather and hinder reindeers to wander off, the extra length of snowmobile driving and the extra amounts of supplementary food used. The current situation with increasing encroachments will unfortunately provide researchers with many new study areas for the years to come.

6 Conclusion

My thesis confirms that both summer farmers and reindeer husbandry are under pressure and face large challenges today and in the future. Some of these challenges are shared and some differ between the two types of northern pastoralism. In my thesis I have attempted to contribute to a deeper understanding on how challenges as well as combinations of challenges affect extensive pastoralism for these two groups in northern Sweden. I also wanted to contribute to an understanding of the role of TEK in livestock farming and reindeer husbandry in daily life and how TEK has been used in the past. Finally, a retrospective perspective places the current situation for summer farmers and reindeer herders in a more solid context.

Throughout the work with the thesis the benefits of combining methods from different sources and adding a historical perspective were evident. My aim has been to achieve a broader picture of these forms of land use and to understand how the detailed investigations fit into this picture. The historical records, the contemporary data, the interviews and the experimental results all provide important pieces of a larger jigsaw-puzzle (cf Bürgi et al. 2017 a, b).

In the following I will conclude the result of my research in relation to my specific aims (see Section 2).

6.1 Challenges to continued land use by summer farmers and Sami reindeer herders

Although both summer farming and reindeer husbandry are recognized as important carriers of tradition, it is clear that the long history of traditional land uses is under strong external pressure today. These practices take place in the "outskirts" of contemporary society where increasing numbers of other forms of land use now compete, causing major problems for the traditional land use. A position in the societal periphery also means less political power and less

influence on decision taken in different legislative and administrative authorities.

Summer farmers in Sweden and Norway are as many small-scale farmers throughout Europe, dependent on agri-environment payments to support the conservation of ecological and cultural functions at the farms (Ivascu et al. 2016, von Glasenapp and Thorton 2011). Scandinavian summer farmers experience that different views on their land use from different authorities affect them negatively. It is not so much that their grazing land is reduced by competing interests, as compared to reindeer husbandry, but that summer farmers today has to do a lot of administrative work due to the many different regulations, beside the actual labor on the land. These regulations often have contradicting goals, and include contacting and writing reports to many different authorities (paper I).

This situation is mainly the result of different societal interests in summer farming and the summer farming areas, and that they are handled by different authorities with no or minimal coordination. Even though the overall goals do not always contradict each other on an overall level, they may in detail cause contradictory regulations. For example, agri-environmental payments in other countries have been shown to sometimes disfavor the traditional elements that are essential to preserving the cultural features wanted (Babai et al. 2015, Ivascu et al. 2016, Plieninger et al. 2006).

In clear contrast to the interviewed reindeer herders forestry was not identified as a main problem by the interviewed summer farmers, but the increasing populations of large carnivores is very much a worry for the farmers. This is a clear parallel to other regions where the numbers of large carnivores have increased in modern time and conflicts with livestock farmers have re-emerged (Bisi et al. 2007, Chapron et al. 2014, Dorresteijn et al. 2014, Kojola et al. 2006, Zlatanova et al. 2014). The increase of large carnivores clearly is negative for the Scandinavian summer farming and therefor represents a conflict between the continued conservation of large carnivores on the one hand, and biodiversity values dependent on continued summer farming on the other. This conflict is a recent phenomenon looking in a longer time perspective. The last time there were large numbers of carnivores in Sweden/Scandinavia, lasting until the end of the 19th century, pastoralism was very important in the agrarian society and large carnivores were to be reduced in number or even exterminated because they were a threat to livestock husbandry and animal food production (Kardell 2008, Kardell and Dahlström. 2013, Nyrén 2012). The observation that current depredation levels are similar to the levels around the turn of the 19th century, combined with the stark contrast between the present protection of carnivores and relatively low

numbers of forest grazing livestock and the historical intense hunting of carnivores and livestock in much larger numbers, raises questions as to how so varying conditions can result in so similar effects (paper II).

Increased levels of carnivores are also contributing to the increasingly urgent situation for Sami reindeer husbandry (Hobbs et al. 2012, Åhman et al. 2014, Ramberg Sivertssen 2017). Although this is a problem that reindeer herders thus share with summer farmers, there are basic differences between the two land use practices. Due to a governmental decision aimed at reducing depredation on reindeer, wolves (*Canis lupus*) are not allowed to reside and reproduce in areas where reindeer husbandry is prioritized by the state (Proposition 2012/13:191). In paper II it was evident that this creates differences in depredation levels of livestock within and outside the prioritized area. Despite this management reindeer depredation remain high. While the livestock depredation rates ranged from 0.004 to 0.43% (in paper II), the depredation on reindeer is higher, ranging from 7.1 to 18.4% in annual female mortality (Åhman et al. 2014), and 30-50% of calves born where missing at calf marking, of which 63-100 % were presumably killed by brown bear (Karlsson et al. 2012). In 2013, the Sami parliament together with Swedish environmental protection agency agreed upon a maximum of 10% injures caused by carnivores on the actual numbers of reindeer (Naturvårdsverket 2013).

While compartmentalization with much bureaucracy and increased depredation from large carnivores are found here to constitute major challenges for summer farmers, the reduction of winter grazing land and the overriding effects of modern forestry on all remaining winter grazing areas cause large problems to traditional reindeer husbandry. Both today and in the past, the amount of available winter grazing area is, and has been, a critical bottle neck for reindeer husbandry. Increasing number of roads, wind farms, and railroads reduce the pasture area and as reindeer are easily disturbed the functional loss in grazing areas is even larger than the actual surface expropriated for the construction itself. The actual reduction in grazing land is further reduced by the fact that some encroachments block the access to traditional grazing land. Every single encroachment may not be large in itself, but the combined effect is larger than the sum of each encroachment since it is the cumulative effect of many encroachments that creates the fragmented landscape in which reindeer husbandry operates today (e.g. Tyler et al. 2007, Pape & Löffler 2012). Apart from the fragmentation, the forest itself has changed dramatically due to modern forestry during the last century. Areas with ground lichens (Kivinen et al. 2012, Korosuo et al. 2014, Sandström et al. 2016) and arboreal lichens (Horstkotte et al. 2011) have decreased dramatically.

The herders in our study also tell us about increased weather uncertainties that change the prerequisites for traditional reindeer husbandry. Thus the effects of encroachments are further enhanced by climate changes since increasingly difficult winters conditions create a need for a wider range of different areas to always find good grazing (Rasmus et al. 2016, Turi 2016, Turunen et al. 2016), while in fact this range has been reduced.

As the amount and quality of winter grazing grounds have decreased, the herders compensate by keeping the reindeer on larger areas. They also compensate by giving supplementary food to a larger degree. The younger herders spend much more time keeping reindeers away from railroads, roads, hydroelectric dams, and mines compared to their elder colleagues, implying that the workload has increased for the younger herders, but also that the land affected by irreversible encroachments are larger than the actual industry or railroad itself.

In conclusion it is obvious that summer farmers and reindeer herders share challenges to some extent; most important of which are the conflicts with other forms of land use and increasing carnivore populations. The main differences are due to the scale of land use and the resulting areal extent. Reindeer husbandry is operating on a much larger scale and therefore the competition with other forms of broad-scale land uses such as forestry becomes very evident. Also, the encroachments come from outside the reindeer husbandry, such as wind farms, roads etc., whereas the decline in summer farming is more of an internal process and above all the result of rationalization of livestock farming (Larsson 2012, Myrdal and Morell 2011). Due to the shared challenges reindeer herders and summer farmers today meet and try work towards common goals.

6.2 The importance of TEK in daily work and to handle challenges

By documenting TEK and using a historical-ecological perspective we gained an understanding of the main challenges facing summer farmers and reindeer herders today and how conditions have changed over time. But is it also possible to handle these day-to day challenges by using TEK? A conclusion from my studies is that TEK is still widely in use and necessary for summer farmers and reindeer herders in daily life when taking care of their animals. But it is also evident that the "old" knowledge may not be enough to handle the new challenges that summer farmers and reindeer herders face.

The return of large carnivores in the 1990´s forced today's summer farmers to face a totally new situation, of which they had no previous experience and

little local knowledge about. However, the farmers could build on their knowledge about livestock behavior and soon acquired new knowledge and learned how to avoid and prevent carnivore attacks, both from each other, from their livestock and with help also from Viltskadecenter (Wildlife Damage Centre) and county authorities. A reflection from placing the current conflict in a historical perspective is that the old methods depended on unrestricted hunting and that much more people worked at the summer farms than is economically feasible today. As a result of increasing carnivores, farmers may choose not to bring their livestock (especially sheep) to the summer farm anymore but keep them closer to the home farm, a solution that was not possible in late 19th century, due to hard competition for available grazing areas. It has also been noted that there is an obvious lack of knowledge about these matters and thus a need for more studies on the experiences of preventive measures to protect livestock under the new conditions since there is little systematic evidence on which measures actually work (Eklund et al. 2017).

During my PhD studies I was fortunate to have the possibility to also study other aspects of TEK in relation to Sami subsistence in an historical perspective. Although Sami plant use was already studied by Carl Linné (Linné and Fries [1732] 1905), it became evident in paper III that essential knowledge of historical Sami plant management of *Angelica archangelica* was lacking. Angelica has traditionally been used for many purposes in the Sami culture, among others Angelica was widely used by the Sami for its healthy properties (Fjellström 2000, Qvarnström 2006, Svanberg and Tunón 2000). The wild growing plants in northern Scandinavia are now receiving increasing interest by commercial enterprises working with health products. Since other species of Angelica have decreased to the degree of being critically endangered due to heavy commercial exploitation and habitat loss in the Himalayas (Kala 2000, Vashistha et al. 2006, 2007) it was important to document and spread the Sami TEK that can contribute to protection against commercial harvest of wild growing Angelica populations and lead to more sustainable harvest techniques based on Sami plant knowledge. This study also put focus on the vulnerability of TEK and that documentation of experience based knowledge sometimes relies on a single person. In the case of Angelica, our informant provided knowledge that was in the process of disappearing.

The reindeer herding strategies used to handle the current loss of winter grazing areas are based on traditional ecological knowledge on how to manage yearly variation of grazing resources, the usefulness of which therefor is severely limited. The explanation to why traditional knowledge is not sufficient in the current situation can be explained by two factors that have changed recently. First, the traditional strategies depended on flexibility in the use of

different types of land – land that has been strongly restricted by various combined encroachments. Second, climate change has altered the winter conditions to the degree that there is no previous knowledge about how the snow and ice cover currently varies. The traditional strategies based on earlier winter experiences simply are not valid any longer sometimes leaving young herders on their own as they face very difficult situations when trying to find food for their reindeers in the winter (Liljemalm 2017). The only remaining alternative to the herders today is often to buy supplementary food to the reindeer, a strategy that lies outside the range of sustainable traditional reindeer husbandry.

A rich body of traditional ecological knowledge is omnipresent in the land use of both summer farmers and reindeer herders. Whereas the knowledge of preventive measures at summer farms and Angelica plant use was sensitive to long periods of no use, the traditional reindeer herding knowledge is difficult to apply to the rapid changes of the amount of available land areas and increasing weather uncertainties.

TEK is important for the identity and cultural heritage of both summer farmers and reindeer herders. TEK is also important to the future land use and consequently to future mountain management. Although it is important to document this knowledge to future generations, as done in this thesis and in the outstanding work by for example Linné (Linné and Fries [1732] 1905), Roturier and Roué (2009), and Ryd (2001), it is also evident that simply documenting TEK and not maintaining and supporting these practices in various ways is not sufficient.

There is also another aspect that I want to bring forward here. By acknowledging TEK as a valuable tool in research, we are also being respectful towards local societies (cf. Turner et al. 2000) and, in this case, to the people who are actually working as summer farmers and reindeer herders. Science has a tendency to look at things from above and create its own array of questions and answers. TEK forces scientists to look at real-world questions and real-world solutions. The involvement of summer farmers and reindeer herders in my research has been decisive for my understanding of these topics.

6.3 The future of summer farming and reindeer husbandry

Today summer farming is practiced on a very limited scale, compared to in previous times. If the remaining farmers stop bringing their livestock to the summer farms, this will have severe effects on these marginal landscapes. Both the cultural and the ecological qualities connected to low-intense summer

farming in forests, on wetlands and on mountain heaths in Scandinavia will gradually disappear as the few remaining summer farmers have a critical role in keeping this ancient tradition alive. It is however important to note that this change may primarily be a threat to the practice of summer farming, but does not necessarily threaten the farmers´ existence. Today there are often available grazing grounds nearer to the home farm, e.g. former arable land. However, within the remaining summer farming community there exists a strong sense of belonging and responsibility towards earlier and future generations, both with respect to nature and cultural heritage but also with respect to identity, human and animal wellbeing and therefore they keep their summer farms.

For the reindeer herders, current changes may lead to more severe results. If the costs of handling the loss of grazing areas, such as long transports and much supplementary food become too high, reindeer herders may have to stop practicing reindeer husbandry for economic reasons. The scale of this potential change is much larger than the change connected to the decline of summer farming, because reindeer husbandry is practiced on a much larger scale and has not decreased in the same way as the summer farming. A decline in Sami reindeer husbandry would also severely affect the entire Sami community negatively as reindeer husbandry is an important and traditional part of indigenous Sami livelihood and culture (Beach 1981, Lundmark 1982, 2008) and also an important keeper of the claim to Sami land rights (Cramer and Ryd 2012).

Through my thesis I have discovered a number of possible solutions that could enhance the continuation of summer farming and reindeer husbandry. The statements below may not be exhaustive but suggest a number of solutions that I have concluded from my studies.

Summer farmers in Sweden and Norway would welcome a common view on summer farming from the different agencies having an interest in summer farming in order to reduce the compartmentalization (Rouzel 2011) that exist in the views on the summer farming landscapes. In Sweden those agencies are, among others, the Swedish board of agriculture, the National food agency, the Swedish forest agency, the Swedish national heritage board and the Swedish environmental protection agency. Such a development could potentially limit bureaucracy, give the summer farmers more time to work on the farm rather than filling out administrative forms, as well as make them feel support from the society.

The main concern for the Sami reindeer husbandry regards the right to, and amount of, available grazing land, as the different encroachments have decreased the land available for winter grazing. During recent years there have been attempts of more participatory managements with, for example, forestry

(Sandström 2015) but the reindeer herders´ opinions are seldom noticed or adhered to (Sandström and Widmark 2007). Several of the herders interviewed in our study state that there is no way for them to stop a clear-cut, at most postpone it for some time. There are furthermore so many pending future encroachments and as each and every application should be discussed with the reindeer-herding group concerned (thought this is not always the case), the amount of meetings become overwhelming. Thus the herders have to concentrate on the "worst" cases. To summarize, there is a need for an overall view on the whole reindeer grazing area, on each and every new and old encroachment and that the cumulative effects thereof are put in perspective.
Summer farming and reindeer herding would both benefit from a strategic oversight on the impacts of the different competing interests in the mountain area, both on a larger spatial, and temporal scale, as well as from involvement in future mountain management planning. Today there is no such strategic management planning for the mountain area in northern Sweden.

Although the growing awareness of the need to involve local stakeholders in management decisions (CBD, IPBES), these are still often omitted from such processes (Lawrence and Mörkenstam 2016, Reimerson 2015, Risvoll et al. 2014). To involve stakeholders in research can be exhausting and challenging but this participatory research is the only way to bring forth both practical and theoretical knowledge (Höchtl et al. 2006) and several studies argue that an enriched picture involving local and traditional knowledge can be used as a starting point to improve future management planning (Hernández-Morcillo et al. 2014, Kis et al. 2016, Sutherland et al. 2013). There are however still practical and structural problems with integrating indigenous and local knowledge in resource management and there are, among other requirements, a need for new frames for integration, and involvement of inter-cultural "knowledge bridgers" (Bohensky and Maru 2011).

The full consequences in the eventuality of discontinuance of summer farming and Sami reindeer husbandry in northern Scandinavia are hard to foresee. For the summer farmers and the Sami there will be loss of identity and well-being strongly linked to the traditional practices of seasonal movements, comparable to that of fishing communities in northern Norway (Kaltenborn et al. 2017) were local vision of the "good life" emerged from a combination of satisfied preferences and struggle, hardships and capabilities inflicted by a demanding environment and challenging work conditions, but also the local control of resources and surroundings.

The future consequences of reduced reindeer grazing may be multiple, such as loss of mountain species diversity as less reindeer graze the mountains. With decreasing traditional mountain land use there might also be a change in

ecosystem services (Harrison et al. 2014) linked to that mountain use (Blicharska et al. 2017) and a decrease of the open landscape that is highly valuated for recreation both by locals and tourists. The traces of cultural heritage and visible signs of historical land use will also slowly disappear and become increasingly underestimated leaving only "the last wilderness of Europe".

A central question requiring more research beyond the scope of this thesis is whether traditional knowledge systems that have developed and adapted to environmental variability over thousands of years can develop and adapt to today´s socio-ecological context of relatively sudden and sometimes violent changes in the earth´s climate and ecosystems (see Turner and Spalding 2013). It is important to continue to work with traditional land users in northern Scandinavia in order reveal how much their traditional land use have changed and to find solutions to how their knowledge can be integrated in the future planning of an ecologically and socially sustainable mountain management.

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