Reindeer Herding and Modern Forestry

– the Historical Impacts on Forests of Two Main Land Users in Northern Sweden

Anna Berg
Faculty of Forest Sciences
Department of Forest Ecology and Management
Umeå

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Abstract

Forestry and reindeer herding are the two geographically most extensive forms of forest utilisation throughout the northern parts of Sweden today. Until the 18th century the interior parts of northern Sweden were predominately occupied by native Sami people. From the mid-18th century the area was rapidly colonized by farmers. In the late 19th century forestry, first in the form of high-grading of the larger trees and later as sustainable forest management, was introduced to the vast inland forests of northern Sweden.

The overall aims of this thesis were to characterise and analyze different aspects of the effects of reindeer herding and modern forestry on the forest ecosystem in inland northernmost Sweden in the past, up to present time, and their consequent effects on each other. Two aspects have been of particular interest: (i) the effects of the practice by reindeer herders to cut trees to feed their reindeer with arboreal lichens, and (ii) the effects of modern forestry practices on forests important for reindeer winter grazing. The investigations have been based on a combination of field surveys, dendrochronological analysis, analysis of historical records including maps and forest surveys, and landscape analysis.

The main findings of this thesis are 1) cutting of lichen trees for reindeer fodder have been a widespread and important practice up until the beginning of the 20th century. Scots pine and Norway spruce trees with abundant lichen cover were cut, and the practise were performed for different purposes, including emergency feeding during harsh winters and to gather the reindeers during movements. 2) Early forestry (logging of larger trees in old sparse forests) did not adversely affect winter grazing conditions for reindeer. 3) The fragmentation of the forest landscape and the use of various forestry measures greatly accelerated with the introduction of clear-cutting in the mid-20th century and this have had a predominantly negative influence on reindeer winter grazing areas. The overall conclusion is that forestry has mainly had negative influence on reindeer herding, especially since the mid-20th century. Despite this, reindeer herding have been able to adjust to major changes in overall land-use during the last few centuries. Historical information, preferably achieved from a combination of several methods, provide a background for the current land-use conflicts in reindeer herding areas and give important insights into longer trends of ecosystem changes.

Keywords: forest history, Sami, interdisciplinary, lichen, grazing

Author's address: Anna Berg, SLU, Department of Forest Ecology and Management, 901 83 Umeå, Sweden
E-mail: Anna.Berg@svek.slu.se

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 Anna Berg, Björn Gunnarsson & Lars Östlund (2010). At this point, the lichens in the trees are their only means of survival– the history of tree cutting by native Sami people in northern Sweden to feed their reindeer during harsh winters. Accepted for publication in *Environment and History* (In press).

II Anna Berg, Torbjörn Josefsson & Lars Östlund. Cutting of lichen trees – quantification of a survival strategy used before the 20th century in northern Sweden (Submitted manuscript).

III Anna Berg, Lars Östlund , Jon Moen & Johan Olofsson (2008). A century of logging and forestry in a reindeer herding area in northern Sweden. *Forest Ecology and Management* 256 (5):1009-1020.

IV Sonja Kivinen, Anna Berg, Jon Moen, Lars Östlund & Johan Olofsson. Long-term changes in boreal forest landscapes from a reindeer husbandry perspective. (Submitted manuscript, pending revision).

V Sonja Kivinen, Jon Moen, Anna Berg & Åsa Eriksson (2010). Effects of modern forest management on winter grazing resources for reindeer in Sweden. Accepted for publication in *AMBIO* (In press).

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Introduction

Reindeer herding and forestry are the two most geographically extensive forms of forest utilisation throughout the northern parts of Eurasia. Reindeer are herded by several peoples, for example the Nenets (Forbes *et al.*, 2009; Golovnev & Osherenko, 1999) and the Evenki (Vitebsky, 2005) in northern Siberia, the Sayan people in southern Siberia (Vainshtein, 1980) and the Sami in northern Europe (Ruong, 1979). The properties and history of reindeer herding have received much attention from historical (Hansen & Olsen, 2006; Lundmark, 1982; Hultblad, 1968; Wiklund, 1918), anthropological (Roturier & Roué, 2009; Vitebsky, 2005; Krupnik, 1993; Vainshtein, 1980; Ruong, 1945) and archaeological scientists (Bergman *et al.*, 2008; Liedgren *et al.*, 2007; Hansen & Olsen, 2006; Storli, 1994; Aronsson, 1991). While reindeer herding has been carried out for several centuries modern forestry has a much shorter history. During the last 150 years several waves of commercial logging have swept through the northern coniferous forests, and there has been extensive forest exploitation in both Fennoscandia (Storaunet *et al.*, 2005; Löfman & Kouki, 2001; Östlund *et al.*, 1997) and the periphery of northern Russia (Yaroshenko *et al.*, 2001). There has also been extensive research on silviculture and forestry methods, as well as the ecological effects of forestry. Furthermore, the relationship between forestry and reindeer herding has received interdisciplinary attention, but predominately with respect to the present relationship between these two forms of forest utilisation. Studies that address historical components of this intricate relationship have so far been scarce.

Past land use in northern Sweden

For millennia, people's ability to survive the harsh winter conditions in the tundra and the northernmost forests of Eurasia has been closely linked to the reindeer (Forbes & Kumpula, 2009; Burch JR., 1972). Far back in time wild reindeer were hunted, but subsequently reindeer herding developed in Russia and Scandinavia. In northern Sweden the precise starting point of reindeer domestication is disputed among scholars (Bergman *et al*., 2008; Hansen & Olsen, 2006; Storli, 1994; Aronsson, 1991; Lundmark, 1982), but it is clear that reindeer herding was well established in several areas by the 16th century (Wheelersburg, 1991; Hultblad, 1968; Holmbäck, 1922). Although the reindeer herding tradition has its roots far back in time, important changes in the practice have occurred – particularly since the late 19th century. Before that time an intensive form of reindeer herding prevailed – in which whole Sami families moved along with their reindeer herds and used the reindeer in a variety of ways, e.g. for transport, milk and meat for food, furs for clothing and cots and sinews for strings (cf. Schefferus, [1673] 1956). Reindeer herding was usually combined with other activities, generally fishing, hunting and gathering of foods. However, after the late 19th century intensive reindeer herding was succeeded by an extensive form of herding based on meat production (Hansen & Olsen, 2006; Lantto, 2000; Ruong, 1979). Since then the herds have become larger and fewer people are now involved in reindeer herding. Today all reindeer in Sweden are semi-domesticated and owned exclusively by Sami people (Anon., 2006).

Up until the 18th century the interior parts of northern Sweden were predominately occupied by Sami people. However, from the mid-18th century until the late 19th century forests close to rivers and the larger lakes were rapidly colonized by farmers, mainly as a result of governmental subsidises for settlers, which led to a rapid population increase (Rudberg, 1957; Bylund, 1956).

In the late 19th century forestry was introduced to the vast inland forests of northern Sweden (Östlund, 1993). The start of this large-scale forest exploitation was prompted by the increasing demand for wood from the growing industries in central Europe (Björklund, 1984). Accordingly, a timber frontier swept over the northern forest landscape, initially only targeting the largest trees (Östlund, 1995; Arpi, 1959). This phase in the logging history of northern Scandinavia can best be described as a mining process, and although discussion on sustainable forest management and forest regeneration had begun, no methods were applied to rejuvenate the forest after logging. At the beginning of the 20th century the state of the cut-over forests became a concern for the foresters. Forest management was developed, based on the general idea of sustainably transforming the "wild forest" into a high-yielding domesticated forest (Östlund *et al.*, 1997). Consequently, forest management practices also began to affect the forests during the first part of the 20th century (Östlund *et al.*, 1997; Ebeling, 1955). After the 1950s clear-cutting followed by prescribed burning or manual scarification became the prevailing harvesting and regeneration methods in northern Sweden (Ebeling, 1959). This general development is comparable to trends not only in neighbouring areas such as Finland and Norway, but also in North America.

Land-use effects and legacies in the present forest

Reindeer herding, farming and forestry are in close interaction with the environment and all three forms of land use have been important contributors to the structure and composition of boreal ecosystems in northernmost inland Sweden – but at different temporal and spatial scales. The land use by reindeer herders extended over large geographical regions, but the overall intensity was generally low. Although there has been extensive ecological research on the impact of reindeer on forest and tundra environments (cf. van der Wal, 2006; Stark *et al.*, 2000; Suominen & Olofsson, 2000), little is known about the ecological effects of past reindeer herding activities on the boreal forests. The extent of forest exploitation in pre-industrial times, especially by native people, has been consistently underestimated. One example is the traditional practice by reindeer herders of cutting trees with abundant arboreal lichen cover to provide supplementary food for reindeer. This practice has now been largely abandoned, and the stumps from such cuttings, commonly known as 'lichen-stumps', constitute quite anonymous cultural remains in the few remaining unmanaged forest areas. Therefore the extent and effects of such cuttings have been overlooked.

The spatial extent of farming was minor; less than 1 % of the forest land was transformed to arable land (Östlund *et al.*, 1997). Most agrarian activities, such as cutting of trees for firewood and wooden constructions, were very local while some activities like cattle grazing were spatially much more widespread, but generally of low intensity (Ericsson *et al.*, 2000).

Forestry, on the other hand, has been carried out extensively and today there are very few areas that have escaped logging. The ecological effects of forestry in northern Scandinavia include large-scale changes in forest structure (Axelsson & Östlund, 2001), loss and fragmentation of old forests with subsequent losses of most of the arboreal lichen biomass associated with such forests (Dettki & Esseen, 1998), and overall increases in forest productivity (Elfving & Tegnhammar, 1996). However, forestry has not historically constituted a simple repetitive form of disturbance to the forest. There have been considerable changes in the methods used, the spatial extent and both the species and sizes of trees targeted for logging since modern forestry was introduced ca. 150 years ago. Nevertheless, thorough knowledge of the effects of forestry on the structure and composition of the forest during different time periods is lacking.

The relationship between reindeer herding and forestry is complicated by the overlapping nature of the spatial extent of these forms of land use. Most forests within traditional reindeer herding areas are today owned by forest companies that use the land for timber production (Anon., 2008), and the reindeer herders have the right to graze their reindeer on these lands. Since both the reindeer herders and the forest owners use the same areas, albeit for different purposes, the overlapping use has led to conflicts between the two parties (Sandström *et al.*, 2006; Widmark, 2006).

Objectives

The overall aim of this thesis is to study how land use by reindeer herders and modern forestry has affected the forest ecosystem in inland northernmost Sweden in the past and up to present time, and if and how they thereby have affected each other. The main foci have been two aspects of these activities;

1) The effects of the ancient practice of reindeer herders cutting trees to feed their reindeer with arboreal lichens. The studies of this activity covered a period of ca. 200 years, from the late 17th century until the late 19th century. The history, ecology and extent of this forest use were examined to address the following questions:

- How widespread was this practice? (I)
- To what extent were trees cut for this purpose at a local scale? (I, II)
- How did these cuttings affect the forest? (II)
- When and why did these cuttings cease? (I, II)

2) Modern forestry practices on the forest that has affected winter grazing by reindeer. The development of forests transformed by forestry since the late 19th century, and associated changes in key features for reindeer herders were studied in an area in which winter grazing by reindeer has been very important for a long time. The specific questions addressed were:

- How has the forest structure been affected by forestry during different times? (III)
- What types of forestry practices have been used during different times? (III)
- How has the forest been affected by these practices at a landscape scale? (IV)
- What effects did the various forestry practices have on reindeer winter-grazing, mainly through changing the availability and abundance of lichens? (III, IV, V)

In this thesis I present the results from these studies in a broader context of land use in northernmost inland Sweden and in relation to key political and economic factors during three periods separated by major shifts in land use: 1) the period up until the 1880s before the introduction of modern forestry and large-scale changes in reindeer herding practices; 2) the period between 1880-1950 when forests were mainly selectively logged and reindeer management became more extensive; and 3) the period from the 1950s onwards since the beginning of intensive forest management and modernisation of reindeer herding techniques. I also discuss how diverse scientific methods have been combined to address the questions posed in the studies.

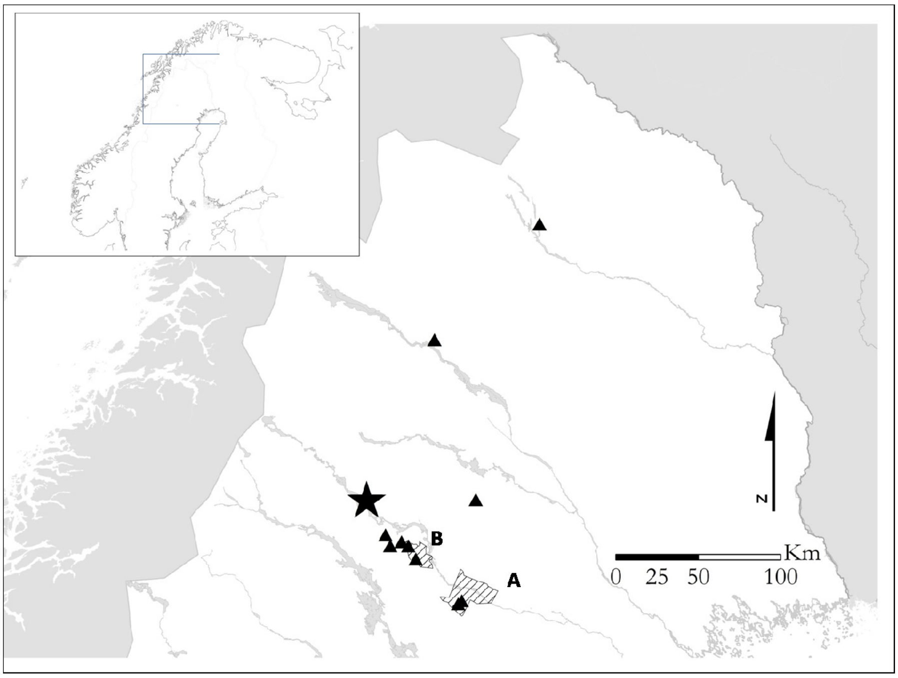

Figure 1. Location of study sites (I-IV) in northern Sweden. The ten areas with lichen stumps surveyed in Paper I is indicated by filled triangles, Tjeggelvas nature reserve (II) is indicated by a star (*)(II), and the areas studied in Paper III and IV are indicated by dashed polygons (A: Akkajaur/Abraur, B: Eggelats).

Environmental setting

The circumpolar belt of boreal forest covers vast areas in North America, Russia and Fennoscandia. The environment in this region is largely governed by its seasonal climate, with short mild summers and long, cold winters. Geographically, the focus of the studies has been on the reindeer herding area in northernmost Sweden within the forest zone, mainly within the county of Norrbotten (Fig. 1). This area stretches from the coast of the Gulf of Bothnia in the east to the Caledonian mountain range in the west where it meets the Norwegian border. The Finnish border is the limit to the north. In northern Sweden snow covers the ground for more than half the year and, accordingly, the vegetation period is short, only 100-150 days/year (SMHI, www.smhi.se). Humans and animals have adapted to the seasonal environment in various ways. Some animals hibernate while others move south during the coldest period. A few animals, such as reindeer (*Rangifer tarandus*) have adapted to feed on the restricted resources that are still available during winter. They survive the winter period by feeding on lichens, which maintain a high content of carbohydrates during this period, when the nutritional value of most other species declines to very low levels (Heinrich, 2006). In winter and early spring lichens constitute as much as 50-80% of reindeer forage (Heggeberget *et al*., 2002; Storeheier *et al*., 2002). Reindeer mainly feed on ground-growing, mat-forming lichens (e.g. *Cladonia* sp.), which they can find under thick snow cover and dig for with their large hooves. Arboreal lichens (e.g. *Bryoria* sp., *Alectoria* sp.) growing on the tree stems and branches, and sometimes falling on the snow, also contribute to their diet during winters, especially when thick or icy snow prevents them from digging (Roturier & Roué, 2009; Helle & Jaakkola, 2008). The number of reindeer in Sweden has varied between 150 000 to 300 000 animals since 1885 (Moen, 2008), the numbers further back in time are extremely difficult to estimate (Anon., 2006).

The forest landscape in northernmost Sweden is dominated by the coniferous tree species Scots pine (*Pinus sylvestris*) and Norway spruce (*Picea abies*), occasionally interspersed with deciduous species, mainly birch (*Betula pubescens*), but also other species, e.g. aspen (*Populus tremula*) and alder (*Alnus incana*). 54% of the forests are pine dominated (>70% pine) (Taxwebb, http://www-taxwebb.slu.se). Only 16% of the forests are spruce dominated (>70% spruce), but spruce commonly grows together with pine and birch. Deciduous trees generally grow intermixed with other species, and also typically in open areas close to water. The forest productivity is generally low with an expected growth of 2-4 cubic meter of wood per ha per year. It also declines gradually towards higher altitudes to the west and towards higher latitudes, and consequently harsher climates, to the north. The lower productivity towards the north-west is also partly due to the generally less fertile soils in these areas since they are situated above the highest coastline (Fredén, 1998). Most of the forest, except the least-productive areas close to the mountains, is used for wood production. The forest reaches maturity from a forest production perspective, and is harvested, at an age of 100-120 years. The ground layer in these forests is generally dominated by feather-mosses such as *Pleurozium schreberi* and *Hylocomium splendens* and lichens such as *Cladonia* spp., *Cetraria* spp. and *Stereocaulon* spp.. The field layer is dominated by dwarf-shrubs, such as *Vaccinium* spp. and *Empetrum* spp., while herbs are infrequent. The majority of people in this area live in the largest cities by the coast and the population decreases towards the west and north.

Figure 2. The study area in Tjeggelvas (Paper II), looking northwards (Photo: Lars Östlund)

Methods

Study sites

Within the larger setting of the study region I have chosen to conduct detailed studies at several sites for different purposes. Sami lichen stumps are rare in the current forest landscape because they have decomposed or been destroyed by modern forestry practices that have affected most forests in northern Sweden (Östlund *et al.*, 1997). To find suitable study sites the county board register of forest reserves was consulted and professionals working in the forests were contacted to acquire information about the distribution of lichen stumps in the current forest landscape. Finally, ten areas with lichen stumps were chosen for the initial study (I). The areas were chosen to cover as large a region as possible to obtain information about the geographical distribution of the lichen tree cuttings. In the second study of lichen tree cuttings (II) we focused on the extent of lichen tree cuttings in time and space, and its legacies on the present forest structure. In Tjeggelvas nature reserve (Fig. 1 and 2) several studies of the historical effects of humans had already been conducted, which had revealed much about the history and land use of humans in the area, but the practice of lichen tree cuttings remained to be analysed (Josefsson, 2009). The extensive background data and the high degree of forest preservation within the reserve, a large continuous landscape of old Scots pine forest virtually unaffected by forestry, made this area ideal for detailed studies of lichen tree cuttings.

The studies of the effects of forestry on the forest within important reindeer herding areas are based on time-sequences of historical documentation of forestry (III; IV). The areas were chosen because suitable archival material was available. The large-scale forest owner Domänverket (today Sveaskog and Fastighetsverket) compiled inventories of its forests, especially the national forest areas, and these documents are usually well preserved and easy to access. After a thorough study of these archival sources, areas covered by repeated inventory material of good quality were chosen. This set of studies was conducted in two steps. In the first study (III), we analysed changes in the forest structure and interpreted the changes in terms of effects upon grazing reindeer. After this initial study, it became apparent that more information was required about the actual effects of logging on the ground-growing lichens, so we performed a field survey of lichen cover in stands with different logging histories (IV). In addition, to visualise the effects of forestry on reindeer herding at a landscape level, we digitized the inventory material used in the study described in paper III for spatially explicit landscape analyses.

Figure 3. Stump remaining from cuttings of trees to feed reindeer with arboreal lichens in Tjeggelvas (II) (Photo: Lars Östlund)

Field surveys

In the studies described in papers I and II the stumps remaining from lichen tree cuttings (Fig. 3 and 4), together with the standing structure of the remaining forest, were surveyed in the field using a well-established approach including both plot and transect sampling (Josefsson *et al.*, 2009; Andersson *et al.*, 2008). The stumps were counted, measured and GPS-positioned in the field. The lichen stumps were identified based on the following criteria: they were tall, thin trunks, compared to the cut stumps left by commercial forestry, and occurred within characteristic clusters of similar stumps. Stumps remaining from early selective logging can also be quite tall, but generally have larger diameters and are not clustered. Moreover, the remains of the cut lichen trees are sometimes visible on the ground. Remains of trees that were cut during the period of selective logging and then found to be rotten may also appear on the ground, but these logs usually have both larger diameters and cut marks on the trunk showing where foresters had checked how high in the tree the rot had extended.

The areas described by the forest inventory material used in papers III and IV were surveyed in the field with the aim of studying the ground lichen cover across sites with different stand characteristics and forest history. Forest stands with different ages and histories were chosen for this purpose, with the help of the inventory material. The cover of ground lichens and stand structure variables, such as basal area, height and age of trees, and canopy openness were measured in field.

Dendrochronology

The seasonal climate in northern Sweden influences the growth of trees, and the seasonal growth variation creates characteristic annual rings in the wood. In addition, the annual growth rate of trees in this region is highly correlated with the summer temperature (Briffa *et al.*, 1992). Thus, the climate creates a similar growth pattern in trees within the same region, and by examining wood samples of different ages, then matching their annual growth patterns, it is possible to build long chronologies of annual rings. Such master chronologies, based on data compiled from several samples, can be used for dendrochronological dating of old wood samples.

Scots pine trees can often reach ages up to 500 years, and their fallen stems are often preserved for hundreds of years in anaerobic environments, such as bogs or lakes (Gunnarson *et al.*, 2003; Grudd *et al.*, 2002). Dead pine trees may also be preserved for hundreds of years in open air, especially at dry sites, because decomposition processes are slow due to the low productivity and harsh climate in northern Sweden. Analysis of pine tree rings has been successfully used for dating wood material in this region, e.g. culturally modified trees (Andersson *et al.*, 2005a; Östlund *et al.*, 2004), and fire events (Niklasson & Granström, 2000; Zackrisson, 1977).

In the studies reported in papers I and II dendrochronological methods were used to date the lichen tree cutting events, using measurements of tree ring widths and cross-dating with master chronologies (Schweingruber, 1988; Fritts, 1976). All samples were measured using a tree-ring measuring station with a resolution of 1/100 mm and TSAPWin software and statistics (LINTAB, Rinntech technologies, www.rinntech.com). Cored samples from living trees were measured and the acquired information was combined with both local chronologies and more comprehensive master chronologies from Torneträsk (Grudd *et al.*, 2002), Tjeggelvas (unpublished) and Lycksele (unpublished).

Historical records

Historical records have been repeatedly analysed in the studies included in my thesis. The analyses in papers III and IV are based on primary historical sources from the Swedish National Forest Service (Domänverket) and recent data (2005-2006) compiled by the current forest owners Sveaskog and Fastighetsverket. The historical records (forest inventories including maps and annual management data) used in these studies provide detailed data on the forest structure relatively far back in time and at a more detailed level than any other source or method can provide. They contain quantitative data on tree species composition, tree age, timber volume etc., and collectively cover the period from 1895 to 2006. These types of sources have been used for various purposes in many similar studies, and have been found to be consistent and reliable for temporal interpretations of forest changes (Gimmi *et al.*, 2008; Gimmi & Burgi, 2007; Axelsson & Östlund, 2001; Burgi, 1999; Östlund *et al.*, 1997). However, careful evaluation of the sources, their origin and quality is essential when working with historical documents of any kind (Whitney, 1994; Cipolla, 1991). When using these kinds of historical records it is especially important to bear in mind that forest management ideas have profoundly changed during the 20th century, and so have the forests. In turn, this has influenced the methods used to compile the forest inventories (Axelsson & Östlund, 2001). Generally, after the shift from selective logging to clear-cutting in the middle of the 20th century there was a corresponding shift in the methods used to record the stands (Östlund *et al.*, 1997), therefore careful interpretation of primary data and re-classification is required when comparing inventories, especially those from before and after this shift. Various records documenting silvicultural measures were also analysed.

In addition, for the studies of lichen tree cuttings (I; II) various historical sources were analysed. The hypothesis was that if lichen tree cuttings had been frequent events, they would have been mentioned by the foresters at the time when the economic value of the forest started to be recognised in the late 19th and early 20th centuries. To assess this possibility I searched various types of archival material, mainly annual reports from the foresters (Jägmästarnas årsberättelser), in which they reported major concerns regarding the forests. Finally, written interviews with reindeer herders from the mid-20th century were analysed for information concerning lichen tree cuttings.

Spatial analysis

To analyze the fragmentation of the forest landscape caused by forestry, the inventory maps used in the investigations reported in paper III were digitized (IV). The effects of fragmentation on lichen abundance were also analyzed. The fragmentation of old coniferous forests was addressed in detail in this study because old coniferous forests provide both important habitats for arboreal lichens (Dettki & Esseen, 1998) and preferred grazing grounds for reindeer (Helle *et al.*, 1990).

Historical land use in the inland northernmost forest in Sweden

Before 1880: Reindeer herders and settlers

Population dynamics

In the mid-18th century the population in the northernmost, inland parts of Sweden was extremely sparse and almost all of the people living there were Sami, making their living from reindeer herding, hunting, fishing and gathering food (Anon., 2006). From the 17th century the Swedish government began attempts to persuade more non-Sami people to move to the interior of northern Sweden, but the agrarian colonization rate remained slow until the mid-18th century (Anon., 2006). Before this time there had been a natural division between Sami reindeer herders, mainly using the interior forests and the mountain areas, and the farmers cultivating the more productive lands by the coast. With increasing colonization these two types of land uses were brought closer together and uncertainties concerning land use rights became evident. Additionally, the differences and conflicting interests between coastal farmers and farmers in the interior became apparent. For clarification concerning land use rights, a border, "Lappmarksgränsen", between the reindeer herding area and the coastal farming area, was established in the 1750s (Anon., 2006).

At this time, increasing the Swedish population became a major political issue in Sweden, and the key was thought to be development of new farming methods and expansion of agricultural lands (Eliasson, 1997). Several new regulations were introduced, allowing people to settle on state forest land and offering benefits for settlers, such as exemption from taxes and military duty. To settle in this region and qualify for these benefits people were obliged to cultivate the land and build houses. The aim was to increase food production to enable the population to grow, and thus increase the potential for deriving taxes from, and controlling, this large but remote region (Lantto, 2000; Eliasson, 1997). This policy was very successful, the population increased rapidly and with time the Sami became a minority. During the 19th century the Sami population slowly increased, and the health status in Sami population's improved (Sköld & Axelsson, 2008). Many Sami, mainly forest reindeer herders, also established settlements during this period. However, some of them continued to make their living, either part- or full-time, from reindeer herding (Lantto, 2000). As the colonization by farmers expanded further towards the mountain region the need for an additional border became apparent, to protect the least productive areas close to the mountain range from colonization and devote this area exclusively to reindeer herders. In 1867 the government decided to establish this border, "Odlingsgränsen", but it would take several more decades before it was finally set.

Forest use by farmers

The increasing population led to new types of land use being introduced and increasing pressure on the resources in this region. Cultivating the land in the region proved very difficult and the farmers also had to rely on a wide variety of activities to make a living. The land use was most intense around the farmsteads, where land was cultivated to various extents (Ericsson, 2001). Areas extending up to tens of kilometres around settlements were used for various purposes, although generally the intensity of land use decreased gradually with distance from the settlement sites. Cattle made important contributions to the livelihoods of most farmers. Mires were used for cattle grazing, especially during spring and early summer. In addition, the mires were used to collect hay for winter fodder. To increase the area suitable for grazing, the forests were repeatedly opened by fires, and the use of fire inevitably changed the fire regime in the region. Generally, the fires became more numerous, but smaller during times of human impact (i.e. 1650-1870) (Niklasson & Granström, 2000). Since fire kills most spruces and young pines it reduces tree density and hence benefits the surviving old pine trees (Wirth *et al.*, 1999). Frequent fires and grazing probably shifted the forest structure towards the relatively opened stands, dominated by large pines, typically found in the 19th century boreal landscape (Linder & Östlund, 1998; Östlund & Linderson, 1995).

Another type of land use by farmers that had a substantial affect on the forest was the collection of firewood (Östlund, 1993). Predominantly dead trees were used for this purpose, and sometimes trees were girdled to increase the amount of suitable firewood (Ericsson, 2001). Another activity by farmers that affected the forest, especially the pine-dominated forest on the sedimentary soils along the major rivers, was tar production. Local tar production was an important source of income for the farmers and for linking the local economy with the outside world (Borgegård, 1996). During the 18th century, tar production spread to the northern parts of Sweden along with the increasing population and developments in the infrastructure and, during the 19th century, the northern parts of the country became the main area of tar production (using pine trees and stumps as raw materials). Since transport was difficult the tar pits were located in places near to sources of the raw material, and as close as possible to the farmsteads. Tar production affected the nearby forest substantially, but the effects were generally restricted to a few kilometres around villages. Potash production was another additional source of income for farmers, but it was not as common as tar production (Östlund, 1996). Potash is a substance primarily made from wood of deciduous trees, and is used e.g. in glass and soap production. In northernmost Sweden, potash production was restricted to a 50-year period in the beginning of the 19th century, and mainly located in the lower parts of the main river valleys and around a few villages in the interior. All these agrarian and pre-industrial activities affected the forests across small-scale and large-scale gradients in the landscape. Areas around settlements were intensively used, but the majority of the forest was still at this time only marginally affected by people.

Forest use by reindeer herders

Reindeer herding was variable in several respects during this period. For example, some families owned a few dozen animals, while a few rich herders owned more than a thousand (Anon., 2006). During the 18th century, ca. 30-50 female reindeer, corresponding to a herd of ca. 200 reindeer in total, were considered enough to provide a Sami family with milk products (Lundmark, 1982). To provide a whole family with meat the herd had to be somewhat larger. During a week, 4-6 persons could feed on the meat from one reindeer (Lundmark, 1982). However, most Sami families did not solely rely on reindeer herding, but also made their living from hunting, fishing and gathering food, and hence had much smaller reindeer herds. All reindeer herders had a more or less nomadic lifestyle, moving between different areas to use different resources. Essentially, there were two main types of herding systems, one practiced by the mountain herders and the other by the forest herders. The mountain herders generally travelled long distances between the coastal and mountain regions with large herds, while the forest herders had fewer reindeer and moved within the forest (Anon., 2006). Forest herders were especially dependent on additional activities for their livelihoods (Lantto, 2000).

Reindeer affect the forests in numerous ways. For example, by grazing, trampling and depositing manure they affect below-ground processes, such as microbial activity and nutrient cycling (Stark *et al.*, 2003; Stark *et al.*, 2000; Väre *et al.*, 1996). The composition of the understory vegetation is also affected by reindeer grazing, generally promoting increases in the abundance of bryophytes at the expense of lichens (den Herder *et al.*, 2003; Väre *et al.*, 1996; Väre *et al.*, 1995). Furthermore, grazing by reindeer has been found to impair the regeneration of pine (Roturier & Bergsten, 2006; den Herder *et al.*, 2003), but increase the growth of pine trees (Fauria *et al.*, 2008). However, all these effects are highly context-dependent, and vary with regards to the forest type (Fauria *et al.*, 2008), the density of reindeer and the season. Since the numbers and movements of reindeer further back in time than the 1880s have been extremely difficult to estimate (Moen, 2008; Anon., 2006; Lundmark, 1982), the history of the abovementioned effects of reindeer on forests is challenging to assess.

Lichen tree cuttings

Snow conditions strongly influence the availability of ground lichens, so winters with especially extensive snow cover or ice crusts can be devastating for reindeer populations (Miller & Barry, 2009; Vitebsky, 2005). Today, reindeer are fed with hay or pellets and feed on lichens growing on tree stems and branches or falling from the trees during such periods. One of the hypotheses in our studies was that cutting of lichen-covered trees was a traditional practice to provide supplementary feed for reindeer during winters with extremely adverse snow conditions (I). However, subsequent analyses showed that the situation was more complex: lichen-covered trees appear to have been cut under three different types of conditions (I, II). First, as we hypothesised, lichen trees were cut when ice crusts formed or the snow cover was exceptionally deep, preventing reindeer from grazing the ground. At these times areas with thin, easily cut trees with a high abundance of arboreal lichens were chosen and many trees were cut in the same place (Rensund, 1982), resulting in areas with many thin stumps. Second, lichen trees were cut during short stops when travelling. On these occasions, features other than the availability of easily cut lichen-rich trees may have been important when choosing spots, and only a few, sometimes larger, trees were cut. In the third kind of cases, lichen trees appear to have been cut repeatedly during a prolonged period (Fig. 5)). This seems to have occurred in Tjeggelvas nature reserve (II), where lichen stumps could be analysed in a large area undisturbed by modern forestry, and datings of lichen-tree cutting events did not show any spatial or temporal patterns supporting the initial hypothesis. Instead, they seem to have been cut repeatedly at scattered sites over a period of almost 200 years.

Figure 4. Characteristic high stumps with logs still present on the ground; remains from lichen tree cuttings in Sjaunja nature reserve (Paper I). The trees were cut in the 1930s. (Photo: Anna Berg)

The practice of cutting lichen-rich trees was noted by Carl von Linnaeus during his travels during the early 18th century (von Linné, 1732), and some of the cutting events we detected appear to date back even further, to the late 17th century (II). Most likely this practice originated even further back in time. When reindeer herding became the major means of subsistence for the Sami, keeping their reindeer herds alive and healthy became essential for the survival of these people, hence much time and effort was invested in this (Lundmark, 1982). Lichen trees provided food for reindeer and at the same time a way of keeping the reindeer together, which was essential to protect the animals from predators. In addition to predators, ice-crusts in the snow preventing reindeer from digging were major threats to the reindeer herds.

Evidently, during times with such conditions the herders had to do everything in their power to help the reindeer survive, and hence secure their own survival. In addition to cutting lichen trees they also helped the reindeer to dig through the snow with a special shovel-shaped ski pole, and they manually pulled down arboreal lichens from standing trees (I).

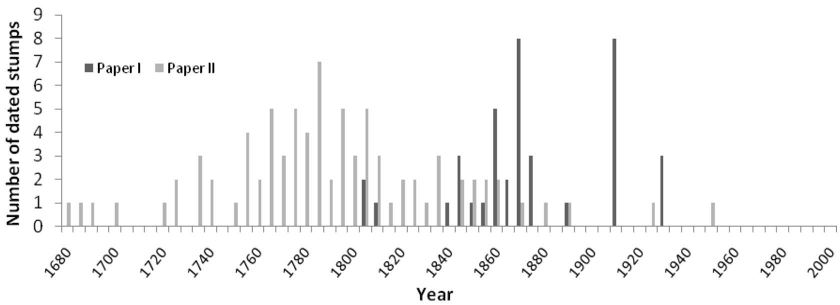

Figure 5. All dated lichen stumps examined in studies reported in papers I and II.

Due to forest fires up until the late 19th century, the widespread use of heavy forestry machinery during the 20th century, and also natural decomposition of wood, most lichen stumps have disappeared with time. Only pine stumps were found in the search for lichen stumps across the interior parts of northernmost Sweden. This was despite the fact that spruces were more frequently cut for lichens according to historical records and old literature (I) (Rensund, 1982; Pettersson, 1979; Cajanus, 1977; Manker, 1947; Manker, 1931; Drake, 1918). However, spruce wood decomposes faster than pine wood (Alban & Pastor, 1993), thus spruce stumps have disappeared to a greater extent.

Tjeggelvas was an ideal site for a case study of the extent of lichen tree cuttings. Since pine was virtually the only tree species available in this area only pine trees had been cut. Furthermore, the area has been largely unaffected by modern forestry, greatly increasing the probability of finding culturally modified trees in the forest (Andersson & Östlund, 2004). Hence, the majority of stumps could be expected to have been preserved. We found that stumps from a period of ca. 200 years, from the late 17th century to the late 19th century, were still present in the landscape. A large-scale inventory of cultural remains in Tjeggelvas had already shown that most lichen stumps were limited to an area north of an old settlement (Josefsson, 2009), hence the study was confined to this area (II). The study revealed that more than three fifths of this area had been affected by lichen tree cuttings. The stumps were found in clusters with stump densities ranging from five to 150 stumps/ha, with an average of eight stumps/ha. These patterns and numbers were similar to those found in the areas considered in paper I; where clusters of various sizes typically contained 10-30 stumps per hectare but, in extreme cases, more than 100 stumps/ha were also found.

Josefsson et al. (2009) analysed the overall effects of Sami forest use in Tjeggelvas at a landscape scale and compared the area considered in paper II (where there are abundant lichen stumps) and the surrounding forest (where there are far fewer lichen stumps), and found that the forest in the area with high stump density was significantly younger, and had a higher stem volume and basal area. However, in the study reported in paper II, in which lichen tree cutting was analyzed at higher resolution, no significant differences in forest structure between plots with different densities of lichen stumps were found. The differences observed by Josefsson et al. (2009) were probably combined effects of higher grazing pressure and more abundant lichen-tree cutting in the area with abundant lichen stumps. Grazing reindeer affect the forest in various ways. For example the removal of the lichen mat by reindeer has been found to enhance tree growth in northern Scots pine forest (Fauria *et al.*, 2008), hence the reindeer grazing may have had a positive effect on tree volumes.

Although the analysis of lichen stumps has provided very useful insights into the practice of cutting lichen trees, the extent of lichen tree cuttings at a landscape level cannot be fully understood by analysing the remaining lichen stumps, simply because most stumps have disappeared. Also, since this practise almost has been forgotten, and the stumps do not provide obvious or remarkable cultural remains, they have largely been neglected in archaeological field surveys of cultural remnants in northern forests. This is a parallel to other types cultural remnants in forests, such as bark-peeled trees (Östlund *et al.*, 2002). However, the literature and historical archives provided additional useful information about such practises. Lichen tree cuttings during harsh winters are frequently mentioned as a common practice in the old literature (Rensund, 1982; Pettersson, 1979; Cajanus, 1977; Manker, 1947; Manker, 1931; Drake, 1918; Laestadius, 1831; von Linné, 1732). Several sources describe the cutting of lichen trees as being a time-consuming activity, which required everyone available who could handle an axe to cut trees all day (Rensund, 1982; Pettersson, 1979; Drake, 1918; Laestadius, 1831). A considerable number of trees could be cut down in one place under such conditions. One or two trees were cut every day for each reindeer (Pettersson, 1979; Blomqvist, 1959), for as long as the ground forage was limited or until it was possible to find better grazing elsewhere.

Conflicting forest use by farmers and reindeer herders

The increasing colonization by farmers progressing towards the west, mainly driven by national policies, brought these two forms of land use and two differing societies closer together. Initially the colonising farmers were not thought to conflict with the reindeer herders since they were assumed to use the lands in different ways (Lantto, 2000). However, the environment in this area did not allow farmers to survive solely on traditional farming techniques since cultivation of the lands proved extremely difficult. Instead, they became dependent on other activities, such as fishing and hunting, thus exploiting resources traditionally used only by the Sami. Farmers also became dependent on extensive areas around their settlements to obtain enough food for their cattle. Conflicts concerning land use arose between settlers and reindeer herders during the 19th century (Lantto, 2000). A frequent source of conflicts was reindeer feeding on the hay farmers had collected for their cattle to feed on during winter (Anon., 2006). Farmers left the hay on drying-racks in remote meadows after harvest and waited for the snow cover to be deep enough to travel on before they collected it. When the reindeers passed these places during migrations to their winter pasture lands, the collections of hay were an easily available food resource. On the other hand the farmers' use of fire to improve the grazing for their cattle was a concern for the reindeer herders since the fire destroyed the lichen pastures (Cajanus, 1977).

The uses of the forest by farmers also aroused concern among the authorities at the end of this period (Borgegård, 1996). Official investigators of the state of the forests in northern Sweden came to the conclusions that the forests were in a very poor condition and that the forest use, e.g. by farmers, would soon result in total depletion of the forests (Anon., 1871). While this was a gross exaggeration, it mirrors the view of forest use by farmers as being extremely extensive and destructive, in contrast to the view of forest use by Sami, which was considered to be negligible, in accordance with the general view of Sami culture during this period, as being less developed than the culture of farmers and, especially, industrialized societies (Lundmark, 1982). Since the level of development of nomadic Sami culture was thought to be very low it was assumed that their effects on the forest were minor, and consequently the forest use by these people was not even considered worthy of further investigations. Thus, we found no evidence of complaints by foresters about the cutting of lichen trees (I). This view of the low impact of forest use by Sami was probably derived from eye-witness observations, but it did not necessarily provide the whole truth since the land use by Sami was not as obvious to authorities as the land use by farmers.

The effects of forest use by farmers, e.g. logging for firewood and tar production, could be substantial around farmsteads, and their settlement sites can be seen as "cultural islands" surrounded by vast forest areas (Ericsson, 2001). These islands were obvious to people travelling in northern Sweden at this time, since they sharply differed from the otherwise continuous forest landscape. Sami forest uses (e.g. logging for firewood, harvesting pine inner-bark and cutting lichen trees) could also be discerned around settlement sites (II; (Östlund *et al.*, 2003), but since the reindeer herders moved between settlements during different seasons and rarely stayed close to each other this effect never became as substantial as around farmsteads and villages. The effects of land use by Sami have nevertheless accumulated over a longer time, and it has been shown that this type of low intensity use over vast areas during long periods of time had substantial, persistent effects on the forest (Josefsson, 2009). If the farmers created "cultural islands", the effects of Sami land-use around settlements can be viewed as "cultural reefs" between these islands, nearly rising over the surface of mostly continuous forest canopies, and therefore difficult to discern.

1880-1950: European industrialisation reaches the northernmost parts of Sweden

Large-scale changes in Sami society

During the latter part of the 19th century northern Sweden was in a state of rapid development. The process of colonisation intensified and reached even further inland, utilising even more of the traditional grazing areas for reindeer (Hultblad, 1968; Bylund, 1956). This development was driven by economic and political factors. The first laws concerning reindeer herding were passed during the 1880s, e.g. regulating the organisation of reindeer herders to work collectively in reindeer herding districts, the rights to use different lands for pasture and the obligations reindeer herders and farmers had towards each other. Reindeer herding was also declared to be an exclusive right of the Sami (Anon., 2006). In the late 19th century the politicians' view of the Sami was largely influenced by the general idea that societies inevitably evolve from hunter-gatherers to nomads, to farmers and (finally) fully industrialised communities (Lantto, 2000). Politicians during this period were concerned with "saving" the Sami from their nomadic way of life, so they could "develop" to become farmers in order to avoid their extinction. Around the turn of the century this view changed completely, and serious efforts were made instead to conserve the Sami's nomadic lifestyle. It became clear to the authorities that cultivating these northernmost interior parts of the country was never going to be the best way of using these lands. Instead, the reindeer herding and nomadic lifestyle was recognised as being the most suitable way of living in this environment, especially for the Sami people. Several political actions were taken in the early 20th century to encourage reindeer herders to continue their nomadic lifestyle. For example, special schools were arranged for their children, with the intention to give them "a fair amount of education" but avoid them acquiring "a taste of the comfortable life in permanent settlements because then they would be weakened and refuse to return to being nomads" (Lantto, 2000).

International politics among countries within the Sami region also came to substantially affect the reindeer herders (Anon., 2006). Before the mid-19th century the national borders did not really constitute any hindrance for reindeer herders migrating in this region, but in 1852 the border between Norway and Finland (which belonged to Russia at that point) closed. This resulted in many reindeer herding families moving from Norway to Sweden with their herds, in order to be able to continue to migrate to Finland, since the border between Sweden and Finland was still open. This increased the grazing pressure substantially in some areas in northern Sweden, which led to a deterioration of relations between Sweden and Norway, so in 1883 a law regulating the reindeer herders' movements between these countries was passed. By 1889 the border between Sweden and Finland was also closed. At this point many of the Norwegian reindeer herders moved back to Norway. Many also stayed in the northernmost part of Sweden, and yet others moved with their reindeer herds further south to other areas within the reindeer herding region, to areas already utilized for reindeer herding. This could be considered the start of the large-scale dislocation of reindeer herders from the north to more southern parts of the reindeer herding district in Sweden, which continued until the 1920s, driven by political decisions at multiple levels (Ruong, 1979).

The reindeer herders in northernmost Sweden practiced a more extensive form of herding, involving larger herds that were less intensively attended and spread over larger areas. This type of herding was primarily aimed at meat production. Although there was widespread scepticism among the reindeer herders in the south about these new methods initially, the extensive system proved to have many benefits and fitted well with general social developments, thus with time it became the dominant type of herding (Lantto, 2000; Ruong, 1979). Since the extensive type of herding is primarily aimed at producing meat, for which there was a market, this type of herding also fitted well with trends towards a money-based economy. The shift to more extensive herding led to large-scale changes in the Sami's way of life. As less people were needed to attend the reindeer, some family members, usually women, abandoned reindeer herding and settled down.

The changes in the reindeer herding society resulted in many traditional practices being abandoned in the late 19th century, such as milking reindeer and collecting pine inner bark (Zackrisson *et al.*, 2000; Ruong, 1979). The cutting of lichen trees also ceased at this time (Fig. 5; I; II). When the herds became larger, more freely roaming and tended by fewer people, it became too time-consuming and impractical to feed the reindeer in this manner. Furthermore, in the first Swedish regulations of 1883 concerning reindeer herders, the use of trees was regulated and reindeer herders were only allowed to cut trees for household requirements – preferably dead or deciduous trees and no healthy coniferous trees (Cramér & Prawitz, 1970). However, in 1923 a paragraph was added to the law which allowed them to cut lichen-rich trees if it was absolutely necessary to feed the reindeer, and this paragraph is still included in the latest version of the law (Anon., 1971).

Beginning of large-scale timber exploitation

The increasing concern about the forest during the late 19th century was mainly due to the increasing value of timber, which made it profitable to export timber even from the remoter forests in northern Sweden. The timber price increased 3-4 fold in the early 1870s (Holmgren, 1959), largely as a result of an expanding sawmill industry starting in the 1850s (Arpi, 1959). The initial logging can be described as a timber frontier that swept across the country, targeting the largest pine trees and progressing northwards (Östlund, 1993). At this time the timber transport was dependent on floatable streams (Törnlund & Östlund, 2002) and consequently the frontier generally moved from south to north, and from the coast up the major rivers. At the end of the 19th century the logging frontier thus really started to the important winter grazing areas for reindeer. Developments in the areas studied in the investigations reported in papers III and IV were consistent with these general trends. In Akkajaur/Abraur (Fig. 1) a minor proportion of the forest was logged before the initial inventory in 1895. However, the forest at Eggelats, which is located further northwest, was still not affected by logging at this time, at which the river Piteälven had only been prepared for floating up to Akkajaur/Abraur. At the time of the following inventory in 1926 Eggelats was still reported as being less affected by logging than Akkajaur/Abraur. After the initial frontier had removed all the largest pine trees, also smaller trees and spruce were targeted as the pulp mill industry grew.

The logging in northern Sweden was primarily selective until the 1950s (III). Selective cuttings reduced the standing timber volume to lower levels than those in forests primarily shaped by natural disturbance factors (Myllyntaus & Mattila, 2002; Linder & Östlund, 1998). The forests became increasingly sparse, and the regeneration of trees in such forests was very poor. Before the turn of the 20th century the forests were exploited with no concern for their future or regeneration (Holmgren, 1959). However, the desire to develop sustainable forest management practices to secure long-term timber production grew during the first part of the 20th century. In 1902 the first forestry research institute was established and in 1903 the first Swedish forestry law was implemented, aiming to ensure sustainable re-growth of the forest. However, the majority of the reindeer herding region was not covered by this law. In 1932 a new law (Sw. "Lappmarkslag") was passed, which further regulated the use of forest in this region, and from that time the forest owners were obliged to ensure re-growth after logging. However, since the profitability of forestry in this region was generally quite low, regeneration actions were not required if they were considered too costly.

During the first part of the 20th century modern forestry practices, e.g. non-commercial thinning, soil scarification and sowing, were tested and introduced at a small scale in our study areas (III) and other northern Swedish forests (Östlund *et al.*, 1997; Holmgren, 1959). The soil scarification methods used during this period were generally very gentle and only slightly disturbed the ground vegetation (Holmgren, 1959). Prescribed burning of clear-cuts was also trialled as a way of improving the re-generation of trees. However, the use of fire met resistance from the public and forest employees. Before the beginning of modern forestry forest fires had been widespread. Although fires generally did not consume all the trees, they killed young trees, created scars in the wood and consumed the humus layer. Therefore, fire was considered a threat to forestry since the timber value rose in the late 19th century, and extremely successful fire suppression measures have been applied ever since (Hellberg *et al.*, 2004; Niklasson & Granström, 2000; Zakrisson, 1977).

Forestry and reindeer herding interactions

The increasing concern about the low level of forest regeneration led to foresters in the reindeer herding region becoming increasingly worried that grazing reindeer would devastate the young tree seedlings, and the first conflicts between reindeer herders and forestry arose around this issue. These conflicts became more common than the conflicts with farmers during the beginning of the 20th century. In the 1920s a commission was established to investigate the effects of reindeer on the regenerating forest, which found that their effect was negligible (Anon., 2006). Despite that finding, the effects of grazing reindeer on tree seedlings have continued to rise concerns and further investigations have been made. However, the destruction of seedlings by reindeer grazing has repeatedly been found to be of minor importance (Anon., 2006; Roturier & Bergsten, 2006).

The densities of reindeer herds are a major factor influencing the extent of their effects on the environment (Kumpula, 2000). The large-scale changes in the reindeer herding society do not seem to have resulted in any clear changes in the numbers of reindeer within the reindeer herding region, since there have been no general increases or decreases in reindeer numbers since the late 19th century. Instead, the reindeer numbers in Sweden have fluctuated between 150 to 300 thousand animals during this period (Moen, 2008). The fluctuations have been caused by several factors; harsh winter conditions have been the most important, but diseases, reductions in meat prices and political decisions have also contributed. The forced dislocation of reindeer herders also changed the numbers of reindeer grazing in different areas during different times, and hence the impact of reindeer on the environment has been locally altered.

A change in the forest use by Sami people that accompanied the changes in herding techniques and overall modernization of Sami society was the abandonment of traditional forest uses of trees, like harvesting of pine inner bark (Zackrisson *et al.*, 2000) and lichen tree cuttings (I; II). While substantial amounts of trees had been cut for lichens, the harvesting of bark did not kill the trees, but it created scars that adversely affected their wood quality. Both of these practices ceased at the same time as the introduction of forestry in the beginning of the period, thus the effect of Sami forest use decreased during this period, and did not cause any concern for foresters.

Before the beginning of this period, the forests in the region were largely unaffected by large-scale timber exploitation, except along the major rivers and in the close vicinity of settlements (Holmgren, 1959). The waves of selective cuttings that repeatedly swept through the forest generally reduced the standing volume and the mean age of the trees (III; (Linder & Östlund, 1998). However, continuous forest with a multi-layered structure was generally maintained during the first waves of cutting, at least at a landscape level (III; IV; (Axelsson, 2001). All types of logging reduce the amount of arboreal lichens, which as discussed above is an important food source for reindeer, simply because the substrate of arboreal lichens is removed (Dettki & Esseen, 1998). However, in paper IV it is argued, in accordance with Essen et al. (1996), that selective cuttings did not severely affect the long-term availability and dispersal of arboreal lichens, since continuous cover of trees with arboreal lichens was left that could provide sources for dispersal.

Logging also affects ground-growing lichens, since it influences several key abiotic variables, notably light availability and moisture levels, that strongly affect their growth (Jonsson Čabrajić, 2009; Arnström, 1975). During the period of selective logging the forests became more open, which probably favoured lichen growth, at least in dry sites (III), since open forests with abundant old trees have been found to generally have greater lichen cover than denser forests (Pharo & Vitt, 2000). However, in moist sites increasing light availability may benefit faster-growing vascular species which will compete with the lichens. Logging residues and dead wood were commonly left on the ground after cutting during this period, which constituted a physical obstruction for reindeer foraging (Eriksson, 1976). Furthermore, when logging residues are left on the ground at dry sites reindeer lichens are usually reduced in abundance (Bråkenhielm & Liu, 1998; Olsson & Staaf, 1995; Bråkenhielm & Persson, 1980).

The suppression of forest fires during this period was another factor associated with the growing forestry industry that most likely affected the lichen abundance at a landscape level (III). Since ground-growing lichens are often totally consumed by fire and lichens mainly disperse by fragmentation, their re-colonization after fire is slow. In Canada, reindeer lichen has been found to establish c.10 years after fire (Webb, 1998), and then increase until peaking 40-120 years later (Thomas *et al.*, 1996; Morneau & Payette, 1988; Kershaw, 1976; Ahti, 1959). Webb (1998) found that 15-16 years after fire the cover of reindeer lichens was on average 5.3% in burnt sites compared to 25.2% in reference sites. On the other hand, repeated fires are essential for lichen to be abundant in some types of sites. For example, many pine-dominated stands with abundant lichens in the ground vegetation have developed after severe forest fires on moist soil types that have reduced the soil nitrogen level. In these types of stands, succession will eventually lead to more productive vegetation, and thus reductions in lichen abundance (Ebeling, 1978). Another example was described by (Hörnberg *et al.*, 1999), who found that fire had been an important factor causing the depletion of soil nutrients, thus creating Norway spruce-dominated stands with abundant lichen cover. The lichen cover has also been found to decrease with stand age in old pine forests on dry sites (Lähde & Nieppola, 1987; Bråkenhielm & Persson, 1980). These observations indicate that lichen abundance was probably positively affected by the active fire suppression policy initially, since it gave lichen more time to regenerate. However, from a long-term perspective, succession in moist, fire-suppressed, lichen-rich stands will lead to increasing nutrient levels, closure of the canopy and eventually to lichens being out-competed by dwarf-shrubs (Ebeling, 1978).

In the beginning of the 20th century the colonial attitudes of the authorities, introducing laws about how the Sami should perform their reindeer herding, laws which the reindeer herders thought were mostly beneficial for the farmers, together with the increasing competition with farmers on the lands, led to the beginning of political mobilisation among the Sami (Lantto, 2001). However, forestry and other types of exploitation of the natural resources, such as the construction of hydroelectric power stations and mining, does not seem to have been a major concern for the reindeer herders during this period, at least not to an extent leading to political activity (Lantto, 2001). This is probably because forestry during this period was conducted in a way that did not adversely affect conditions for reindeer herders to any major extent (III). On the contrary, forestry may in some ways have been beneficial from the reindeer herder's points of view, since the cuttings created more open forests, and especially since forestry was accompanied by efficient fire prevention. Forest fires had been a concern to the reindeer herders for several decades since they destroyed the lichen pastures, a concern that arose concurrently with the increasing colonisation of farmers who commonly used fire to improve grazing for their cattle (Ericsson, 2001). Reindeer herders sometimes even argued that farmers set fire to the forest around their farmstead deliberately to keep the reindeer away (Cajanus, 1977). Reindeer herders considered the farmers who settled closer to the mountain region as their major competitors for the land during this period.

After 1950: Efficient forest management and extensive reindeer herding

Forest management in transition

From the mid 20th century, forestry methods and ideas changed radically. Intensive forest management started, including clear-cutting as the main logging method, and the selective logging techniques were largely abandoned, especially on state forest land in northern Sweden (Östlund *et al.*, 1997; Ebeling, 1959). From this point onwards, clear-cutting was considered to be the most cost-efficient way of conducting forestry and ensure re-growth after logging, especially in northernmost Sweden. Consequently, this method has dominated. In the areas examined in our studies, this change was clearly apparent as recent clear-cuts covered c. 40 % of the forest area at the forest inventory in 1960 (III, IV). New efficient machinery was developed and increasingly used to handle the cuttings and facilitate transport; consequently less people were required in forestry.

Silvicultural measures to ensure regeneration had begun during the first part of the 20th century (Holmgren, 1959), but their usage expanded to a large scale by the 1950s (Östlund *et al.*, 1997; Ebeling, 1959). Planting became a necessity to assure good regeneration in the clear-cut areas, and planting of tree seedlings increased concurrently with the use of clear-cutting (III). To improve the rate of successful establishment of both planted and naturally regenerated tree seedlings, site preparation techniques were used. The most common treatment was soil scarification of various kinds, where the top soil was turned over to expose the mineral soil. This influences a number of factors, such as soil temperature and moisture, nutrient cycling, light availability and competition between species, and consequently promotes the development and growth of plants. In 1976 Domänverket recommended three types of soil scarification methods: mounding and disc trenching in dry to moist sites and ploughing for soils with thick, inactive humus layers (Anon., 1976). In Akkajaur/Abraur soil scarification was applied to an average of 0.04% of the forest area per year during the period 1938-1953, increasing to 0.39% of the forest area per year during the period 1977-1984 (III). Prescribed burning was another common site preparation method. In the areas considered in paper III, prescribed burning was applied from 1947 until at least 1963. According to the major forest owner, Domänverket, prescribed burning was mostly used at moist sites with a thick layer of raw humus (Anon., 1976). After 1970 prescribed burning was almost completely abandoned in favour of scarification methods, but was then reintroduced as a tool to improve biodiversity in the late 1990s.

Various thinning methods to partially harvest the forest and to improve the growth of the remaining trees were initially used at the beginning of the 20th century, but their use expanded in the 1950s. Thinning made the forests more open, but usually only for a short while, since it left large trees with high growth potential (Anon., 1976). Another way of increasing tree growth has been to fertilize forests with nitrogen, since readily available nitrogen often limits the growth of trees in boreal forests. According to Östlund et al. (1997) nitrogen fertilization was used approximately from the 1970s to the 1990s in a nearby area on state forest land. The economic value of deciduous trees was limited during the mid-20th century, hence deciduous trees were treated as weeds, and were removed with various chemical treatments, predominantly during the 1950s and 1960s in our study areas (III).

The modern, efficient form of forestry has had far-reaching effects on the forest structure and composition since it began in the 1950s. The switch from selective logging to clear-cutting has fragmented the forest landscape during this period, turning it from a landscape of old multi-storied forest into a patchwork of even-aged forests (IV; (Lofman & Kouki, 2003; Axelsson, 2001). Forestry roads and ditches have further increased the degree of fragmentation (IV; V). The productivity and standing timber volume has increased during the last century (III), but the component of deciduous trees has decreased (Östlund *et al.*, 1997). Furthermore, modern forestry has not only affected the trees, but also other forest organisms. A group of organisms that has been largely negatively affected by modern forestry is the arboreal lichens (IV; (Dettki & Esseen, 1998). The overall biological diversity has also been reduced, especially for species associated with dead wood (Gärdenfors, 2005; Siitonen, 2001).

Modernisation of reindeer herding

The form of reindeer management has also changed during this period, although many traditional features of reindeer herding are still maintained. Increasing mechanization and new techniques have facilitated several aspects of reindeer herding, particularly since the 1970s. For example, snowmobiles started to be used for transport. In addition, all-terrain vehicles are used to move around in the landscape during the snow-free period, helicopters are increasingly utilized to gather and keep track of reindeer, and occasionally reindeer herds are moved between grazing grounds by trucks. GPS and GIS have also been increasingly used by reindeer herders recently, as tools to keep track of reindeer and plan usage of grazing resources (Sandström *et al.*, 2006). Although reindeer are still mostly fed on natural grazing grounds and the traditional movements of reindeer between suitable grazing areas has been maintained, hay and pellets have been increasingly used in recent decades too, mainly as famine foods during extreme weather events. However, supplementary feeding is not an easy solution to sudden adverse changes in snow conditions, since the reindeer need time for their bacterial flora to adapt to the change in food from lichens to hay or pellets (Nilsson *et al.*, 2006; Nilsson *et al.*, 2000). In Finland, supplementary feeding has been used more widely and regularly, leading to increasing populations of reindeer, and in turn large-scale problems with overgrazing of the lichen resources (Kumpula, 2000).

Consequences of changing forestry practices on reindeer herding

The intensive forest management practices have also had far-reaching, predominantly negative, effects for the reindeer. The arboreal lichen biomass has decreased substantially since the introduction of modern forestry, especially since clear-cutting became the prevailing logging technique (IV; (Dettki & Esseen, 1998; Esseen *et al.*, 1996). In clear-cuts the substrate of the arboreal lichens is removed and the long distance between trees with arboreal lichens makes the re-colonisation process slow, since they mainly disperse by fragmentation. Maximum tree lichen biomass is reached at a stand age of ca. 150-200 years (Dettki & Esseen, 1998), substantially more than the c. 100-120 years rotation times of forests in this area.

The effects of forestry on the ground-growing lichens are more complex (III, IV, V). Clear-cutting effects on ground-growing lichens depend on forest type. In mesic forest types that generally have a small component of lichens in the ground layer, the grass *Deschampsia flexuosa* commonly dominates after clear-felling. At dry sites, ground-growing lichens are usually common in the ground layer and may expand after clear-cutting since light conditions improve and competing mosses die (Bråkenhielm & Liu, 1998; Olsson & Staaf, 1995; Kardell & Eriksson, 1992; Nieppola, 1992; Bråkenhielm & Persson, 1980). However, from the reindeer herders' point of view, the potential benefit of an increase in lichen abundance after clear-cutting is overshadowed by other factors. Notably, they perceive clear-cutting of forests to cause serious impediments to reindeer grazing because of its adverse effects on the snow cover and thickness (Roturier & Roué, 2009). They commonly compare clear-cut areas with the mountain areas above the tree-line, which they abandon during the winter because the lichens are made inaccessible by densely packed snow. The snow cover is less deep in the forested areas than in adjacent clear cuts, because in the forest much of the snow is trapped by the trees (Jost *et al.*, 2007; Lofvenius *et al.*, 2003). Another negative factor is the increase in the amount of logging residues left on the ground, which hamper the lichen in favour of mosses (Bråkenhielm & Liu, 1998; Olsson & Staaf, 1995; Bråkenhielm & Persson, 1980) and hinder the movement of grazing reindeer (Helle *et al.*, 1990). Furthermore, the fragmentation of the landscape by clear-cutting has generally hindered reindeer movements across the landscape, although the building of forestry roads has in some cases facilitated transport for reindeer herders (V).

Another forestry practice that affects the reindeer is soil scarification, which has major, immediate negative effects on reindeer herding since it strongly reduces the coverage and volume of ground lichens. In the areas considered in paper IV the cover of ground-growing lichens was significantly lower in recently clear-cut areas than in older forests. The degree of soil disturbance and the effects on ground lichens and their re-colonization depend on the scarification methods used (Roturier, 2009). The scarification method most commonly applied in lichen-rich, pine-dominated sites is harrowing. The proportion of disturbed vegetation and amount of exposed mineral soil after harrowing is 45-55% (Roturier & Bergsten, 2006; Eriksson & Raunistola, 1990), and the effects may last for decades (Roturier & Bergsten, 2006). In addition, reindeer seem to avoid grazing in areas with exposed mineral soil (Roturier, 2009).

Prescribed burning also substantially affected the ground vegetation as forest fires commonly consume most of the ground lichens (Perevoznikova *et al.*, 2007; Webb, 1998). The cover of lichens fully re-establishes only 40-80 years after burning (Kumpula *et al.*, 2000). However, from a long-term perspective fires are necessary to keep lichen abundance in the ground layer at high levels as the lichen cover has been found to decrease with stand age in old pine forests on dry sites (Lähde & Nieppola, 1987; Bråkenhielm & Persson, 1980).

The effects of modern, intensive forestry practices on the forests during the last 60 years have largely been negative for reindeer herding. In paper III we argue that 30-50 percent of the suitable winter grazing grounds in our study area have been lost or severely degraded since the 1950s due to intensified forestry. This estimate agrees with figures from the National Swedish Forest Survey showing that the amounts of lichen-rich grounds have declined by ca. 50 % during the last 50 years (Sandström *et al.*, 2006). Accordingly, reindeer herders consider clear-cut areas as very poor winter forage areas (Roturier & Roué, 2009), and they assert that forest reindeer grazing resources are declining (Anon., 2006; Widmark, 2006). Since the densities of reindeers have not substantially changed during the same period, the decreasing amount of lichen grazing grounds has consequently led to increasing grazing pressure on the remaining lichen resources.

Reindeer herding has persisted despite profound changes in society

Despite various pressures from the surrounding society, large-scale economic changes and loss of grazing grounds reindeer herding has persisted in the circumpolar region. The ways of coping with changes have varied. In Siberia, the reindeer herding system was to a large extent affected by Soviet politics from the 1920s until the 1980s (Vitebsky, 2005). In the post-Soviet time many reindeer herding units have declined or even collapsed (Forbes & Kumpula, 2009) and the traditional family organisation was largely abandoned during this period. However, the Yamal-Nenets in Siberia have managed to maintain much of their traditional organisation. They have also adapted to other types of external pressure, and today manage to coexist with expanding oil and gas industries, despite the loss of territory (Forbes *et al.*, 2009). The unfettered movement of people and animals, which allows them to either avoid or exploit a wide range of habitats has been found to be important features for resilience to changes (Forbes *et al.*, 2009). In Finland the reindeer herding has also persisted, but there has been a marked shift from traditional, highly mobile forms of herding to more static forms with greater reliance on feeding the reindeer (Helle & Kojola, 2006; Helle & Saastamoinen, 1979).

In northern Sweden reindeer herding has adapted to major changes in society, such as expanding industrialisation and agrarian colonisation. Some important traditional features are still largely maintained, e.g. the traditional migration between grazing grounds and the grazing on natural ranges. Several factors have made this possible. One is that ground-growing lichens have remained important components of the ecosystems, despite the various negative effects during the periods of great changes. Another important factor is that Sami community have increasingly gained power over their own subsistence during the 20th century (Lantto, 2000). In addition, arrangements have been made recently to provide greater opportunities for the reindeer herders to make their voice heard and to claim their rights in conflicts with forestry (Sandström *et al.*, 2006). For example, to be certified the forest companies have to consult the reindeer herders before logging an area, and new planning tools have been developed to facilitate for reindeer herders to communicate their needs (Sandstrom *et al.*, 2003). Furthermore, although a very small proportion of the Sami today are dependent on reindeer herding for their living, the tight connections between reindeer herding and Sami culture still persist. Because people value the special way of life associated with reindeer herding, some people still make a living by reindeer herding, despite generally earning far below average incomes (Nordin, 2007). This strong cultural link between the people and the livelihood makes the reindeer herding resilient to changes.

The studies this thesis is based upon were not directed towards understanding the long-term resilience of the Sami reindeer herding economy. However, these studies may help to elucidate how reindeer herding has been able to adapt during times of great changes, primarily by providing detailed information regarding the effects of forestry on the forests from a reindeer herding perspective. Comprehending the history and nature of the disturbance, caused by for example forestry, is essential for understanding how reindeer herders have been able to adapt to these changes, and to evaluate the future resilience of reindeer herding (Danell, 2005). Although extensive reindeer herding is still maintained, it is becoming increasingly difficult, and likely to become still more challenging as the quality of grazing grounds is expected to further deteriorate.

The challenge of interdisciplinary research

Ecology has gradually shifted from treating humans as external to ecological systems towards including humans as ecological objects/subjects, primarily because global environmental changes have made human influences on nature increasingly apparent (Lowe *et al.*, 2009). This has led to growing interest in interdisciplinary work among ecologists, to incorporate methods and concepts from the social sciences and the humanities, among other disciplines. Engaging stakeholders and end-users in the research and enlarging the scope of ecology to include human objects are other ways in which ecologists have attempted to incorporate human dimensions in their work (Lowe *et al.*, 2009). The doctoral studies this thesis is based upon were interdisciplinary, and from the outset the intention was to address scientific problems by incorporating approaches from diverse disciplines, using a broad spectrum of methods originating from several fields.

Interdisciplinarity is not a uniform concept, and interdisciplinary work may take many different forms. Forest history is today a well-established subject in Sweden, whose methods and concepts are assembled from traditionally distinct disciplines, such as ecology, archaeology, history and geography. When studying forest history a set of tools (methods) can be used, each of which provides information with different spatial and temporal resolutions. When choosing the most suitable methods to use I believe that the underlying scientific question should be the starting point and that, if possible, combining methods usually gives the most balanced answers. Different methods provide different, but complementary, perspectives. Therefore, it has been important throughout the studies to incorporate knowledge from different fields when possible and fruitful. Primarily the investigations have been based on field surveys, dendrochronology, analysis of historical records, and landscape analysis.

The studies of lichen tree cuttings (I, II) are examples where the use of a combination of methods proved to be beneficial. Field studies and dendrochronological analyses of stumps provided knowledge about the distribution of this type of cuttings in space and time and the properties of the cut trees and the surrounding forest. Analysis of literature and historical archives also provided information about the character of these cuttings, and additionaly, about the reason for and attitudes to this practice. Combining this information provided a more complete history of this practice compared to if only one method would have been used. For example if my studies had been based on only field surveys, the conclusion would have been that pine were the only species cut for this purpose since only pine stumps were found. On the contrary, if the studies had been based on only literature we would have concluded that spruce trees were cut, only during severe snow conditions.

It should be noted that there are also obstacles connected with interdisciplinary work, for example, the publishing process is generally not well adapted to handling interdisciplinary work, and understanding the views of "the other" is often difficult and time consuming (Campbell, 2005; Lélé & Norgaard, 2005; Turner & Carpenter, 1999). It also takes time to master relevant amounts of knowledge in several distinct fields and to establish successful collaborations, therefore time is one of the major obstacles for interdisciplinary work, especially within PhD projects. Since the time frame is strictly limited, depth is often, of necessity, sacrificed for breadth (Golde & Gallagher, 1999). In my project, collaboration with experienced people in the incorporated fields was a necessity, since it takes a long time to fully master each of the approaches and methods applied. However, I have worked with most of the methods myself (except the landscape analysis), to fully understand the results.

Two important sets of tools available for research in forest history have not been used within the framework of this thesis. One is the analysis of biological archives, such as soil, peat and lake sediments. Since I have a background in pollen analysis I spent much time thinking about possible ways to make use of such skills in my doctoral studies, but came to the conclusion that it was not possible to include them in a fruitful way. For example, it would perhaps have been useful to analyse the abundance of lichens over a long time period, but lichens produce spores that are both difficult to identify and poorly preserved. The other important set of methods that have not been used is oral history. Interviews would surely have been informative, concerning questions about both the historical effects of forestry on winter grazing grounds for reindeer and the practice of cutting trees for lichens. This is an obvious task for future research within this field.

Concluding remarks

Reindeer herding vs. forestry in a historical-ecological perspective

Reindeer have been components of the Scandinavian forest ecosystems for thousands of years. When people started to herd the reindeer they largely adapted their lifestyle to the natural behaviour of the reindeer. Even after domestication the reindeer were allowed to roam quite freely and move between grazing grounds within their natural environment. This is in contrast to most other forms of domestication, in which animals are usually fed and kept in enclosures, or introduced to new environments (Diamond, 1997). The domestication of reindeer therefore probably had relatively limited impact on the forest and mountain ecosystems, especially in early stages. However, the practise of cutting lichen trees to feed reindeer had a direct affect on the forest. In this thesis, and the underlying studies, my colleagues and I have provided new knowledge regarding the nature and distribution of this largely abandoned practice, and estimates of its importance during different times (I, II). However, the general effects of cutting lichen-rich trees on the remaining forests have been difficult to estimate, due to a paucity of suitable study areas and remnant lichen stumps. Depending on the local intensity of lichen tree cuttings, the time-depth within a certain area, the selection of trees and the productivity of the ecosystem, it is likely that these cuttings contributed to shaping the pre-industrial forest. Therefore this issue needs to be addressed in further studies, preferably in more productive sites than the area studied for this purpose (II). Since spruce was found to have been the preferred species for lichen tree cuttings (I), new studies should preferably focus on forests with a spruce component, but since most stumps of spruces cut for use as lichen trees have decomposed, this question needs to be addressed using other methods. I believe that experimental cuttings of lichen-rich trees would be an interesting approach for further studies, to be able to estimate the time used by reindeer herders in this activity and the amount of trees needed to feed reindeers, and to assess the effects of these cuttings on the forest structure. Such studies should be conducted in close collaboration with active reindeer-herders and preferably in an old-growth forest.

The low intensity forest use by reindeer and people subsisting on herding them has been found to have substantial, long lasting impact on the forests (Josefsson, 2009; Andersson *et al.*, 2005b). However, land use by reindeer herders was largely sustainable when it comes to resources critical to their own subsistence as they were dependent on returning to the same lands again and again. Until they began to settle down or turn to extensive herding based on meat production, herders largely subsisted on resources available within the ecosystem and small amounts were exported. During the last century reindeer herders became more dependent on imported resources and also exporting meat, thus since then they have made a larger imprint on the ecosystem. However, the main determinant of the impacts of reindeer on the ecosystem is the density of reindeer grazing in an area (Kumpula *et al.*, 2000). Since it has been extremely difficult to estimate the numbers and movements of reindeer further back in time than the 1880s (Moen, 2008; Anon., 2006; Lundmark, 1982), the historical impacts of reindeer herding further back are also very difficult to estimate.

Trees are key elements in forests, providing resources and shelter, and shaping the microclimate for other organisms (Beagon *et al.*, 1996), therefore cutting trees has a direct effect on the ecosystem. In the papers appended to this thesis three major types of cuttings are discussed (lichen tree cutting, selective logging and clear-cutting) and estimates of their proportions are provided. The lichen tree cuttings differ from the other types in several ways; they were performed during a longer period of time, smaller trees were cut and the whole trees remained within the ecosystem. In contrast, forestry is based on withdrawing biomass from the ecosystem, and both during the period of selective logging and clear-cutting the largest trees have been the main targets. Generally, however, the most nitrogen-rich parts of the trees, the green parts and the roots, are left within the ecosystem. Despite the widespread use of lichen tree cuttings and the extended timespan of this forest use, its impact on the ecosystem never reached the same magnitude as that of the subsequent logging by the forest industry.

Clear-cutting differs from the other types of tree cuttings in another ecologically important respect, namely by fragmenting the forest landscape.

In paper IV we showed that the fragmentation of the forest landscape greatly accelerated with the introduction of clear-cutting in the mid-20th century. However, from different organisms' perspectives, clear-cutting may create either habitat heterogeneity or fragmentation (Tews *et al.*, 2004), in other words, clear-cutting may be either beneficial or create hindrances for different organisms. For example, while clear-cutting undoubtedly fragmented the landscape from the arboreal lichens' perspective, and thus adversely affected their dispersal and diminished their abundance (IV), from a reindeer point of view clear-cutting may create a landscape mosaic that in some respects may be beneficial, since forest patches of different ages may be used for grazing during different weather conditions (Roturier & Roué, 2009). Nevertheless, the clear-cutting phase is mainly considered bad for winter grazing reindeer because of subsequent soil scarification, logging residues left on the ground and the worse snow conditions on clear cuts compared to forests (III; V).

In addition to logging, forestry has affected the ecosystem in several other ways. Forestry measures like soil scarification, fertilization, chemical treatments and prescribed burning not only affect the trees, but also the soil processes and all other vegetation (Palviainen *et al.*, 2007; Roturier & Bergsten, 2006; Smolander *et al.*, 2000). In paper III we showed the extent of various forestry measures in our study areas during different times, while in papers III and V we examined the effects of logging and accompanying forestry measures from a reindeer herding perspective. The conclusion from these studies is clearly that forestry has mainly had negative effects for reindeer herders, especially since the mid-20th century. This agrees well with findings of other studies (Sandström *et al.*, 2006) and perceptions of reindeer herders who stress that forest reindeer grazing resources are declining (Anon., 2006; Widmark, 2006).

Another very important impact of forestry on the forest ecosystem is the altered disturbance regime. Since the introduction of forestry in the late 19th century forest fires have been suppressed by efficient measures to protect the increasingly valuable timber (Niklasson & Granström, 2000; Zackrisson, 1977). From that point, forestry became the most extensive disturbance factor rejuvenating the forest and shaping the forest structure. The study described in paper IV explored long-term changes in lichen abundance in the ground vegetation in forest stands with different histories. The results from this survey did not reveal any clear relationship between forest history and lichen cover, except that lichen cover was significantly smaller in clear-cut areas. However, there appears to be a paucity of knowledge about the effects of the changed disturbance regime on the ground vegetation (Nilsson

& Wardle, 2005), especially the lichens, hence a goal of future studies should be to analyse the succession of ground vegetation in lichen-rich forest types after clear cutting and after the long-term absence of fire. These effects could be examined using a similar, but larger scale approach to that described in paper IV, namely by using historical forest inventories to establish a chronosequence of forests in different stages after clear-cutting and fire, and surveying the ground vegetation within them.

Ericsson (2001) described the areas affected by farmers' use of the forests around settlement sites during the pre-industrial period as "cultural islands" in sharp contrast to the otherwise continuous forest landscape at that time. The pre-industrial forest use by Sami could also be noticeable around Sami settlement sites (II) (Östlund *et al.*, 2003), but its effects never became as substantial as those around farmsteads, thus the areas affected by pre-industrial Sami land-use can be viewed as "cultural reefs" between these islands, almost rising over the surface of mostly continuous forest canopies. The different legacies to the forests by these two forms of pre-industrial land use can primarily be explained by differences in mobility and time-depth in the landscape.

Forestry provides a completely different picture. Since the start of forestry, and especially since its intensification in the 1950s, forestry has turned the majority of the inland northern forests into a cultural landscape consisting of a patchwork of highly managed, even-aged, single-species stands (III; IV; (Axelsson & Östlund, 2001). To extend the metaphor, the legacies of forestry on the forest landscape can be described as "cultural continents" erasing the vestiges of pre-industrial forest use, leaving little space for the original ocean of continuous old growth forest and affecting features that are important for plants, animals and humans in this area. Understanding the complexity of these changes for people and for the ecosystem requires further historical-ecological and interdisciplinary research in a wide range of fields.

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