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288

Lotta Jaakkola

Can learning from the past help to predict the future in the environmental impact assessment on reindeer husbandry?

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ABSTRACT

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Yhteenveto: Ympäristövaikutusten arviointi ja poronhoito – voidaanko menneisyydestä ottaa oppia arvioitaessa tulevaa?
Diss.

Reindeer husbandry takes place in a large and complex system of habitats in which several factors directly and indirectly affect the state of the pastures and the abundance and availability of reindeer fodder. During the 20th century, commercial forestry was the most important form of land use competing with reindeer husbandry. However, reindeer management in Finland and Scandinavia is currently facing new challenges, as land use is intensifying and expanding due to spatially extensive industrial development projects, such as mineral extraction, wind farm, railroad and powerline construction etc. The main objectives of this thesis are to describe the past changes in the operational environment of reindeer husbandry, relate these to changes in reindeer management practices and estimate the impacts of potential future infrastructure construction on habitat availability and reindeer management. During the 20th century reindeer-herd management has experienced two major transitions: extensification of intensive herding and the development of supplementary winter feeding as a response to the reduced availability of winter fodder. This thesis shows that if infrastructure development in the reindeer herding area continues as predicted, the direct and indirect area losses will set new limiting factors on the reindeer management, and the pressure on this livelihood to adapt to changes will continue. Due to the avoidance behavior of reindeer, the area losses following infrastructure development are likely to be substantially larger than the direct area losses indicate. When the environmental impact assessment (EIA) process takes place in the reindeer herding area, the impacts on direct and indirect area losses as well as cumulative effects on several levels of hierarchical habitat selection, must be analysed to avoid serious damage to this livelihood.

Keywords: anthropogenic disturbance; avoidance behaviour; EIA; forest management; semi-domesticated reindeer; winter feeding; zones of influence.

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CONTENTS

LIST OF ORIGINAL PUBLICATIONS

The thesis is based on the following original papers, which will be referred to in the text by their Roman numerals I-IV.

I am the first author of Papers II, III and IV. I performed large part of the field work (interviews of reindeer herders, collection of archive materials, measurements of the sample plots in national parks), statistical analyses and GIS - analyses as well as writing these papers. I contributed significantly to the field work and analyses and participated as a co-author in the preparation of Paper I. The co-authors of the papers commented on the relevant manuscripts.

I Helle T. & Jaakkola L. 2008. Transitions in herd management of semi-domesticated reindeer in northern Finland. *Ann. Zool. Fennici* 45: 81–101.

II Jaakkola L.M., Heiskanen M.M., Lensu A.M. & Kuitunen M. 2013. Consequences of forest landscape changes for the availability of winter pastures to reindeer (*Rangifer tarandus tarandus*) from 1953 to 2003 in Kuusamo, Northeast Finland. *Boreal Environ. Res.* 18: 459–472.

III Jaakkola L., Helle T., Soppela J., Kuitunen M., Yrjönen M. & Niva A. 2006. Effects of forest characteristics on the abundance of alectorioid lichens in Northern Finland. *Can. J. For. Res.* 36: 2955–2965.

IV Jaakkola L. & Vallius E. The cumulative impacts of industrial development projects on reindeer habitats in Finland. Submitted manuscript.

1 INTRODUCTION

1.1 Reindeer husbandry

Reindeer (*Rangifer tarandus tarandus* L. 1758) husbandry is a major form of land use in Scandinavia and northern Finland, and reindeer have been used as a resource by humans for thousands of years (Ruong 1967, Danell *et al.* 1999). This livelihood takes place in a large and complex system of habitats in which several factors directly and indirectly affect the state of the pastures and the abundance and availability of reindeer fodder (Kumpula *et al.* 2014). Until recently, commercial forestry has been regarded as the most important form of land use affecting reindeer husbandry (Östlund *et al.* 1997, Storaunet *et al.* 2005, Berg 2010, Kumpula and Kurkilahti 2010). However, the reindeer husbandry is facing new challenges, as land use is intensifying and expanding due to the building of spatially extensive projects related to mineral extraction, the development of tourism, the building of transportation routes, etc. (Kumpula *et al.* 2008b, Anttonen *et al.* 2011, Kivinen and Kumpula 2014).

The management of semi-domesticated reindeer belongs to a relatively rare form of livestock raising in which the animals live in the same ecological niche as their wild ancestors or present day wild counterparts (Geist 1998). The current practise of reindeer husbandry conducted in Finland south from the Sámi area dates back to the 17th century. Reindeer husbandry developed in forest areas as a part of a relatively sedentary way of life, in which other livelihoods were fishing, hunting or engaging in small-scale agriculture and dairy keeping (Tegengren 1952, Kortesalmi 1996, 1998). It was practised by Finns, but it resembled the small-scale reindeer husbandry of the Forest Sámi people, the earlier inhabitants of the area (Kortesalmi 1996). The southern border of the reindeer husbandry area was established during the 18th century, running approximately to latitude of 64°N. In the north, the closure of the Russian (Finnish)-Norwegian border in 1852 revolutionized old nomadic Sámi reindeer husbandry preventing or shortening seasonal migrations. Furthermore, the area used for reindeer husbandry became more restricted when a total of 65 management units called herding co-operatives were founded in 1898, each having exact borders (Kortesalmi 2007). Today, the number of herding co-operatives is 56.

This means that the home ranges of semi-domestic reindeer in Finland are much smaller than those of wild reindeer or migratory semi-domesticated herds. The sizes of the herding co-operatives vary between 470 and 5690 km^2 (Mattila and Mikkola 2009, Mattila 2012). The herding co-operatives also differ from one another in terms of management practices, natural environment and the extent and types of other land use activities that occur alongside them (Turunen and Vuojala-Magga 2014).

1.1.1 Ecological basis of reindeer husbandry

In natural pastures, reindeer utilise several habitat types, which vary with the seasons and weather conditions (Kumpula 2001, Skarin 2009). During winter, the best fodder for reindeer energy expenditure and digestion consists primarily of terricolous (genus *Cladonia* spp., *Cladina* spp.) and epiphytic alectorioid lichens (*Alectoria* spp., *Bryoria* spp., *Usnea* spp.) (Aagnes *et al.* 1995, Heggeberget *et al.* 2002). If availability is not a restricting factor, lichens may constitute up to 80 % of reindeer forage in winter and early spring (Russell and Martell 1984, Kojola *et al.* 1995, Heggeberget *et al.* 2002). In addition to lichens, common hairy grass (*Deschampsia flexuosa*) is also an important winter fodder (Kojola *et al.* 1991, Kumpula *et al.* 2007). In general, reindeer mainly feed on alectorioid lichens in areas where there is lack of terricolous lichens or in conditions when snow or ice restrict or prevent access to them (Sulkava and Helle 1975, Helle 1984, Johnson *et al.* 2001, Moen *et al.* 2006). In general, in natural pastures the carrying capacity is largely determined by the availability of winter fodder (Klein 1967, 1970, Nieminen and Heiskari 1989, Heggeberget *et al.* 2002), though reindeer and caribou, hereafter generally referred to as ‘’reindeer’’ are physiologically adapted to a reduced food intake during winter (Tyler *et al.* 1999).

During the snow-free period, reindeer graze on a wide range of vascular plant species and, in the autumn, on mushrooms as well (Nieminen and Heiskari 1989, Baskin and Danell 2003, Mårell 2006). High-quality summer forage that is rich in nitrogen is important especially for females to retain sufficient weight after gestation and during lactation. To survive the following winter, calves must also achieve sufficient size (Cameron *et al.* 1993, Rönnegård *et al.* 2002). The quality and quantity of summer pastures directly affects the body condition of reindeer having consequences for fertility, i.e. the calf percentage (Reimers 1977, Cameron *et al.* 1993, Colman *et al.* 2003) and slaughter weights of reindeer (Kumpula 2001).

1.1.2 Habitat selection and reindeer management

The use of habitats can be defined by the theory of hierarchical habitat selection in which the selection is described at the levels of region, landscape and patch (Senft *et al.* 1987, Peterson and Parker 1998). In the Finnish reindeer management system, the area of the herding co-operative, i.e., the home range (Level 1 in Fig. 1) can be added to the habitat selection hierarchy tree. On the regional level, i.e. seasonal home ranges (Level 2 in Fig. 1), selection is limited by the area of home ranges (Level 1 in Fig. 1). At the seasonal level (Level 2 in Fig. 1), the main factor affecting the habitat selection of the animals is site fidelity, which is especially expressed in the use of calving grounds and summer pastures (Helle 1980, Schaefer *et al.* 2000). At that level, the decisions are also often made by the reindeer herder (Skarin 2006). According to Anttonen *et al.* (2011), the selection of seasonal home range areas (Level 2 in Fig. 1) and pasture use within the seasonal home ranges, i.e., at the landscape level (Level 3 in Fig. 1) are also affected by the avoidance of infrastructure and human disturbance. However, the impacts of such disturbances on seasonal home range areas (Level 2 in Fig. 1) vary, and are found to be greater within the home range (Level 1 in Fig. 1) (Anttonen *et al.* 2011). In addition to this avoidance behavior, reindeer prefer forage patches with available feeding sites at the landscape level (Johnson *et al.* 2002). The stand level describes the availability of different pasture types in the reindeer herding co-operative and is important in the impact assessment (Level 4 in Fig. 1). Landscape can be further divided into patches (Level 5 in Fig. 1). In winter, the patches are feeding craters where reindeer feed on terricolous lichens or individual trees bearing alectorioid lichens (Rettie and Messier 2000, Johnson *et al.* 2002). At the patch level, the main factors affecting the decision making of reindeer are the same as at the landscape level. The most important factors are food biomass and food availability, the last of which is determined by the characteristics of the snow cover (Pruitt 1979, Johnson *et al.* 2002). In summer, reindeer seem to select certain plant species instead of patches (Mårell *et al.* 2002).

The forms of reindeer management can also be perceived using hierarchical habitat selection theory. The difference between intensive and extensive herding refers to the intensity with which the habitat selection and movements of the reindeer are controlled (Beach 1981). In the most intensive herd-management practices, the herder regulates the foraging decisions of the reindeer at the patch scale (Level 5 in Fig. 1). At the herd and landscape levels, this means keeping reindeer in an area narrower than few kilometres in radius (Level 3 in Fig. 1) (Itkonen 1948). In extensive herding, the herd is dispersed over a wider area, and is no longer under the constant control of the herder (Beach 1981: 499-508). The aim is to keep the reindeer within a given part of the herding co-operative and indicates intervention by the herder at the level of several landscapes or the region.

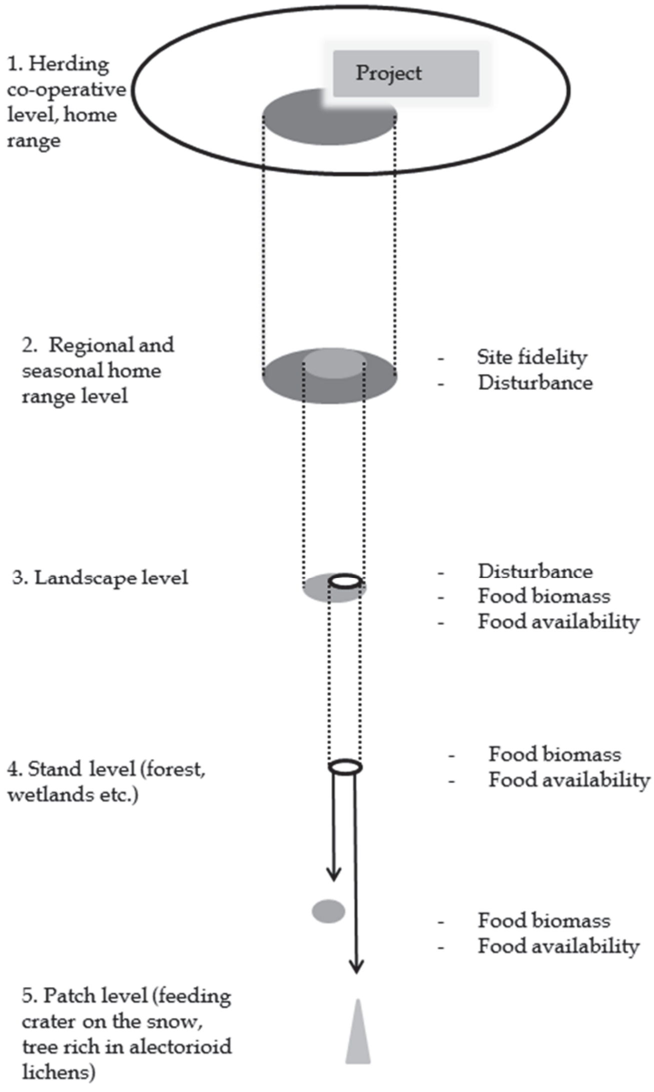

FIGURE 1 The model of hierarchical habitat selection in the Finnish reindeer management system and factors affecting on various levels.

1.1.3 The impacts of forest management on reindeer pastures

Reindeer husbandry operates in a multiple-use environment, in which several land-use activities with spatially and temporally variable intensities utilise the same area (Kyllönen *et al.* 2006). During the 20th century, commercial forestry has been the most important form of land-use competing with reindeer husbandry (Östlund *et al.* 1997, Storaunet *et al.* 2005, Berg 2010, Kumpula and Kurkilahti 2010). The conflicts between reindeer husbandry and forestry reach far back into history (Heikinheimo 1920) and are still under discussion especially in Finland (Saarela 2003, Raitio and Rytteri 2005) and Sweden (Bostedt *et al.* 2003, Widmark 2006, Berg 2010).

Forest management has direct impacts on reindeer husbandry at both the stand and landscape level (Kivinen *et al.* 2010). The regeneration of the forests leads to the loss or reduction of the amount and availability of terricolous and alectorioid lichens (Esseen *et al.* 1997, Kivinen *et al.* 2010). Due to ground scarification, the coverage and biomass of terricolous lichens are decreased, and the impact of this process depending on scarification method applied. According to previous studies, harrowing disturbs the vegetation and exposes of mineral soil, covering 45–55% of the manipulated area (Eriksson and Raunistola 1990, Roturier and Bergsten 2006). On the other hand, in fresh, nutrient-rich regeneration sites, the growth of the common hair grass (*Deschampsia flexuosa*) is enhanced, increasing the amount of winter fodder for reindeer (Hannerz and Hånell 1997). In addition to the availability of natural fodder, studies of semi-domesticated reindeer and woodland caribou (*Rangifer tarandus caribou* (Gmelin, 1788)) have shown a high preference for old-growth forests and the avoidance of clear-cuts and young stands (Apps *et al.* 2001, Kumpula *et al.* 2007). This avoidance behaviour may be partly due to the restricted ability of reindeer to observe predators in young, dense stands (Helle *et al.* 1990, Kumpula *et al.* 2007). Also, logging residues and changing snow characteristics hinder reindeer when digging through the snow to reach terricolous lichens (Helle *et al.* 1990, Kumpula 2003, Ottosson-Löfvenius *et al.* 2003, Roturier and Roué 2009).

On the landscape level during the 20th century, the multi-aged and, from the forestry viewpoint, over-aged forest matrix, has been replaced by a patch- work of forests stands that are mostly less than 100 years old. (Axelsson and Östlund 2001, Berg *et al.* 2008, Kumpula *et al.* 2008a). As a consequence, the winter pastures have become fragmented and less suitable for grazing (Kivinen *et al.* 2010) because reindeer prefer larger patches of uninterrupted habitats (Bentham 2005). According to a Swedish study, up to 30-50 % of the winter grazing ground has been lost during the 20th century as a result of intensified forestry (Berg *et al.* 2008).

1.1.4 Response of reindeer to other anthropogenic disturbance

In addition to forest management, industrial development, infrastructure and other human activities have direct and indirect effects on reindeer habitats and range use (e.g., Helle and Särkelä 1993, Vistnes and Nelleman 2001, Skarin *et al.* 2004, Reimers and Colman 2006, Skarin 2006, Vistnes and Nelleman 2008, Anttonen *et al.* 2011, Skarin and Åhman 2014). Land use activities have been shown to cause direct and indirect habitat loss, the degradation and fragmentation of habitats and movement barriers, as well as direct and indirect mortality and disturbed calving and recruitment (Dyer *et al.* 2001, 2002, Bentham 2005, Cameron *et al.* 2005, Moen and Keskitalo 2010). Indirect habitat loss is caused by the avoidance of infrastructure and human activities (Vistnes and Nelleman 2001). Although reindeer have been found to utilise land near industrial developments, the animal density in these sites is lower than expected (Dyer 1999, Vistnes and Nelleman 2001). According to Sámi reindeer herders, peaceful grazing conditions were considered highly important because as minimal amount of human disturbance ensures the proper feeding of the reindeer (Kitti *et al.* 2006). The avoidance behavior of reindeer varies depending on the season, gender and type of development (Bentham 2005, Vistnes 2008, Anttonen *et al.* 2011).

According to Vistnes and Nelleman (2008), reindeer avoid habitats several kilometers around high-voltage power lines and this avoidance behavior may continue over 30 decades after the construction (Nelleman *et al.* 2003). There is compelling evidence that such avoidance may be linked to the ability of reindeer to detect ultraviolet light (Hogg *et al.* 2011, Tyler *et al.* 2014) because along the power lines standing corona occur and on insulators, irregular flashes from ultraviolet discharges also occur (Tyler *et al.* 2014).

Late winter, calving time and summer are the most sensitive periods in terms of disturbance (Dyer *et al.* 2001, Vistnes and Nelleman 2001, Skarin and Åhman 2014). In winter, when the energy expenditure to ingest nutrition in natural pastures in highest, anthropogenic disturbance can cause substantial additional energy loss (Kumpula *et al.* 2007, Kumpula *et al.* 2014). Additionally, females, which constitute 80% of the Finnish reindeer population, are more sensitive than males especially during calving time and summer when energy demands are high due to lactation (Cameron *et al.* 1992, Helle and Särkelä 1993, Nelleman *et al.* 2000, Vistnes and Nelleman, 2001, Kumpula *et al.* 2008b, Skarin *et al.* 2008). During summer, females prefer undisturbed environments at the expense of forage quality (Maier *et al.* 1998, Helle *et al.* 2012).

During late summer and autumn, reindeer are less sensitive to disturbance because fodder is available in wider areas and the energy expenditure to obtain nutrition is lower than in winter (Skarin *et al.* 2004, Kumpula *et al.* 2007). Open and windy places, such as roads or other places near infrastructure are also preferred by reindeer during summer due to the avoidance of insect harassment (Skarin *et al.* 2004, Kumpula *et al.* 2007). Though some local-scale studies have shown that reindeer can habituate to human activities (Colman *et al.* 2001, Reimers and Colman 2006, Skarin 2006, 2007), the results of long-term and large-scale studies have shown the negative impact of human activity and infrastructure on the habitat selection of reindeer (Skarin and Åhman 2014). Depending on the type of disturbance, the zone of avoidance varies from 1 to 12 km (Helle and Särkelä 1993, Lundqvist 2007, Anttonen *et al.* 2011, Helle *et al.* 2012).

Daily winter feeding has been shown to habituate reindeer to human presence, and in some areas, reindeer have taken the permanent feeding places as a part of their annual pasture rotation (Turunen and Vuojala-Magga 2014). However, according to the results of Helle *et al.* (2012), reindeer density was lower on a 4 km zone around hiking trails and other infrastructure around a Saariselkä tourist resort in 2000, although the recreational activities had been ongoing in the area for over 40 years. In 1986, the same zone was 8–12 km (Helle and Särkelä 1993). The increased tolerance from 1986 to 2000 was most likely due to the improved channeling of recreational use (Helle *et al.* 2012).

1.1.5 Assessing the impact of human activity on reindeer

The piecemeal development of infrastructure and its cumulative effects on wildlife are likely to be two of the largest challenges for wildlife habitat conservation (Theobald *et al.* 1997, Forman and Alexander 1998, Nelleman *et al.* 2003). However, there are only few models predicting the cumulative impacts of infrastructure development on habitats and wildlife (Nelleman *et al.* 2003). Studies designed to measure the influence of human activity on reindeer usually deal with individual effects because including various responses, i.e., behavioural, physiological and distributional (Seip *et al.* 2007, Stankowich 2008, Thiel *et al.* 2008, Fahrig and Rytwinski 2009), and linking them to demographic responses are difficult (Vistnes and Nelleman 2008, Johnson and St-Laurent 2010). On the other hand, studies that map only direct losses of habitat, i.e., surface area that is physically altered by the development project (Martell and Russell 1985), may underestimate impacts (Nellemann *et al.* 2003). In order to assess the influence of infrastructure or human activities on the behaviour of reindeer and therefore habitat use, calculating areas for the zones of influence, ZOI provides more reliable estimates of the cumulative impacts. The ZOIs are difficult to quantify because they depend on the type of response that is measured and also on the type of disturbance (Bentham 2005, Quinonez-Pinon *et al.* 2007, Gunn *et al.* 2011). A direct comparison of results among studies is also complicated because of differences in the types and scales of disturbance, the reactions of different subspecies and methodological differences (Stankowich 2008). The different ZOIs for several types of disturbance vary from 0.2 km to > 12 km for various subspecies populations (Helle and Särkelä 1993, Nelleman *et al.* 2003, Bentham 2005, Lundqvist 2007, Anttonen *et al.* 2011, Boulanger *et al.* 2012, Helle *et al.* 2012, Skarin and Åhman 2014).

2 OBJECTIVES

This thesis is based on interdisciplinary research. It addresses scientific problems by incorporating approaches from the disciplines of forest and environmental history, ecology and landscape ecology. The objectives of interdisciplinary activities are to explore broad issues, answer complex questions and solve problems that are beyond the scope of any one discipline (Klein 1990, Berg 2010). The integration of various disciplines is intended to create a new means of synthesis, but this is not a simple task (Redman 2005). Reindeer husbandry is operating in the network of ecology, socio-economy, culture and politics, why the integration of results from different fields of research as well as across various spatio-temporal scales is necessary. In order to generate solutions for challenges evolving from intensified land use, predicted climate change, coexistence with large carnivores and the interactions of these, a synthetic approach is needed (Pape & Löffler 2012).

The main objective of this thesis was to describe the past changes in the operational environment of reindeer husbandry, relate these to changes in reindeer management practices and estimate the cumulative impacts of potential industrial development projects (such as mineral extraction, wind farms, peat production, railroads, and power lines) on the habitats and reindeer husbandry. The hypothesis suggests that relating changes in reindeer management practices to the past transformation of the operational environment of reindeer husbandry enables the prediction of cumulative impacts in the future. This thesis is based on four separate articles (Papers I-IV), which answer the following questions:

- How has reindeer management changed during the 20th century in relation to changes in environmental, socio-economic and technological factors? (I)
- How has the forest structure changed from 1953 to 2003 and how have these changes affected the availability of winter pasture resources for reindeer? (II)
- How can the biomass of alectorioid lichens be predicted by the forest site and stand variables? (III)
- What are the direct and indirect cumulative impacts of proposed industrial infrastructure projects on the operational environment of reindeer management at different levels of the hierarchical habitat selection model? (IV)

3 MATERIALS AND METHODS

3.1 Study areas

Study I was carried out in six herding co-operatives, Hossa-Irni, Lohijärvi, Poikajärvi, Kemin-Sompio, Hammastunturi and Näkkälä in northern Finland (Fig. 2). These were not randomly selected; the aim was to represent herding co-operatives in different parts of the reindeer management area. In the chosen herding co-operatives, more old data were available than were available for most of the other herding co-operatives. Study II was conducted in northern Kuusamo in reindeer herding co-operative of Alakitka (Fig. 1). Part of the study area, Oulanka National Park, was protected in 1956. According to the IUCN (Dudley 2008) classification of conservation areas, Oulanka belongs to Category II. Study III was conducted in Oulanka, Pallas-Ounastunturi and Lemmenjoki National Parks (Fig. 2). Also, Lemmenjoki national park belongs to Category II and Pallas-Ounastunturi represents Category IV (Dudley 2008). In Study IV, the study area includes the reindeer herding co-operatives of Isosydänmaa, Kemin-Sompio, Muonio, Oraniemi and Hirvasniemi (Fig. 2). They represent herding co-operatives that had at least two industrial development projects taking place during the sampling phase; these projects represented various types of infrastructure, i.e., linear-, point- and areal development projects.

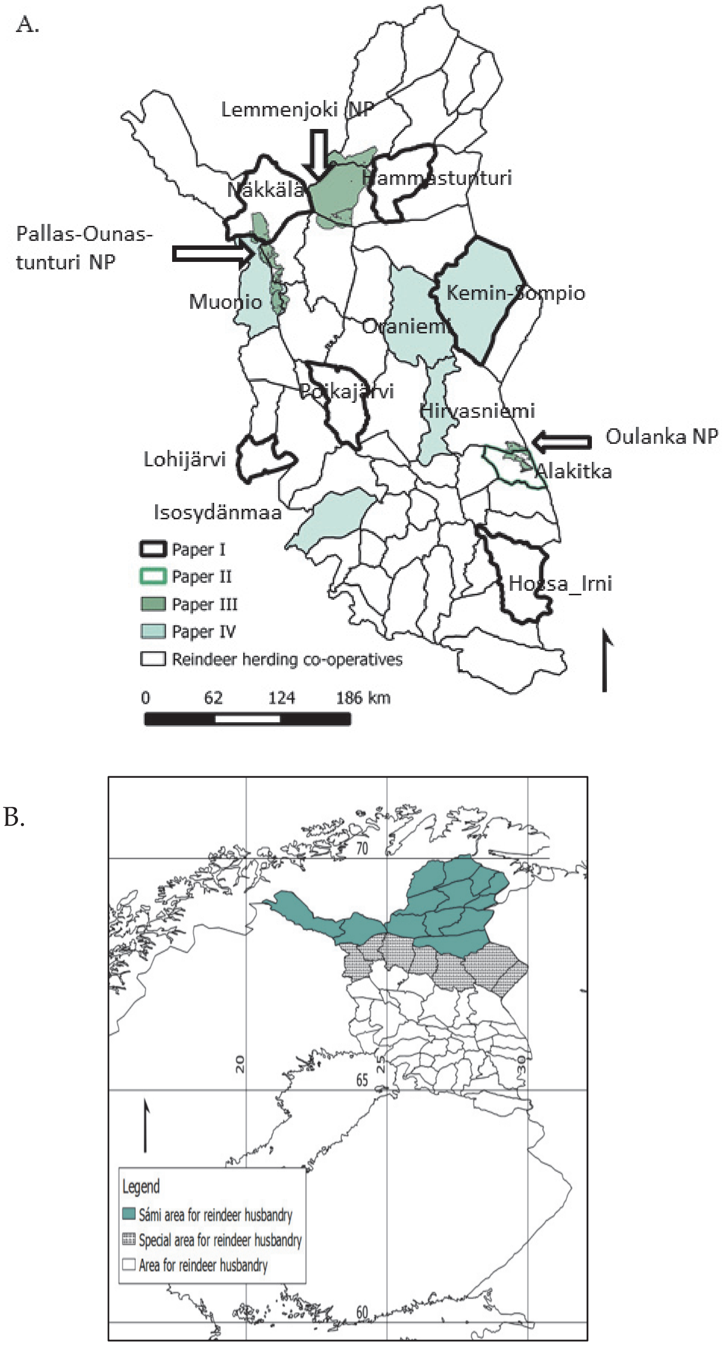

FIGURE 2 The map of the Finnish reindeer herding area divided into the Sámi area, the special area for reindeer husbandry and the area for reindeer husbandry (B.) and the map of the locations of the studied areas and reindeer herding co-operatives (A.).

3.2 Materials, methods and analyses

To describe herding methods and other management practices and to identify the environmental, socio-economic and technological factors influencing these practices, twelve reindeer herders were interviewed (I). The informants were experienced herders, most of them having more than 50 years of experience in reindeer management. To quantify the changes in reindeer numbers, and the environment, archival materials from the Reindeer Herders Association, Metsähallitus and Keisarillinen porolaidunkomissiooni were analysed (Table 1; I).

For the more detailed analysis of forest structure change, black-and-white aerial photographs from 1953, 1977 and 2003 were obtained from the Topographic Service of the Finnish Defense Forces (II). The spatial data management and classification of land use types were carried out using ArcGIS 9.3 (Esri Inc., Redlands, CA, USA). The indices describing the spatial pattern of the structure were further calculated using FRAGSTATS (McGarical *et al.* 2002), and the statistical analysis was conducted by using PASW Statistics Version 18.0 (SPSS Inc.) (II).

In Paper III, the biomass of alectorioid lichens was estimated and forest characteristics were measured for total of 234 sample plots to evaluate the value of the forest as an alectorioid lichen pasture. For the tree-specific estimation, the clump method (Stevenson 1979, Stevensson and Enns 1997) was used.

To estimate the cumulative impacts of conceivable industrial development on the reindeer habitats (Paper IV), maps of 13 projects assessed were derived from EIA - statements. General land cover data were derived from the national CORINE Land Cover 2006 database for Finland. ArcGIS 10.2 software (Esri Inc., Redlands, CA, USA) was used for the spatial data management, and the analysis of landscape structure was conducted by using FRAGSTATS 4.2 (McGarigal *et al.* 2012). A more detailed description of the materials and methods is given in the original papers (I-IV).

TABLE 1 Materials used in the PhD-thesis.

Paper	Materials
I	Interviews of 12 reindeer herders Annual Reports of Reindeer Herding Co-operatives (Reindeer Herders Association, Rovaniemi) Reindeer Herders Association. Annual statistics of reindeer numbers for the period 1910 and 1990. Rovaniemi, Finland. (Reindeer Herders Association, Rovaniemi) Keisarillinen porolaidunkomissiooni 1914. [Reindeer pasture commission 1914]. (The National Archives, Helsinki) Metsähallituksen III arkisto 1948-1970, luettelon nro 519:2. [Archive material of Forest and Park Service III 1948-1970 no 519:2]. (The National Archives, Helsinki) Pasture Inventory 1935 (Reindeer Herders Association, Rovaniemi) Pasture Inventory 1962 (Reindeer Herders Association, Rovaniemi)
II	Aerial photographs from 1953, 1977 and 2003 from Northern Kuusamo (The Finnish Defence Forces Topographic Service, Espoo)
III	234 sample plots in Oulanka, Pallas-Ounastunturi and Lemmenjoki national parks
IV	EIA reports of 13 projects (Finnish environmental administration 2014) Topographic database of the National Land Survey of Finland CORINE Land Cover 2006 database for Finland with 25 m resolution

4 RESULTS AND DISCUSSION

4.1 Reindeer management conditions at the beginning of the 20th century

In Finland, reindeer husbandry area reached its present distribution during the 18th century, and in 1898, a total of 65 herding co-operatives were established (Kortesalmi 1996). Also, the commercial use of forests started in the latter part of 19th century. However, at first, the cutting pressure was on easily accessible sites along rivers running into the Gulf of Bothnia, and most of the forests were located above the zero limit. As a consequence, in the First (1921–1924) and Second National Forest Inventories, the growth and yield of the northern forests was reported to be low due to the high proportion of over-aged forests (I). At that time, only 14% of the forests in northern Finland were younger than 80 years old (Mattila 1979). Because the age and volume of the forest correlate positively with the biomass of alectorioid lichen (III), it can be estimated that the availability of alectorioid lichens were not limiting factor for the carrying capacity of winter pastures (I). At the beginning of the 20th century, the reindeer population in Finland numbered approximately 100 000 (Anon. 1934). Due to increased winter mortality and decreased reproductive rate, reindeer stock size variation was related due to density-dependence and weather conditions, such as icing and snow (Helle 1980, Kumpula 2001). Serious losses in reindeer population typically occurred once in a ten-year period (Kumpula 2001).

In the beginning of the 20th century, reindeer husbandry was characterised by intensive winter herding, meaning tight, continuous control over the herd (I). Herding was necessary in order to protect the herd from predators and the disappearance of reindeer into the areas neighbouring co-operatives, and it enabled the application of a pasture rotation system (I). One prerequisite for keeping the herd under control was a concentrated, rich food supply (usually good terricolous lichen pasture), while a scant or scattered food supply (poor terricolous lichen pasture or trees with arboreal lichens) resulted the dispersal of the animals (Bergerud 1974, Helle 1980). However, in the Lohijärvi herding co-operative, reindeer were herded intensively until WWII, although the condition of the lichen pasture was already graded as "poor" in 1910s (I). This is an expected result because the percentage of potential terricolous-lichen-rich forests is only 1.3 % percent in average in the southern reindeer herding area, while the values for the special reindeer herding and Sámi areas are 9.0% and 33.9%, respectively (Kumpula *et al.* 2004, Mattila and Mikkola 2009; Fig. 2). Therefore, in the southern parts of the reindeer herding areas the low proportion of terricolous-lichen-rich forests had to be compensated for by cutting the trees rich in arboreal lichens for the reindeer in order to keep the herd under control (I). These cuttings occasionally covered large areas. For example, in 1912, in the Kitka district, during one winter, about 12 500 ha were cut for the reindeer, i.e., about 5 % of the total land area (Pohtila 1979). Helle (1986) has calculated that in the 1880s, in Pudasjärvi, 60–100 spruces were cut per reindeer during the winter. Thus the total cutting area varied between 2400–6000 ha. In the northern parts of the reindeer husbandry area, mainly those branches rich in arboreal lichen were cut for the animals (Renvall 1919). In difficult snow or ice conditions the animals were released to feed on alectorioid lichens on standing trees and herding became extensive (I).

4.2 Transitions in reindeer husbandry

4.2.1 Reindeer-herd management

During the 20th century, reindeer-herd management has experienced two major transitions: the extensification of intensive herding and the development of supplementary feeding (I). Transitions from intensive winter herding to more extensive forms took place between the 1910s and the 1960s, and supplementary feeding began in the late 1960s (I). According to Ruong´s (1964) basic definition, the form of herding chosen is a product of interrelationships between land, reindeer and man, and transition in herd management are linked to changes in these interrelationships.

4.2.2 General socio-economic changes

During WWII, the number of reindeer had declined by 53% on average (Alaruikka 1947) and because the post-war rebuilding of the country offered better income sources, the herders did not return to pre-war intensive herding especially in the southern areas (I). Cultural factors as well the lower availability of optional income sources, are the most likely reasons herders returned to pre-war intensive herding in the northern co-operatives (I). An important factor contributing to the transition from intensive to extensive herding in the northern co-operatives was the introduction of snowmobiles in the 1960s (Pelto *et al.* 1968, Müller-Wille 1975, Kortesalmi 2007). According to Näkkäläjärvi (2013), the introduction of snowmobiles did not actually change the nature of traditional Sámi herding significantly. Rather, it enabled a nomadic cultural practice to continue under changing socio-economic conditions.

Intensive herding changed to more extensive herding when the occurrence of large predators, reindeer straying into foreign areas and damage caused by reindeer to stored hay, no longer incurred any considerable costs for reindeer management (I) (Fig. 3). During the 1970s, the numbers of large predators decreased, and in 1975, the state began to pay compensation for domestic animals killed by large predators (I). Fences built first along the state borders and then between the herding co-operatives prevented the disappearance of animals reducing also pasture competition along the border areas (I).

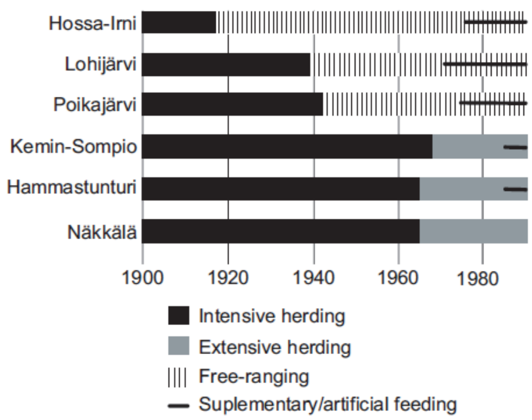

FIGURE 3 Transitions in the herd-management of semi-domesticated reindeer in studied herding co-operatives in 1900–1990 (I).

4.2.3 Changes in winter pastures mediated by forest management

The reduction in the availability of winter pastures has played an important role in the changes that took place in reindeer herd management during the 20th century (I). The reductions have been abrupt, for example, in Hossa-Irni, which lost good terricolous lichen pastures on the Russian side in 1918 due to the cessions of territory (I). A more common pattern has been gradual pasture loss due to intensive forest management starting in the late 1940s (I, II, III). A similar gradual loss was caused by the cessation of the lichen tree cuttings; these first occurred in the south and then throughout the region (I).

At the stand level, the regeneration of the forests leads to loss or reduction in the amount and availability of terricolous and arboreal lichens (Esseen *et al.* 1997, Kivinen *et al.* 2010, Kumpula and Kurkilahti 2010). Because forests abundant in epiphytic lichens are older than those at the end of the current rotation period (III), forest management has significantly reduced the availability and abundance of epiphytic lichen pastures. The most valuable epiphytic lichen forests in the southern and middle parts of northern Finland were in fresh sites dominated by mature Norway spruce forest (III). However in northernmost Lapland, in sub-dry sites, the epiphytic lichen biomasses on Scots pine that grow above the timberline of Norway spruce can reach similar levels (III). The proportion of terricolous-lichen-rich site types increase from south to north (Kumpula *et al.* 2004, Mattila and Mikkola 2009), and the biomasses of terricolous lichens are significantly higher in the north as compared to the average biomasses of alectorioid lichens (III). Therefore, the alectorioid lichens have had an important role in determining the carrying capacity of winter pastures and the productivity of reindeer stock in the southern part of the reindeer management areas prior to the introduction of intensive feeding (Helle and Saastamoinen 1979, Helle and Tarvainen 1984).

At the landscape level, forest management changes the spatial configuration of the winter pasture patches. In commercial forests in Alakitka, the mean size of forest patches decreased by 77% and the areas of terricolous and epiphytic lichen pastures decreased by 20–50% from 1953 to 2003 (II; Fig. 4). During the same time the largest patch index of forest decreased from 70% to 20% (II), indicating that the matrix of homogenous, mature forest was lost. In Kuusamo, where large-scale commercial forestry started in the 1950s, the middle phase of a typical landscape transformation was reached during the first 25 years, from 1953 to 1977 (I, II). In the southern part (except Kuusamo) the same transformation can be estimated to have taken place in the mid-1950s (I). According to Kivinen and Kumpula (2013), the area of continuous forest cover declined from 87.3% in 1972 to 77.5% in 2000 in the Lappi reindeer herding co-operative, located north of Oraniemi and Kemin-Sompio.

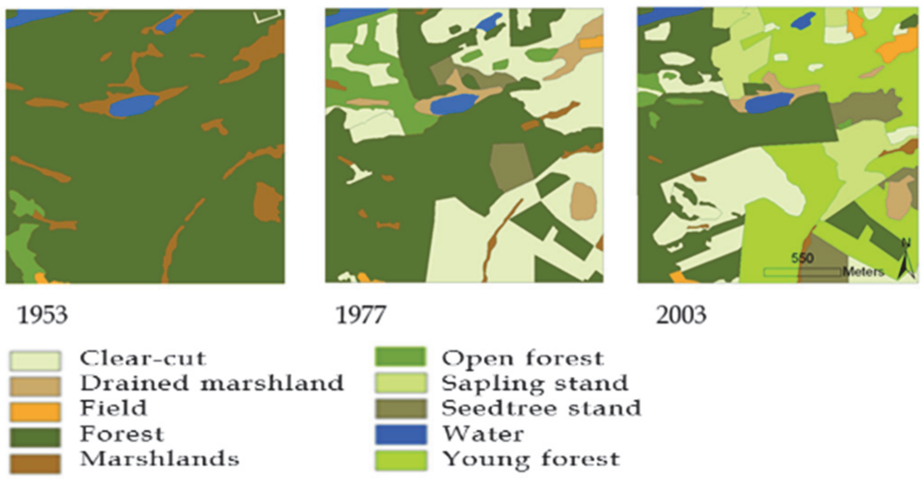

FIGURE 4 Transition in the land use types in one of the study areas in the Alakitka herding co-operative in northern Kuusamo from 1953 to 2003.

4.3 Impacts of transitions

The transition in the forest matrix changed the spatial configuration of the patches and the areas of pastures. Together with the increase in reindeer numbers, the available pasture area per head of reindeer was decreased (II). It is likely that the grazing pressure increased at the unaffected sites, further decreasing the biomass of terricolous lichens (II). The shortage of natural fodder led to the application of the free-ranging system and the beginning of hay feeding at the end of 1960s, which occurred first in the southern co-operatives (I, II, III; Fig. 2).

The free-ranging form of reindeer management has obvious advantages. The labour costs are minimised and the animals are enabled to make optimal use of the available pastures (Helle and Saastamoinen 1979, Ingold 1980). The animals can be gathered together, when necessary, by snowmobiles using less manpower than previously (I). The number of animals is then stabilised at level near or somewhat below the long-term carrying capacity of the pastures while feeding on the natural fodder.

The acute need for supplementary feeding was triggered by difficult snow conditions and by the loss of arboreal lichens due to forest management (I, II, III). The development of winter feeding was enabled by the close relationship with small-scale agriculture (Turunen and Vuojala-Magga 2014), which is a special feature of Finnish reindeer husbandry. At first, animals were fed in the forests. Later, feeding within the enclosures became a normal part of reindeer management (I). However, currently, feeding pens are commonly used in southern areas, whereas in the central and northern areas, field feeding is more common practice. The feeding systems had to be adapted to various pasture type distributions, microclimates, topographies, herding practices and pasture rotations for each herding co-operative and, even herding units within a co-operative (Turunen and Vuojala-Magga 2014). At present, reindeer are fed hay, grass silage and pellets in the field and feeding pens (Nieminen 2010). In the southern part of the reindeer herding area, pens are common and in 2007/08, over 71% of the reindeer were engaged in pen feeding for around 90 days. On the other hand in the middle and northern sections, field feeding is a more common practice, and in 2007/2008, over 60% of reindeer received supplementary feeding in the field (Nieminen 2010, Turunen and Vuojala-Magga 2014). In the present situation, when freely grazing animals are also fed artificially, the number of animals can rise over the natural carrying capacity, leading to the deterioration of slowly growing lichen grounds (II). Over time, reindeer husbandry may become even more dependent on supplementary feeding (Kumpula 2001).

4.4 Estimated impacts of large industrial development projects on reindeer husbandry

It has been estimated that within 20–30 years, high levels of disturbance are likely to occur in 50–80 % of the area of the northern Fennoscandia (UNEP 2001). As the impacts of forest management were directed mainly toward winter pastures (I, II, III), the impacts of industrial development are targeted toward the spring, summer and autumn pastures; calving sites and the pasture migration routes of reindeer. Concerning the cumulative impacts of analysed industrial development projects on the highest level of the habitat selection hierarchy, i.e., at the herding co-operative level, the direct pasture loss varied between 0.7 km^2 (Fig. 5) and 197.0 km^2 (Fig. 6) (from 0.04% to 4.6%) of the area of the herding co-operative (IV). The proposed projects would increase the maximum infrastructure cover by 70.1–764.0% as compared to the situation in 2005–2006 in some co-operatives (IV) (Kumpula *et al.* 2008b). The relative impacts of the projects are higher in herding co-operatives where the landscape is more fragmented representing more land use types and more disturbance even before the development projects (IV). The areas of ZOIs were calculated to estimate the area loss due to reindeer avoidance behaviour. The area of 1000 m zone around the development project varied from 0.8 to 2.9% of the area of the herding co-operative. These results are rather small compared to those of Anttonen *et al.* (2011). However, our results estimate the future addition of the cumulative aerial losses due to industrial development, and the present infrastructure is not included in the analysis.

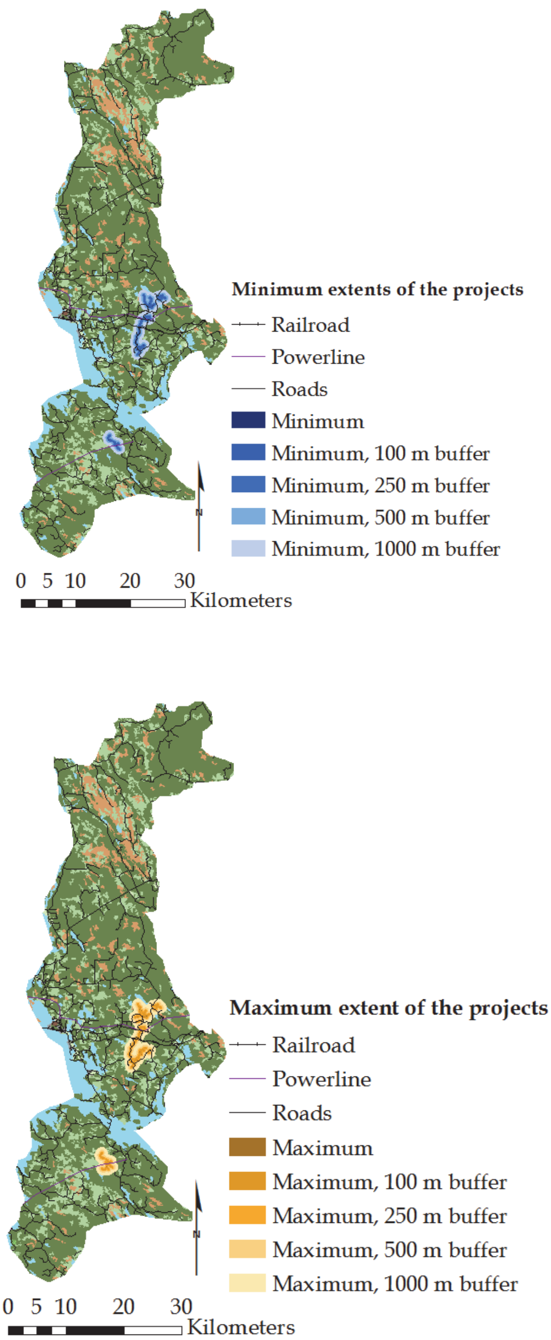

FIGURE 5 The minimum and maximum extent of the direct area losses and ZOIs (100, 250, 500 and 1000 m) of the industrial development projects in the reindeer herding co-operative of Hirvasniemi. (Contains data from the National Land Survey of Finland Topographic Database 09/2013).

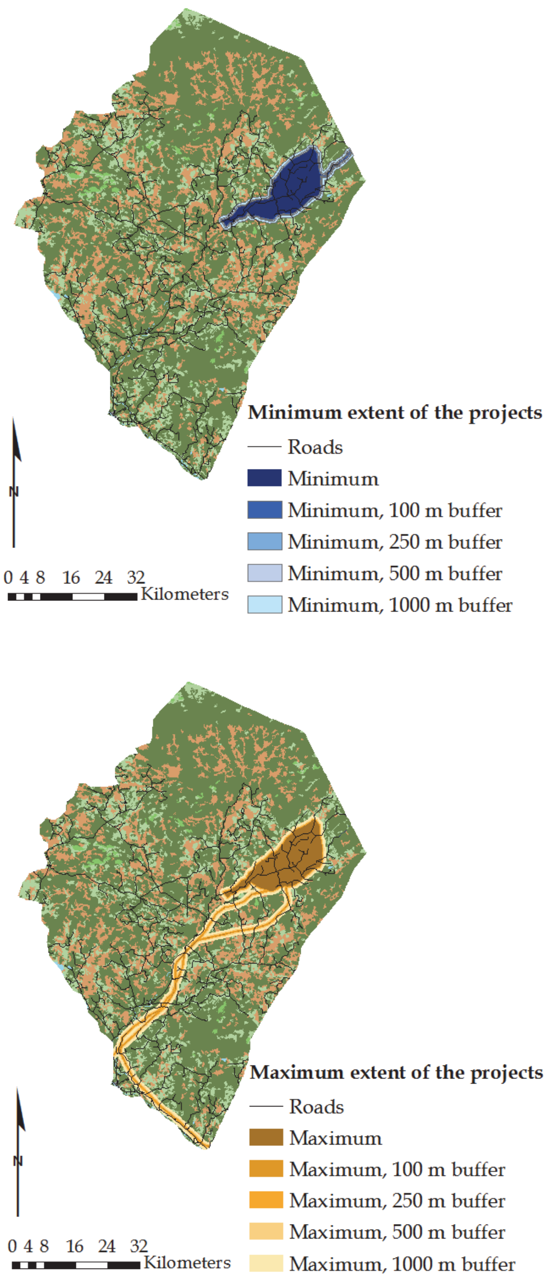

FIGURE 6 The minimum and maximum extent of the direct area losses and ZOIs (100, 250, 500 and 1000 m) of the industrial development projects in the reindeer herding co-operative of Kemin-Sompio. (Contains data from the National Land Survey of Finland Topographic Database 09/2013).

5 CONCLUSIONS

The environment in which reindeer husbandry takes place, has experienced significant changes during the 20th century due to the exploitation of land for commercial uses. Intensive forest management and the building of infrastructure and reservoirs have had various impacts on reindeer pastures (Kumpula 2001, Kumpula *et al.* 2008a, Kumpula *et al.* 2011, Kivinen and Kumpula 2013). High reindeer densities in the 1980s, an inadequate or absent pasture rotation system and changed environment increased lichen pasture deterioration (Mattila and Mikkola 2009, Kumpula *et al.* 2011, Kumpula *et al.* 2014).

As a response to the reduction in the area and availability of winter pastures, supplementary feeding was started in the late 1970s, first from the southern herding co-operatives. And at present, reindeer are fed practically in all herding co-operatives (Kumpula 2001, Turunen and Vuojala-Magga 2014). Winter feeding is costly, but meat production is enhanced due to decreased mortality and increased reproduction and carcass weights (Kojola and Helle 1991, Helle and Kojola 1993, 1994, Kumpula 2001). According to Turunen and Vuojala-Magga (2014), the costs of feeding constitute 30-50 % of herding costs in the southern and central parts of the reindeer management area.

In the past, the decreased abundance and availability of winter fodder resources was compensated for by feeding, which markedly increased the stock productivity, as did calf slaughtering and anti-parasitic treatment (Kumpula 2001). However, if the expansion and intensification of land use continue as estimated, summer pasture resources may become the limiting factor for reindeer stock productivity in the future (Kumpula 2001, UNEP 2001). As the reindeer densities increase in the summer pastures, slaughtering mass and meat production per reindeer decrease (Kumpula 2001). Similar results have been found for wild reindeer and caribou, indicating that the loss of summer pastures is a likely cause of the declining reproduction rate (Cameron *et al.* 1993, Russell *et al.* 1996). Therefore, the maximum stock size for reindeer can be regulated on the basis of the quantity and quality of summer pastures (Kumpula 2001).

At the beginning of the 20th century it was claimed that reindeer number were unnaturally high, causing terricolous lichen pastures to deteriorate and the need for emergency feeding to increase. At that time, there was also a fear that unnaturally high reindeer numbers would prevent the regeneration of forests (Metsähallitus 1907, Renvall 1919). In 1907, the Forest and Park Service predicted that semi-domesticated reindeer management would disappear and be replaced by agriculture (Metsähallitus 1907). Despite these predictions, semi-domesticated reindeer management has succeeded in adapting to many changes in many ways during the 20th century, but this continuous adaptation is not easy.

If infrastructure development continues in the reindeer herding area as predicted, direct and indirect area losses will set new limiting factors for reindeer management, and the pressure to adapt will continue. At the same time the impacts of predicted climate change are setting also new challenges to reindeer husbandry. In order to maintain the adaptive capacity and resilience against in the changing climate would require maintaining a maximum choice of grazing sites (Moen 2008). To indemnify the future of the reindeer husbandry there is a need to analyse and consider the impacts on area losses on several different levels of hierarchical habitat selection in the environmental impact assessment taking place in the reindeer husbandry area. Despite their long domestication, the avoidance behaviour of reindeer is similar to that of its wild counterparts. Therefore, special attention should be paid not only to direct area losses, but also to the areas on avoidance zones around the development projects as well as the cumulative effects of various development projects, present infrastructure and anthropogenic disturbance.

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YHTEEVETO (RÉSUMÉ IN FINNISH)

Ympäristövaikutusten arviointi ja poronhoito – voidaanko menneisyydestä ottaa oppia arvioitaessa tulevaa?

Poronhoito on yksi Pohjois-Suomen vanhimmista maankäyttömuodoista, jolla on ollut ravinnon ja toimeentulon saatavuuden lisäksi myös kulttuurista merkitystä. Luonnonlaidunten hyödyntämiseen perustuvana elinkeinona poronhoito on edellyttänyt laajojen, monipuolisten ja riittävän hyväkuntoisten laidunalueiden olemassaoloa. Suomessa noin 75 % poroista laiduntaa pohjoisboreaalisella havumetsävyöhykkeellä, jossa suojelualueita lukuun ottamatta on harjoitettu intensiivisemmin metsätaloutta viimeiset 70 vuotta. Myös monet muut maankäyttömuodot, kuten matkailu, kaivostoiminta ja vesistörakentaminen vaikuttavat porojen laidunten laatuun, määrään ja saavutettavuuteen.

Tutkimuksessa on tuotettu tietoa poronhoidon toimintaympäristössä tapahtuneista muutoksista ja niiden vaikutuksista porolaitumiin ja poronhoitoon sekä arvioitu poronhoitoalueelle suunniteltujen uusien maankäyttöhankkeiden mahdollisia vaikutuksia elinkeinoon tulevaisuudessa. Tutkimuksen lähestymistapa on monitieteinen ja väitöskirjassa on yhdistetty metsä- ja ympäristöhistoriallisia, ekologisia ja maisemaekologisia menetelmiä käyttäen aineistoina mm. poronhoitajien haastatteluja, porotilastoja, historiallisia asiakirjoja, ilmakuvia, metsikkökoealoilla suoritettuja mittauksia sekä erilaisten maankäyttöhankkeiden YVA-selostuksia. Tutkimuksen aineisto on kerätty Suomen poronhoitoalueelta käsittäen alueita eteläistä, keskistä ja pohjoista poronhoitoaluetta edustavista paliskunnista. Osa tutkimusalueista sijaitsi suojelualueilla ja osa talousmetsissä.

Poronhoidolle oli tyypillistä 1900-luvun alkupuoliskolla intensiivinen talvipaimennus, joka oli välttämätöntä tokan suojelemiseksi pedoilta ja eläinten pitämiseksi oman paliskunnan alueella. Intensiivinen paimentaminen mahdollisti laidunkierron toteuttamisen ja toisaalta menestyksekäs paimennus edellytti paikallisesti runsaita ravintovaroja ts. hyviä jäkälälaitumia. Eteläisimmissä paliskunnissa hyviä jäkälälaitumia oli luonnostaan vähemmän, mutta maajäkälien puutetta pystyttiin kompensoimaan luppokuusihakkuilla eli luppokaskilla. Pohjois-Suomen metsistä 1920- ja 1930-luvuilla 14 % oli alle 80-vuotiaita. Koska naavamaisten epifyyttijäkälien esiintymisrunsaus lisääntyy puuston iän ja tilavuuden kasvaessa, voidaan arvioida, ettei epifyyttijäkälien saatavuus rajoittanut porokannan kokoa, jonka arvioitiin 1900-luvun alussa olleen noin 100 000 eläintä. Luppokaskien hakkaaminen kiellettiin 1930-luvulla.

Poronhoidossa tapahtui 1900-luvulla kaksi merkittävää muutosta: siirtyminen intensiivisestä talvipaimennuksesta ekstensiiviseen vapaaseen laiduntamiseen 1910–1960–luvuilla ja talviruokinnan aloittaminen 1960–luvun loppupuolelta alkaen. Muutosten ajankohdissa oli merkittäviä eroja paliskuntien välillä muutosnopeudessa ja taustoissa, mutta eteläisimmissä paliskunnissa muutokset tapahtuivat ensimmäisinä. Toisen maailmansodan jälkeen etenkin eteläisemmissä paliskunnissa oli tarjolla muita tulonlähteitä eivätkä poromiehet palanneet enää sotaa edeltäneeseen intensiiviseen paimennukseen, mihin ei ollut

enää aikaisemman kaltaista tarvetta mm. alhaisten petomäärien, paliskuntien aitaamisen, ja myöhemmin myös petovahinkokorvausjärjestelmän ansiosta. Toisaalta myös 1950-luvulla alkanut metsien laajamittaisen uudistamisen ja metsien rakenteen pirstaloitumisen seurauksena naavamaisten epifyyttijäkälien määrä väheni ja metsien käsittelyllä oli myös jäkälien runsauteen suoria ja epäsuoria vaikutuksia. Tutkimuksen mukaan Kuusamossa metsälaikun keskimääräinen koko pieneni 77 % ja suurimman metsälaikun koko 20–50 % vuodesta 1953 vuoteen 2003. Tämä muutos metsien rakenteessa oli eräänä merkittävänä tekijänä poronhoidon muutoksessa intensiivisestä ekstensiiviseen ja toisaalta myöhemmän talvisen lisäruokinnan aloittamiseen. Laiduntaessaan vapaasti porot pystyvät tehokkaammin hyödyntämään pienempiä ja toisistaan kauempana sijaitsevia ravintovaroja pirstaloituneessa metsämaisemassa ja lisäruokinnan ansiosta poromäärissä ei esiinny luontaisenkaltaista populaatiokoon vaihtelua. Laidunalueiden määrän vähenemisellä on ollut merkittävä vaikutus laidunnuspaineen kasvuun ja jäkälikköjen kulumiseen.

On arvioitu, että seuraavien vuosikymmenten aikana infrastruktuurin vaikutusalue kasvaa merkittävästi pohjoisilla alueilla. Poroille ominaisen välttämiskäyttäytymisen seurauksena teollisuuden ja muun infrastruktuurin rakentamisesta johtuvat aluemenetykset ovat huomattavasti laajempia kuin mitä niiden aiheuttamat suorat aluemenetykset osoittavat. Tutkituissa paliskunnissa suunnitteilla olevien hankkeiden suorat aluemenetykset vaihtelivat 0,04–4,6 % välillä, mutta kilometrin välttämisvyöhykkeiden epäsuora aluemenetys oli 0,8–2,9 % koko paliskunnan alasta. Laskelmissa käytetty kilometrin välttämisvyöhyke on varsin varovainen arvio epäsuorista aluemenetyksistä, koska karibuilla, poroilla ja tunturipeuroilla tehtyjen tutkimusten mukaan eläinten välttämiskäyttäytyminen voi ulottua jopa 12 km etäisyydelle häiriöstä. Metsätalouden vaikutusten kohdistuessa pääasiassa porojen talvilaitumiin teollisuuteen ja infrastruktuurin rakentamiseen liittyvä maankäyttö kohdistuu em. lisäksi myös kevät-, kesä- ja syyslaitumiin, vasonta-alueille sekä kulku- ja kuljetusreiteille. Tästä saattaa olla seurauksena se, että kesälaidunvarojen vähenemisestä tulee tulevaisuudessa (talvilaidunvarojen vähenemisen rinnalle) uusi ylimääräinen porotalouden tuottavuutta rajoittava tekijä etenkin mikäli infrastruktuuriennusteet seuraaville vuosikymmenille toteutuvat. Myös muuttuva ilmasto vaikuttanee tulevaisuudessa poronhoitoon ja elinkeinon sopeutumiskyvyn turvaamiseksi erilaisten elinympäristöjen esiintymiseen paliskunnissa olisi kiinnitettävä erityistä huomiota.

Poronhoitoalueella suoritettavissa ympäristövaikutusten arviointimenettelyissä (YVA) olisi ensiarvoisen tärkeää selvittää suorien aluemenetysten lisäksi myös niiden vyöhykkeiden laajuus, joilla esiintyy poron välttämiskäyttäytymistä, sekä kumulatiiviset vaikutukset hierarkkisen elinympäristönvalinnan eri tasoilla. Näin voitaisiin arvioida todellisia vaikutuksia porotalouselinkeinoon sekä minimoida rakentamisen vaikutuksia ja vähentää jatkuvaa tarvetta muutokseen sopeutumiselle porotalouselinkeinon piirissä. Tutkimuksen tuloksia ja johtopäätöksiä on mahdollista soveltaa käytäntöön poronhoitoalueella maankäytön suunnittelussa ja erityisesti ympäristövaikutusten arviointimenettelyssä.

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ORIGINAL PAPERS

I

TRANSITIONS IN HERD MANAGEMENT OF SEMI-DOMESTICATED REINDEER IN NORTHERN FINLAND

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Transitions in herd management of semi-domesticated reindeer in northern Finland

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In northern Finland, reindeer-herd management has experienced two major transitions: extensification of intensive herding, and development of supplementary/corral feeding in winter. The transitions were studied in six herding associations in different parts of the Finnish reindeer management area. It was suggested that intensive herding turns into more extensive forms as the reasons for intensive herding (predation, reindeer disappearing to foreign areas, protection of agricultural fields) gradually ceased to exist. The results of the study, based on interviews of elderly reindeer herders, were variable. In the three southern areas intensive herding changed to the free ranging system at the latest during WWII, whilst in the northern areas intensive herding was replaced by extensive herding with the aid of snowmobiles in the 1960s. In the southern herding associations, especially, supplementary/corral feeding in winter was considered necessary, from the 1970s onwards, to compensate for the loss of arboreal lichens associated with forest regeneration.

Introduction

The theory of hierarchical habitat selection describes the habitat selection of animals at the scale of patch, landscape and region (Senft *et al*. 1987, Peterson & Parker 1998). In the case of reindeer (including caribou) (*Rangifer tarandus*), the patches used by reindeer in winter are the feeding craters made by the animals in the snow, or other objects such as a tree bearing arboreal lichens (*Alectoria* sp. and *Bryoria* sp.) (Rettie & Messier 2000, Johnsson *et al*. 2002). The main factors affecting habitat selection at the patch level are dietary preferences, food biomass and food availability, the last of which is determined by the characteristics of the snow cover (Pruitt 1979, Johnsson *et al*. 2002). The landscape consists of a collection of such patches, and the factors guiding decision-making are therefore mainly the same as those at the patch level. For reindeer, the regional level often corresponds to the area of the seasonal home ranges, and the main factors affecting the decision making of the animals are site fidelity, primarily expressed with respect to calving grounds and summer pastures (Helle 1980a, Schaefer *et al*. 2000).

Although semi-domesticated reindeer mainly use the same habitats as their wild ancestors, reindeer herders have had a considerable influence on reindeer habitat selection. This presupposes that the reindeer are herded, *viz*. kept under control. In full nomadism, herding was

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self-evident throughout the year, but herding in winter continued when associated with permanent settlement. Herding has been necessary to protect reindeer against large predators, and to prevent the reindeer from moving into the area of neighbouring herding associations (Itkonen 1948, Kortesalmi 1996), as well as causing damage to agricultural fields or stored hay (Reindeer Management Act 1932). In addition, herders were ready with their herds for the seasonal migrations and to respond, within the winter pastures, to changes in local food availability by moving to more suitable areas (Itkonen 1948, Beach 1981: 92–93).

The herders, as well as anthropologists, have traditionally divided herding into two forms, intensive and extensive (Tomasson 1918, Ruong 1964, Hultblad 1968, Beach 1981: 34–36, 499–500). Furthermore, in northern Finland herding has to a great extent been replaced by a free-ranging system (Kortesalmi 1996) or ranching (Ingold 1980), in which reindeer was gathered only twice a year. Supplementary feeding started in the southern half of the Finnish reindeer management area in the late 1960s, spread rapidly towards to the north, and has had a drastic impact on management routines (Helle & Saastamoinen 1979, Nieminen & Autto 1989, Kumpula *et al.* 1998).

According to Ruong's (1964) basic definition, the form of herding is the product of inter-relationships between land, reindeer and man. Thus the transition in herd management might be linked to the changes in these inter-relationships. Ruong's (1964) "land" comprises various aspects of grazing conditions, including the impacts of reindeer grazing and other forms of land use. First of all, the herding form has to be adapted to the fragmented grazing lands associated with modern forestry (Beach 1981: 267). In northern Finland, the diverse conflict between reindeer management and forestry goes far back in history. Up until the beginning of the 20th century, reindeer herders felled trees rich in arboreal lichens for reindeer ("reindeer cuttings") in mid and late winter in the southern part of the reindeer management area (Kortesalmi 1996), which is a practice that the forest authorities and foresters considered to be a waste of wood (Metsähallitus 1907, Heikinheimo 1920). From the early 1960s onwards, reindeer herders have blamed that cuttings cause damage to the most important winter pastures (Aikio 1975, Sipilä *et al.* 2000, and Annual reports of the herding associations of Ivalo and Hammastunturi). That is in agreement with the findings that semi-domesticated reindeer and wild rangifers dwelling in forest areas prefer in winter mature or old-growth forests, irrespective whether the animals are feeding upon reindeer lichens (*Cladina* ssp.) or arboreal lichens (Chichowsky 1989, Helle *et al.* 1990, Goward 2000, Kumpula *et al.* 2007).

The purpose of this study was to describe the forms of herding in use at different times and in different areas, to identify relevant factors and changes in such factors using Ruong's (1964) "herding triangle" as a frame, and to evaluate their relative importance for the intensity of herding and development of supplementary/corral feeding in northern Finland. In order to avoid the confusion caused by the historically and geographically variable use of the terms "intensive" and "extensive" herding (Ruong 1964, Beach 1981: 509–510), we applied the theory of hierarchical habitat selection (Apps *et al.* 2001, Rettie & Messier 2000, Johnson *et al.* 2002) in describing the herding form. The study covers the period from the 1930s to the 1980s, and is based on interviews with elderly reindeer herders. In economic terms, the form of herding is primarily determined by the size of the investment *versus* the return (Beach 1981: 333, 474–476). As result, we suggested that intensive herding changes to more extensive herding in conditions where occurrence of large predators, straying of reindeer into foreign areas, and damage to stored hay, no longer cause any considerable costs to reindeer management, or side-jobs provided higher incomes than intensive herding. In addition, we examined the effect of the condition of winter pastures and forestry-mediated changes in forest structure on the transition process and on the development of supplemental/corral feeding.

Background of the study

Herd-management practices

In Finland, reindeer husbandry reached approximately its present distribution — the northernmost third of the country — during the 18th century (Kortesalmi 1996). In 1898, the Senate of Finland decreed that the reindeer husbandry area must be divided into herding associations, each responsible for the proper management of reindeer in its own area. A total of 65 herding associations were established, each having precisely defined borders (at present the number is 56) (Fig. 1). Every reindeer owner is a member of the local association, although the reindeer are owned individually. As regards pasture use and institutional systems, the organisation is based on the Finnish model, while some of the herding associations in the Saami area in northernmost Lapland (communities of Utsjoki, Inari and Enontekiö) have followed their own old system, in which the reindeer are managed by smaller collective units, *siidas*.

The greatest threats in traditional reindeer management were large predators, reindeer straying into foreign areas, and damage caused by reindeer to agricultural fields and stored hay. All these threats required the herd to be kept under control or the problems to be solved by other means (Itkonen 1948, Kortesalmi 1996). R. Helle (1966) described in detail the annual rhythm of reindeer management, with its range of different activities. The most drastic change since Helle's publication is, in addition to the introduction of snowmobiles, that hay making in mid-summer has been a normal summer activity of reindeer herders, especially in the southern half of the area ever since the early 1970s.

Data on the numbers of large predators are based, especially in earlier days, on bounty statistics (Pulliainen 1965, 1974, Siivonen 1972, E. Nyholm unpubl. data). The state started to pay bounties for killed large predators in the middle of the 19th century, first in southern and central Finland but, by the end of the 19th century, also in northern Finland. This continued up until 1975, when the bounties were replaced by compensation paid by the state for domestic animals killed by large predators.

In the beginning of the 20th century the number of wolves (*Canis lupus*) in the whole of Finland amounted to a few dozen individuals (Pulliainen 1965) and, according to the bounty statistics, wolves were almost totally absent in northern Finland up until the end of the 1930s. Reindeer kills by wolves were reported at the end of the 1930s and early 1940s, followed by clear peaks in the late 1940s and early 1950s, the beginning of the 1960s and the middle of the 1970s. In 1975, the state paid compensation for a total of 557 reindeer killed by wolves, most of them in herding associations located close to the Finnish–Soviet Union border.

In the beginning of the 20th century, wolverines (*Gulo gulo*) occurred regularly only in the eastern and northern parts of Lapland. Annually bounties were paid for about 20 wolverines up until the 1940s. In 1951 and 1952 the number of bounties amounted to between 40 and 80, after which they stabilized to about 40 around the middle of the 1970s. In 1975, the number of reindeer killed by wolverines totalled 204, most of them in northern or northeastern Lapland (E. Nyholm unpubl. data).

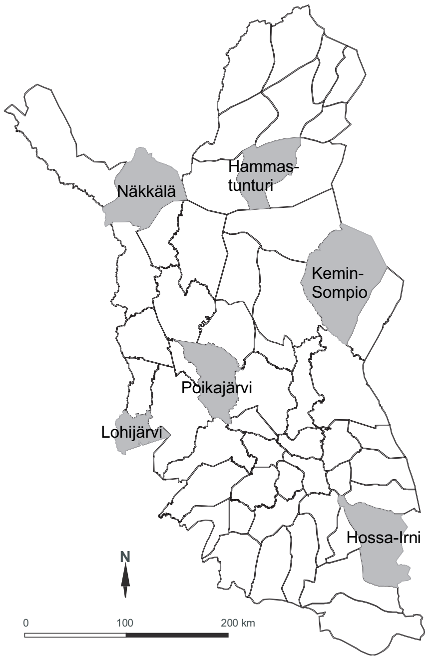

Fig. 1. The Finnish reindeer management area and the study herding associations.

The Reindeer Management Act (1932) stipulated that reindeer had to be managed in the area of their own association. The primary aim of the law was to prevent the intentional use of the pastures of a neighbouring herding association but, due to widely roaming stray animals, the law also stipulated how the reindeer found in roundups of neighbouring herding associations were to be managed. These orders included, for instance, so called "redemption payment", which the herding association was charged for the extra work done with their reindeer. The aim of this practice was to ensure that reindeer that had strayed into foreign areas were reported to the reindeer owner or herding association in question. Very little is known about the occurrence of reindeer thefts, although it is commonly mentioned as one reason for herding (Paulaharju 1922, Kännö 1992, Kortesalmi 1996, Alapuranen 2003).

In addition to herding, the fences built along the state borders and between herding associations served to keep the reindeer in their own area. The fence along the Finnish–Soviet Union border was built already in the beginning of the 20th century, and along the Norwegian and Swedish borders in the middle of the 1950s. In northernmost Lapland most of the herding associations were fenced during the 1960s, whilst in the southern half of the reindeer management area fencing has been uncommon.

It is a common assumption that one of the limiting factors in the old management systems based on intensive herding was labourious. The history of reindeer husbandry is full of anecdotes about how a relatively rich herder became poor when he got older, because he could no longer keep the herd under control (Paulaharju 1922, Kännö 1992). In open or semi-open terrain, the optimal herd size in relation to food availability and labour requirement ranged between 1500–3000 reindeer, although herds of up to 7000 were reported (Itkonen 1948). In normal snow conditions an average-sized herd required two men, possibly with dogs, for the daily herding activity. In difficult snow conditions, or if there was a threat from wolves and wolverines, more herders were needed and herding was necessary also during the night. More labour was needed when the reindeer were fed on the arboreal lichens of felled trees. Trees were felled for reindeer in mid and late winter especially in the southern and southeastern parts of the reindeer management area during the late 19th and early 20th century (Heikinheimo 1920, Kortesalmi 1996).

In Finnish Lapland, intensive winter herding was commonly associated with leach-calving. The female reindeer were tethered to trees or small logs, and each day were moved 2–4 times to an area with fresh, lichen-dominated vegetation. The newborn calf was earmarked just after the birth and the female with her calf was released. Leach-calving started in April and ended in mid-June (Hannula 2000). One man could manage about 100–150 reindeer, or possibly less (Hannula 2000). Leach-calving was a widespread practice in the middle and northern parts of the reindeer management area until the beginning of the 20th century, and continued in northeastern Lapland up until the 1960s (Hannula 2000). In the 1970s a system was developed for use together with supplementary/corral feeding, in which calving took place in yard corrals (southern area) or large calving corrals (northern area) in natural pastures, where the reindeer received some supplementary food, usually dry hay. The latter system was characteristic especially in Inari.

The "snowmobile revolution", which took place in the northern part of the reindeer management area in the early–mid-1960s, reduced the amount of manpower needed in herd management and altered the reindeer–man relationships (Pelto *et al*. 1968, Pelto 1973). Tight, continuous control over the herd became unnecessary because the animals could be gathered together, when necessary, by snowmobiles with less manpower than earlier. Another novel feature has been supplementary feeding with dry hay in winter, starting in the southern part of the reindeer management area around 1970 and spreading rapidly towards the north (Helle & Saastamoinen 1979, Nieminen & Autto 1989).

Forestry

The commercial use of forests in northern Finland started in the latter part of the 19th century (Pohtila 1979). The saw, pulp and paper mills were located on the coast. The main pressure in commercial cuttings was initially on the easily accessible, dry upland forest sites along the rivers running into the Gulf of Bothnia. The low average growth and yield of these "natural" forests, reported by the 1st and 2nd National Forest Inventory (in the years 1921–1924 and 1936–1938, respectively), was a consequence of the high proportion of over-aged forests from the viewpoint of forestry. At that time, only 14% of the forests in northern Finland were less than 80 years old and the forests, over-aged from the viewpoint of wood production (Mattila 1979), covered more than 50% of the forested land area.

Forest use intensified after WWII due to the ceding of Finnish territory and the payment of war indemnities to the Soviet Union, and the need to rebuild the country's infrastructure. As compared with the pre-war period, the amount of cuttings doubled. From the late 1940s onwards, the seed tree and shelter wood cutting methods replaced selective cuttings based on minimum diameter, and clear-cuttings requiring seeding or planting also became more and more important (Pohtila 1984). The main cutting pressure was still on the forests located along rivers and brooks that made floating possible (Pohtila 1979). In the 1950s and 1960s chain saws, tractors, lorries and mechanized road construction techniques removed the "zero limits", and transportation of the timber became economically profitable even from the most remote areas.

In the 1960s, the main goals of the forestry programs in northern Finland were to regenerate, at a relatively fast rate, the old forests into young Scots pine (*Pinus sylvestris*) stands. The establishment of new processing plants by the timber industries, or enlargement of the old ones, set new goals on wood production. As a consequence, large clear-cutting areas appeared in northern Finland accompanied, except on the driest sites, by soil scarification (Pohtila 1979). The changes in the age structure of the forests in northern Finland are given in Fig. 2.

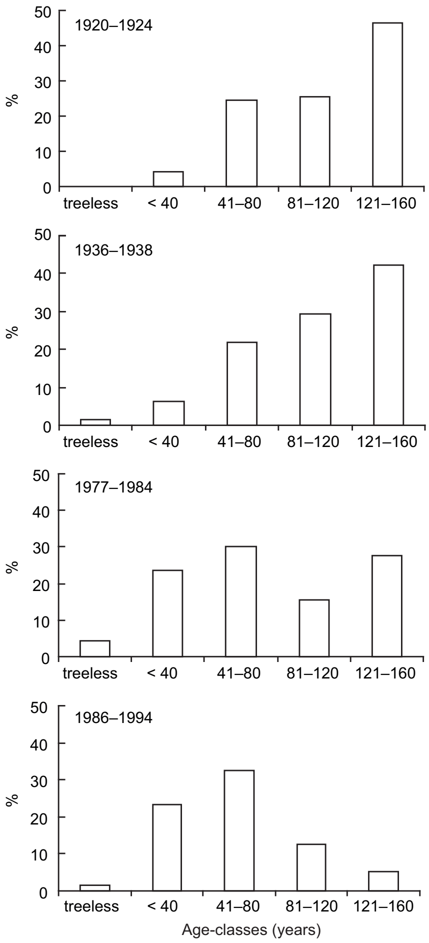

Fig. 2. The age structure of forests in northern Finland according to four national forest inventories between 1920–1924 and 1986–1994. Data covers the counties of Lapland and Oulu, from which 44% belong to the reindeer management area. Sources: Ilvessalo (1927, 1948), Kuusela *et al.* (1986) and Tomppo *et al.* (2001).

Material and methods

Study herding associations

This study describes the management practices and transitions in six herding associations in northern Finland (Fig. 1). The associations were not randomly selected, but the aim was to find herding associations that represented the "typical" herding association in each region. In these herding associations, especially Hossa-Irni

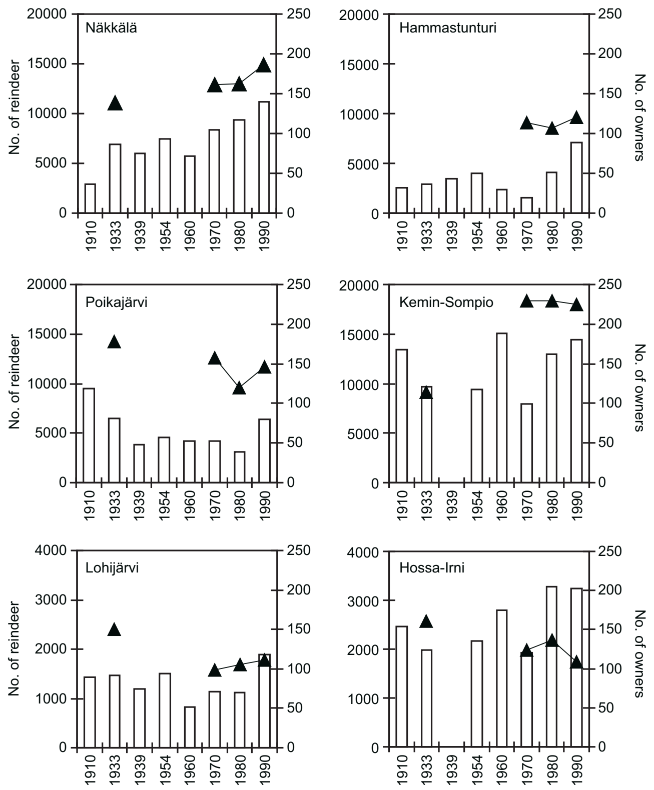

Fig. 3. The number of reindeer (colums) between 1910 and 1990 and the number of reindeer owners (triangles) at four points of time in the study herding associations in northern Finland. Source: Reindeer Herders' Association (Paliskuntain Yhdistys) and Anon. (1934).

(Kortesalmi 1996) and Lohijärvi (Holster 1948), there is more old literary information available than for most of the other herding associations. The neighbouring herding associations are, in general, very similar to each other as regards the natural conditions, reindeer density, reindeer per owner, as well as herding practices (Keisarillinen porolaidunkomisiooni 1914, Helle *et al.* 1980, Nieminen & Autto 1989), and therefore the results can be generalized over larger areas.

Two of the study herding associations, Näkkälä and Hammastunturi, are located on and around the coniferous forest line, which comprises both Scots pine forests and fell tops. Most of the herders are Saami. In the other herding associations the reindeer are owned and managed by Finnish people with the exception of the reindeer owners in Lohijärvi, who still in the beginning of the 20th century considered themselves to be forest Saami, who moved from Sweden to Lohijärvi in the 1830s (Holster 1948). Data on the number of reindeer owners are available from 1933 (Anon. 1934) and 1967 onwards (Reindeer Herders' Association) (Fig. 3). The number of owners reached a maximum in the three southern herding associations (Hossa-Irni, Lohijärvi and Poikajärvi) in 1933, whereas in Kemin-Sompio and Näkkälä (data for Hammastunturi lacking) the number were higher in recent decades (Fig. 3). The average herd size for the whole period was lowest in Lohijärvi (11) and Hossa-Irni (15), and ranged in the four northernmost associations between 29 and 41. One should note, however, that the number of reindeer per household has been considerably higher, because often all the family members, including children, had their own earmark and are therefore treated in the statistics as reindeer owners. With few exceptions, there were full-time herders only in Kemin-Sompio, Hammastunturi and Näkkälä; elsewhere reindeer husbandry has been a subsidiary livelihood combined with small-scale agriculture, dairy farming, fishing and forest work, and most of the herders also had their own forests.

The reindeer numbers in Lohijärvi, Hammastunturi and Näkkälä peaked around 1990, in Poikajärvi already in 1908, and in Kemin-Sompio in 1960 (Fig. 3). When the reindeer numbers are compared over the decades one should note that, still in the 1960s, the numbers were obvious underestimates (Alaruikka 1964). All the reindeer, spread out in the remote wilderness, were simply not found, or else confused animals could not be driven over long distances to round-up corrals; the latter case was characteristic in the 1960s during the "snowmobile revolution" (Pelto 1973, Lenstra 1975).

The reindeer numbers in relation to the total land area and area with lichen-rich land (Kumpula *et al*. 1997) are presented in Table 1. In two herding association the borders changed during the study period. Hossa and Irni, which had originally been separated, were joined in the 1950s. In order to make the reindeer numbers comparable, the reindeer numbers for Hossa and Irni were summed. Hammastunturi, in contrast, was separated from Inarin Kyrö in the 1950s, and attained its present borders in the 1960s. The reindeer numbers for earlier times are based on the assumption that the number of animals in the present Hammastunturi herding association has been proportional, with respect to the area, to the number in earlier larger units.

The gross reindeer density increases, but the density per lichen pasture decreases, on moving from the south to the north due to fact that the proportion of lichen-rich land increases along the same gradient (Mattila 1981) (Table 1).

The cuttings peaked in Turtola-Ylitornio (Lohijärvi) and Raudanjoki (Poikajärvi) already during the 1950s, and in Ylikemi (Kemin-Sompio) and Inari (Hammastunturi) 10–20 years later (Fig. 4). In Näkkälä, coniferous forests occur only on the southern edge of the area, and therefore the volume of cuttings was relatively low. Kuusamo differs from the other southern areas, since most of the forests were located, up until the 1950s, beyond the "zero limit"; the cuttings peaked there in the middle of the 1960s.

Table 1. Reindeer density (summer herd) calculated for land area (Density 1) and area of lichen pasture (Density 2) (Kumpula *et al*. 1997) in the study herding associations in northern Finland in 1910–1990. Pasture quality (condition of lichen vegetation): + = poor; ++ = moderate; +++ = good; – = lacking data (Keisarillinen porolaidunkomisiooni 1914, Paliskuntain yhdistys 1935, 1962, Kärenlampi 1972, Helle 1980b, Mattila 1981, 1998).

Herding association		1910	1933	1939	1954	1960	1970	1980	1990
Hossa-Irni	Density 1	0.7	0.6		0.6	1.0	0.7	1.2	1.2
	Density 2	5.4	4.4		4.7	7.7	5.3	9.0	8.9
	Pasture	++	++			+		+	+
Lohijärvi	Density 1	1.0	1.0	0.8	1.1	0.7	1.0	1.0	1.6
	Density 2	12.7	13.1	10.6	13.4	9.1	12.6	12.4	20.9
	Pasture	+	+			+		+	+
Poikajärvi	Density 1	3.1	2.1	1.3	1.5	1.7	1.7	1.3	2.7
	Density 2	19.2	13.1	7.9	9.3	10.6	10.6	7.9	16.2
	Pasture	++	–			+		+	+
Kemin-Sompio	Density 1	1.9	1.4		1.3	2.6	1.4	2.3	2.5
	Density 2	11.8	8.6		8.3	16.6	8.8	14.3	16.0
	Pasture	+++	+++			++		+	+
Hammastunturi	Density 1	1.0	1.1	1.3	1.5	1.1	0.7	1.9	3.3
	Density 2	3.3	3.7	4.4	5.2	3.8	2.5	6.5	11.4
	Pasture	++	++			++		++	–
Näkkälä	Density 1	0.7	1.7	1.4	1.8	1.7	2.5	2.8	3.4
	Density 2	2.2	5.3	4.5	5.7	5.4	8.0	8.9	10.6
	Pasture	++	–			++		++	–

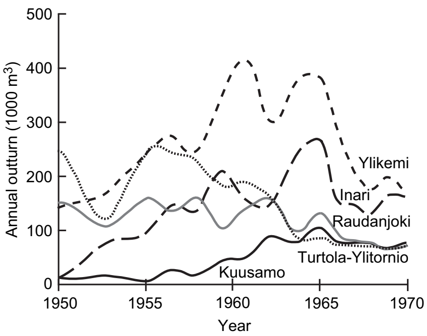

Fig. 4. The annual outturns in 1949–1970 in the forest districts of Forestry Board (Metsähallitus) covered by the study herding associations. Inari (Hammastunturi), Ylikemi (Kemin-Sompio), Raudanjoki (Poikajärvi), Turtola-Ylitornio (Lohijärvi) and Kuusamo (Hossa-Irni). Source: Metsähallitus 1948–1970, no. of register 510: 2.

Interviews with reindeer herders

We interviewed a total of 12 reindeer herders. Most of them had been involved in the management of reindeer for more than 50 years, and they all held important positions (foreman or a member, vice chairman or chairman on the board of the herding association) in the organization of the herding association, reserved for the most active professional herders (Table 2). Some of them also belonged to the board of the Reindeer Herders' Association, the highest decision-making body in reindeer management. If more than one person was interviewed in the same herding association, then the interviewees represented different *siidas* i.e. teams.

Our approach was based on qualitative content analysis (Slater 1999). The questions posed to the interviewees (Table 3) were aimed to describe the herding methods and other management practices, and to identify the environmental, socio-economic and technological factors influencing these practices. The interviewees were encouraged to tell about things related to the actual question in order to ensure that all essential aspects were included. The interviews, which were recorded and transcribed, were carried out at interviewees' homes. An interview lasted about 5 hours.

Table 2. Information on the reindeer herders interviewed in sex herding associations in northern Finland. Abbreviations: HA = herding association, RHA = Reindeer Herders' Association.

No.	Name	Herding association	Year of birth	Herder since	Occupations	Duties in reindeer management
1	Veikko Väisänen	Hossa-Irni	1925	1941	Reindeer husbandry, farming	Head of HA in the 1970s, on the board of RHA in the 1970s and 1980s
2	Mikko Holster	Lohijärvi	1916	1932	Reindeer husbandry, farming	Head of HA > 25 yrs in the 1950s-1970s
3	Martti Mustonen	Poikajärvi	1926	1941	Reindeer husbandry, farming	On the board of HA 1968-85, before that foreman
4	Jouko Mustonen	Poikajärvi	1938	1956	Reindeer husbandry	Head of HA 1975–1981, vice head 1981–1987
5	Kauko Hannula	Kemin-Sompio	1931	1947	Reindeer husbandry	Foreman in the 1950s and 1960s, > 20 yrs on the board of HA since 1968
6	Voitto Leskisenoja	Kemin-Sompio	1932	1945	Reindeer husbandry	Foreman in the 1950s–1960s, on the bord of HA in 1960s and 1970s
7	Matti Merivirta	Kemin-Sompio	1937	1951	Reindeer husbandry	Foreman 14 yrs in the 1960s and 1970s
8	Yrjö Mattus	Hammastunturi	1930	1945	Reindeer husbandry	On the board of HA several 3 yrs periods since 1968
9	Olavi Magga	Hammastunturi	1931	1945	Reindeer husbandry	On the board of HA in the 1960' and 1970s
10	Juhani Magga	Hammastunturi	1939	1955	Reindeer husbandry	Head of HA 1983–1990, on the board of RHA 16 yrs., of which 13 yrs as a vice chairman
11	Juhan-Taneli Magga	Näkkälä	1931	1946	Reindeer husbandry	Head of HA in the 1970s, on the board of RHA in the 1980s
12	Esa Kumpulainen	Näkkälä	1943	1956	Reindeer husbandry	On the board of HA since 1968, vice head from the 1990s

In qualitative content analysis it is known that the concepts and terms used by the interviewer influence the answers of the interviewees (Slater 1999). Therefore in the interviews we did not use the terms for various herding forms (intensive, *tiukka* in Finnish; extensive, *löyhä*; free-ranging, *vapaa laidunnus*), because their meaning has varied with time and geographic area (Ruong 1964, Beach 1981: 509–510). The form of herding was determined afterwards based on the descriptions of the interviewees by applying the theory on hierarchical habitat selection (Apps *et al*. 2001, Rettie & Messier 2000, Johnson *et al*. 2002).

In the most intensive herd-management practices the herder regulated the foraging decisions of the reindeer at the patch scale. At the herd level, herding was considered intensive if the reindeer were not allowed to disperse over an area wider than that which two men could ski around daily and turn back reindeer trying to leave the herd. The radius of such an area was maximally a few kilometers (Itkonen 1948) and corresponded to the landscape level, or part of it, in hierarchical habitat selection.

In extensive herding the herd is dispersed over a wider area and is no longer under the constant control of the herders (Beach 1981: 499–508). The aim is to keep the reindeer within a given part of the area of the herding association, and this corresponds to intervention by the herder at the level of several landscapes or of the region. In a free-ranging system (Ingold 1980, Kortesalmi 1996), the reindeer roam freely in small herds, except during short periods of calf marking in mid-summer and round-ups in autumn–winter. In Finland, the area of a single herding association varies between 470 and 5690 km^2 (Reindeer Herders' Association), but each individual reindeer does not necessarily use the whole area.

In herding by snowmobiles, the herd is commonly allowed to spread out over an area comprising several landscapes, but it can be gathered together in one or some few days, as was the case in intensive herding on skies. In this study we classify such a herding as extensive, i.e. corresponding to habitat selection at the level of several landscapes. When reindeer were given supplementary fodder on natural pastures in mid and late winter, the reindeer gathered voluntarily at the feeding places. As the hay was normally spread along the snowmobile trails crossing several landscapes, we also call such a herding practice extensive herding.

The distribution of the reindeer is not the only difference between intensive and extensive herding. The time devoted to managing the rein-

Table 3. Questions presented for the reindeer herders at the interviews in six herding associations in northern Finland.

Herding	Pastures	Change	Adaptation
Herding before WWII	Condition of the pastures reindeer lichens and arboreal lichens	At what time intensive herding ceased?	How has reindeer husbandry adapted to various changes?
Herding after WWII	When were reindeer lichens used?	What was the role of large predators?	
When and how were the reindeer herded?	When were arboreal lichens used?	When were the fences between the herding associations built?	
Why were the reindeer herded?	Were trees cut down for reindeer?	What was the role of man-power and snowmobiles?	
How many men were needed?	Did reindeer graze on cutting areas?	When did supplementary/corral feeding start and which were the reasons?	
Were the reindeer fed? How?	Were the reindeer assembled in the forest felling areas?	How were the reindeer fed?	

deer increases the tameness grade of the reindeer (Beach 1981: 430). In extensive herding using supplementary feeding, the reindeer are as tame or even tamer as in old kind of intensive herding, although contacts between the herders and animals might be less frequent. Supplementary feeding is used also in the free-ranging system. Reindeer can still select their pastures freely, and hay is transported to areas selected by the reindeer.

The analysis was continued by connecting the form of herding to various environmental, economic and technological factors, such as those described by the interviewees. In the interpretation of the results, we attempted to evaluate the relative importance of the various factors and the variation in them.

Results

Old intensive herding

The interviewees had personal experience of intensive herding, except in Hossa-Irni. Otherwise the management practices were rather similar despite the considerable differences in environmental conditions. Gathering the reindeer for round-ups normally started in November, and the largest round-ups were arranged in January–March. The reindeer were kept in separate herds in order to prevent the counted and uncounted animals from becoming mixed. After the round-ups, each *siida* i.e. herding team moved with their reindeer to their own winter grounds with lichen pastures, keeping the herd together until calving was over or the females were taken for leach-calving.

Dogs were used regularly in the three northernmost areas and, to a lesser extent, also in Lohijärvi and Poikajärvi. In Näkkälä, Hammastunturi and Kemin-Sompio, the herd was moved once a week to a new area with an undisturbed snow cover. Thus the reindeer were kept in better condition and the movement also served, as mentioned by the interviewees, pasture rotation, *viz.* an area grazed by reindeer during the winter was left outside the grazing range for a number of consecutive years in order to give the lichen vegetation time to recover.

In Näkkälä, both interviewees told that, during difficult snow conditions, the herders assisted the reindeer to crater down to the ground vegetation, even for as long as one month: the herders started the feeding craters with a shovel, allowing the reindeer to widen the feeding holes by themselves (int. 11, 12). The same was done, if needed, in leach-calving in Kemin-Sompio (int. 5, 6, 7). There, the females were taken into leach on the average on 8 April, when the ice-crust period was still to come. Arboreal lichens were also used to keep the reindeer in the herd by felling single, less valuable trees or, more commonly, by cutting off dead branches rich in arboreal lichens from the trees onto the snow. This was practiced in every herding association involved in this study, in the southern areas more commonly than in the northern ones.

Depending on the snow conditions, intensive herding could be changed into extensive herding or the free-ranging system. The best-known case is Lohijärvi (int. 2, Holster 1948), where "bad winters" occurred in 1893–1968. Icing in early winter or deep and hard snow in mid-winter caused problems for the reindeer in 15 winters, six of which (1911/1912, 1935/1936, 1939/1940, 1948/1949, 1954/1955 and 1968/1969) were considered "famine years" due to the high winter mortality and a low calf crop. In "bad winters" the reindeer were allowed to disperse and feed on arboreal lichens, although they were intensively herded in "normal winters" before WWII. However, in April–May the reindeer gathered in their normal calving ground, where they were taken under control and managed as one herd until August. In summer female reindeer were milked up until the late 1930s (int. 2), which was at that time completely exceptional outside the Saami area in northernmost Lapland.

In Kemin-Sompio the reindeer were released from intensive herding in February–March in four winters during 1942–1964 due to the excessive snow conditions, which prevented access to reindeer lichens and caused failure in leach-calving (int. 5, 6, 7). Even in "normal" winters reindeer attempted to disperse to seek arboreal lichens (mainly in old Scots pine forests) that dropped onto the snow after winter storms (int. 7). In Näkkälä and Hammastunturi, an occasional thick and hard snow cover in the forest pastures was avoided by taking the reindeer to the adjacent fells, where food availability was better on the wind-swept slopes (int. 8, 9, 10, 11, 12). The herd was allowed to disperse over a wider area than in intensive herding. However, if an ice layer covered the fell pastures, reindeer were allowed to disperse for feeding on arboreal lichens; in the northern *siida* of Näkkälä even mountain birch forests were considered important (int. 12).

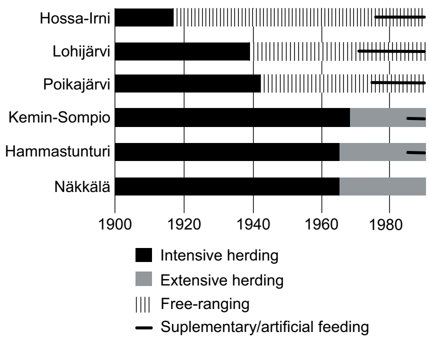

Fig. 5. Transitions in the herd-management of semi-domesticated reindeer in the study herding associations in northern Finland in 1900–1990.

Extensification of herding

The transition from intensive herding to more extensive practices took place during a time span of about 40 years, starting in the late 1910s in the Hossa-Irni herding association, and in the northern herding associations in the 1960s (Fig. 5). In the three southern herding associations intensive herding changed abruptly to the free-ranging method, whilst in the north intensive herding was replaced by extensive herding based on the use of snowmobiles. In Lohijärvi and Poikajärvi the transition from intensive herding to the free-ranging system took place during wartime (1939–1945). In Kemin-Sompio intensive herding ceased during wartime, because it was located in the frontline area occupied by Finnish, German and Soviet troops.

As regards the protection of reindeer against large predators, it was a common experience among the interviewees that the "worst killer" was the wolf, followed by wolverine. Losses caused by wolverines to herded reindeer were generally rather small, whilst dispersed reindeer were easy prey for wolverines (int. 1, 7). Nevertheless, the transition was not directly related to the decline in the numbers of wolves and wolverines. In the beginning of the 20th century, wolves were absent but wolverines rather common in Hossa-Irni. Lohijärvi and Poikajärvi were the only areas that were practically predator-free prior the transition, and the occurrence of wolves and wolverines was occasional already in the 1920s and 1930s. In Kemin-Sompio, Hammastunturi and Näkkälä, wolverines were a constant threat to the reindeer in the beginning of the 1960s during the time of extensification of intensive herding. Predator peaks, such as that in Hossa-Irni in the mid-1960s (11 wolves killed in one winter) or in Kemin-Sompio in the late 1960s and early 1970s (a lot of wolverines), did not result in return to intensive herding. In Hossa-Irni, the development of corral feeding in the 1980s was, at least partly, associated with the high predator risk in areas close to the Soviet border (int. 1).

In those herding associations where transition took place despite a prevalence of wolves and especially wolverines, many herders used the time released from herding for predator control, which was encouraged by "killing payments" paid by both the state and the herding association (int. 7). Therefore, professional hunters also participated in predator control, before the state began to compensate in 1975 for the losses caused by large predators. The wolverine has been protected since 1979, but there is still a hunting season for wolves.

The importance of fencing as a necessity in transition was variable. Hossa-Irni and Kemin-Sompio had fences along their borders already in the beginning of the 20th century, or at least in the most critical directions (the eastern national border), and they were considered to be an important factor making the transition possible (int. 1, 5, 6, 7). During the time of transition during WWII, Lohijärvi and Poikajärvi had no fences on the borders of the herding association (int. 2, 3). In Näkkälä and Hammastunturi fences were built in the beginning of the 1960s, which the interviewees considered to be an important factor that made intensive herding unnecessary.

As regards runaway reindeer, the interviewees in the three southern reindeer associations told that it was an old rule that foreign reindeer must be handled as one's own animals (int. 1, 2, 3, 4). It was a common practice, also elsewhere, that the herding associations sent their representatives to the round-ups of neighbouring associations, where they decided what do with their reindeer. In Näkkälä, both interviewees (int. 11, 12), representing different *siidas*, admitted that the disappearance of reindeer was a constant problem requiring intensive herding in old times. Later on, extensive herding and edge guarding (*see* Beach 1981: 500) with aid of snowmobiles at border areas was needed in order to keep the reindeer within the area of the *siida*; fences did not separate these from each other. Both indicated that reindeer which were not looked after could disappear. This was the main reason why the herders did their utmost still in the 1970s to prevent the dispersal of reindeer to look for arboreal lichens (int. 11). However, if extensification of herding was necessary in order to prevent starvation of the reindeer, edge guarding by skiing or later by driving snowmobiles was used to prevent movement into foreign areas (int. 11, 12).

None of our interviewees considered that the protection of hay piled in open fields required intensive herding since WWII. Agricultural fields were fenced, if needed.

The work involved in herding has played an important role in transition. The lack of manpower during the war (1939–1945) left the reindeer practically unmanaged for years. In Lohijärvi and Poikajärvi the herders did not return to pre-war intensive herding. Interviewees in both herding associations told that rebuilding the devastated county and forest work offered a better income than the strongly reduced reindeer herds (int. 2, 3). In Kemin-Sompio, in contrast, most of the herders returned to pre-war routines, including leach-calving, despite the drastic reduction in the number of reindeer. One interviewee (int. 7) told that his father-in-law had 890 reindeer before the war, but only 90 were left after the war. Similarly, in Näkkälä and Hammastunturi herding was intensified after the war.

Transitions in relation to pasture conditions and forestry

In Hossa-Irni, the early and abrupt transition from intensive herding to the free-ranging system was caused by the loss of extensive, good lichen pastures on the Russian side of the border when Finland became independent in 1918. That was told to our int. 1 by older reindeer herders who had been involved in the management of reindeer during that time (*see* also Kortesalmi 1996). The accepted free ranging system did not mean that the reindeer were totally left on their own: their food availability, as well as the movements of wolves and wolverines, was followed.

In other study herding associations our interviewees had their own experiences of the transition from intensive herding to more extensive herding forms, but the comments on the importance of the condition of lichen pastures were rather few. However, it was a common observation that lichen vegetation recovered due to the decline in the reindeer population during WWII. Despite this, the herders in Lohijärvi and Poikajärvi did not return to intensive herding after the war (int. 2, 3, 4).

In Kemin-Sompio, the three interviewees considered forestry as the main reason for the cessation of intensive herding and associated leach-calving, which took place within a few years in the beginning of the 1960s (int. 5, 6, 7). The best lichen pastures were located along the largest rivers (Pihtijoki, Kairijoki, Kemijoki, Värriöjoki), where there was a relatively thin snow cover as compared with that on the surrounding hills. Forestry with large clear-cuttings started in the beginning of the 1950s, and cutting advanced rapidly through the riverside forests where there were good opportunities for floating. According to the interviewees, reindeer did not stay in clear-cutting areas because of compaction of the snow.

Despite strong herding efforts (still without snowmobiles), reindeer escaped to neighbouring extensive felling areas to feed on arboreal lichens or dispersed into the surrounding upland areas with deeper snow, but lesser lichens, making intensive herding impossible. In addition, the most traditional leach-calving sites located along the riversides could not be used because of cutting residues (int. 7).

The later years were described as "chaotic" due to the loss of the best lichen pastures in combination with high reindeer numbers (Fig. 3), "bad winters", and difficulties in using snowmobiles to gather the reindeer. In addition to which, calf-marking had to be organized in a new way, *viz*. by calf-marking round-ups in mid-summer (int. 5). These problems were partly solved in the late 1960 by the construction of a new fence along the northeastern edge of the area of the herding association. The old fence to prevent reindeer straying into the Soviet Union, located about 10 km from the border, was replaced by a new one built close to the border. The new pasture area had been ungrazed since the late 1930s and only extensive herding was needed to keep the reindeer within the area. During the 1980s a new winter pasture area, about 630 km^2 in size, was fenced in the northern edge of the herding association in the Urho Kekkonen National Park (int. 7). Outside these actual winter pastures the reindeer lived in small herds looking for uncut patches in the fragmented forest landscape (int. 5, 6, 7).

All the interviewees unanimously stressed the negative impacts of forestry. Heavy criticism was levelled especially against the large clear-cuttings from the late 1940s onwards, and soil scarification, which was introduced during the 1960s. In Hossa-Irni, Lohijärvi and Poikajärvi the interviewees drew attention to the loss of old forests rich in arboreal lichens. The interviewee from Hossa-Irni (int. 1) told that reindeer never faced a food shortage as long as there were uncut forests rich in arboreal lichens, even in conditions where access to ground lichens was occasionally prevented by icing already in early winter. This reduction of arboreal lichens was also mentioned in the northern herding associations studied, but there the negative impacts of cuttings on the abundance of reindeer lichens were considered to be even more important.

Until the 1970s, most of the commercial cuttings were carried out in wintertime and this provided arboreal lichens for reindeer. In Kemin-Sompio cuttings were considered negative even from this point of view, because they attracted reindeer and thus made herding difficult, resulting in failure in leach-calving. In contrast, in the more southern study areas "the noise of the chainsaw was the dinner bell for reindeer", and the reindeer were also gathered intentionally into cutting areas (int. 1, 3, 4). On cutting areas, however, falling trees frequently killed reindeer. Therefore interviewees from the three southernmost herding associations pointed out that reindeer herders also worked as forest workers, being able to advise the less experienced workers about how to avoid such situations.

Supplementary/corral feeding

Supplementary feeding with dry hay was carried out in Lohijärvi and Poikajärvi for the first time in winter 1968–1969 (int. 2, 3, 4), which was characterized by exceptionally difficult snow conditions. Even so, the winter mortality was high. In winter 1972–1973, the snow conditions were even worse in the northern half of the reindeer management area. Dry hay was also used in Kemin-Sompio and Hammastunturi to prevent starvation. As mentioned by the interviewees, these were the first occasions when dry hay could be used for reindeer. Earlier all the hay was needed for cattle. As int. 1 expressed it: "The wife would have gone on strike if the hay had been given to the reindeer". The acute need for supplementary feeding was triggered by the difficult snow conditions, but it was underlined, especially in the three southernmost herding associations, by the loss of arboreal lichens due to cuttings.

Winter-feeding rapidly developed into a normal practice. In order to be prepared for bad conditions in the coming winter, hay had to be harvested every summer and hay was used even though supplementary feeding would have not been necessary; hay could not be stored until the following winter. In Lohijärvi, most of the reindeer were gathered into feeding corrals for 2–4 winter months since the late 1970s (int. 2), whilst Hossa-Irni and Poikajärvi invested more in supplementary feeding on natural pastures up until the 1980s. In corral feeding, the reindeer received, in addition to hay, dried birch (*Betula pubescens*) leaves, reindeer lichens (purchased from the area south of the reindeer management area) and commercial reindeer feed. During the 1980s, some teams or *siidas* in Kemin-Sompio and Hammastunturi started to use supplemental feeding as a mixture of corral feeding and feeding on natural pastures (int. 8, 9, 10). The three interviewees in Hammastunturi pointed out that hay supplement was used in order to keep the reindeer within the traditional area of the *siida* and also to reduce herding efforts. Feeding tamed the reindeer, which helped the gathering of reindeer by walking which, still in the 1980s, was a normal practice in southern areas in summer and autumn.

Discussion

This paper describes, based on interviews with elderly reindeer herders, the transitions in the herd-management of semi-domesticated reindeer in six herding associations in northern Finland. The transition from intensive winter herding to more extensive forms of herding took place between the late 1910s and the 1960s. In the three southern study areas (Hossa-Irni, Lohijärvi and Poikajärvi) intensive herding changed directly to the free-ranging system, whilst in the three northern ones (Kemin-Sompio, Hammastunturi and Näkkälä) intensive herding was replaced by extensive herding with the assistance of snowmobiles.

Factors affecting the transition process

We suggested that intensive herding changes to more extensive herding routines in conditions where the occurrence of large predators, the straying of reindeer into foreign areas and the damage to stored hay no longer cause any considerable losses costs to reindeer management, or side-jobs provide higher incomes than intensive herding. Data received from the interviewees supported, to a large extent, these suggestions, but there were considerable differences between the study herding association in how the interviewees evaluated the relative importance of the factors influencing the intensity of herding.

As regards the predator threat, Lohijärvi and Poikajärvi were practically predator-free prior the transition, whilst in Hossa-Irni and the three northernmost areas, intensive herding ceased despite the occasional prevalence of wolves and the constant threat of wolverines. Reindeer could not be defended against predatory attack, if they were not under continuous supervision by the herders (Ingold 1980). In order to prevent losses among dispersed reindeer, gathering of reindeer for round-ups often changed to wolf hunting (Hossa-Irni), and many herders especially in Kemin-Sompio directed their attention to hunting predators, which also provided income in terms of bounties, fur and meat (bear). One should note that the snowmobile could be legally used in predator hunting up until 1968, i.e. during several winters. The increasing efforts in predator control reduced the abundance of large predators everywhere in northern Finland (Siivonen 1972, Pulliainen 1974). In 1975, the state changed its predator policy and replaced kill payments with indemnifications covering the value of the reindeer killed by predators, and by protecting the wolverine, according to Bern's treaty in 1979. The role of the herders subsequently became to search for and report killed animals.

In the southern part of the reindeer management area, especially in Lohijärvi and Poikajärvi, fencing was considered of minor importance for transition by preventing the dispersal of reindeer into foreign areas. The regulations dealing with foreign reindeer were written in the Reindeer Management Act (1932), and they followed the old institutional systems developed by the reindeer herders themselves (Kortesalmi 1998). The basic message of the regulations was that one's own reindeer and reindeer from foreign herding associations had to be handled in the same way, and money from the slaughtered foreign reindeer must be sent to the owner of the animal; this was obtained, if otherwise not known, from the " reindeer earmark booklet" maintained by the Reindeer Herders Association. The regulations strengthened the reciprocal trust that "runaway reindeer" did not disappear.

In contrast, in Näkkälä and Hammastunturi fences around the herding associations were considered to be an important factor in the transition. "The fence makes good neighbours" was told to Lenstra (1975) by reindeer herders in northern Lapland. This ensured that reindeer did not disappear into foreign areas, and it also reduced pasture competition along the border edges. In Näkkälä, however, the reindeer *siidas* have their own areas, which are not separated from each other by fences. Both interviewees considered open borders to be an important factor requiring at least extensive herding in terms of "edge guarding" (*see* Beach 1981: 500).

In Lohijärvi and Poikajärvi the ultimate factor for the cessation of intensive herding was the post-war period, which can be generalized to concern the whole southern part of the reindeer management area (Alaruikka 1964). The whole of society experienced radical changes. Before WWII people in the countryside mainly followed a subsistence way of life (Massa 1994). In order to get the devastated country back onto its feet after the war, the state made large investments in reconstruction, field clearance and forestry (Ursin 1980, Pohtila 1984). A monetary economy rapidly replaced the pre-war subsistence way of life characteristic of large parts of the countryside.

This change was also reflected in reindeer management, which had earlier been practiced as a subsidy livelihood by backwoods farmers. Now they used opportunity to choose between reindeer management and wage work provided by forest cuttings in winter. Many herders choose forest work, because the number of reindeer had declined during wartime by 53% (204 600 *vs*. 96 800) on the average (Alaruikka 1947). This fits in with Beach's (1981: 333) conclusion that intensive herding changes to less intensive forms, when side-jobs provided a better income than investment in intensive herding. Differences in the timing of herding and forest work helped the transition: the largest round-ups were commonly over in December–January, making it possible to be engaged in forest work in the later part of the winter and in spring and early summer (floating) without the threat of the reindeer not being properly managed.

Despite the fact that the herds declined even more in the three northernmost areas, the herders returned to pre-war intensive herding. Large predators, wolverines especially, were still abundant and this required intensive herding. Moreover, people continued their earlier subsistence way of life because the general socio-economic development, with its new working opportunities, did not reach these remote areas until the 1960s. Cultural reasons were also important. The Saami did not rate forest workers very high and this distinction still existed after the war (Saami herders interviewed in this study). Even in Kemin-Sompio, although the herders were Finnish speaking, young men from herder families were more likely choose reindeer herding than forestry.

In our three northernmost herding associations, the transition to extensive herding was associated with the "snowmobile revolution", which is a commonly used example of how a single technological innovation had profound influences on herding practices, as well as on the economics and social relations in the herders' society (Pelto *et al*. 1968, Pelto 1973). The emergent ranching-like management system was characterized by completely wild reindeer, which were distributed over extensive areas according to the food availability, and collected only twice a year using snowmobiles in winter (Ingold 1980). The reduced tameness was considered a serious problem in our northern herding associations during the "snowmobile revolution", although the transition did not lead to a ranching-like system, in contrast to many other northern herding associations at that time (Pelto *et al*. 1968, Lenstra 1975, Ingold 1978, 1980). The great variation in the number of reindeer between successive years without a high mortality indicated failure in gathering the reindeer for the round-ups, and resulted in reduced harvesting and marketing opportunities, corresponding to what Beach (1981: 476) called "over-extensification", which was characteristic especially in Kemin-Sompio in the mid-1960s.

Relationships to pasture conditions and forestry

The reason for the transition has been explained by the deterioration of lichen pastures due to over-grazing (Tomasson 1918, Ingold 1976, 1980). This is in agreement with knowledge of the social organization of wild rangifers: a concentrated, rich food supply (usually good lichen pasture) enables a gregarious herd structure, whilst a scant or scattered food supply (poor lichen pasture or forest with arboreal lichens) results in dispersal of the animals (Bergerud

1974, Helle 1980a). This is consistent with the experience of our many interviewees that reindeer lived in larger herds and stayed in the same area longer if the lichen vegetation was in good condition.

In this study, the association between the condition of lichen pastures and the herding form appeared to be highly variable (Table 1 and Fig. 5). In Lohijärvi, reindeer were herded intensively until WWII, although the condition of lichen pastures was graded as "poor" (lichen height about 1 cm) already in the 1910s (Keisarillinen porolaidunkomisiooni 1914; Table 1). The reduction in availability of reindeer lichens was considered to be the primary factor resulting in extensification of intensive herding in two of our study herding associations. In Hossa-Irni that was associated with the loss of good lichen pastures on the Russian side 1918, whilst in Kemin-Sompio the three interviewees related the transition to the pasture loss caused by forestry in combination with the high reindeer numbers (Table 1 and Fig. 3) and difficult snow conditions in winter. Clear-cuttings advanced along the riversides, which were the forests most valuable for herding because of their rich lichen vegetation and easy snow conditions, and which were used also for leach-calving. The influence of snow on access to forage is commonly acknowledged (Pruitt 1979, Helle 1984), and it strongly influences the habitat selection of reindeer in open fell habitats which offer almost snow-free wind-swept ridges in mid and late winter (Skogland 1978, Helle & Särkelä 1993). In forest habitats, snow-mediated spatial heterogeneity of food availability has received less attention. However, Kumpula *et al.* (2007) found that the snow depth and the snow hardness increased with the altitude influencing the pasture use of semi-domesticated reindeer.

In addition, our interviewees in Kemin-Sompio especially pointed out the avoidance of large clear-cut areas due to wind-hardened snow, as reported e.g. by Alaruikka (1964), Eriksson (1976) and Beach (1981: 266), which is in agreement with the general relationship between wind speed and the snow hardness (Pomeroy & Brun 2001). Therefore one would expect that lichen vegetation would recover on clear-cuts and seedling stands due to the low grazing pressure. However, extensive inventory data from the late 1970s showed a completely opposite trend especially in northern Lapland (Mattila 1981). The mean lichen biomass in Kemin-Sompio (and adjacent Pohjois-Salla) on dry sites (mainly *Empetrum–Myrtillus–Cladina* type) was about 44% lower in young forests (< 70 yrs) than in mature ones (> 70 yrs), the corresponding figure in sub-dry sites (mainly *Empetrum–Myrtillus* type) being 29%. Also in Inari, including Hammastunturi, the mean lichen biomass in young forests on dry sites was 20% and on sub-dry sites 27% lower than in mature forests.

In general, the percent cover and biomass of reindeer lichens are related to reindeer density calculated on the basis of the area of lichen pastures (Helle 1982, Kumpula *et al.* 2000, *see* also Mattila 2004), therefore the condition of lichen pastures was poor in the southern part of the reindeer management area already before the time of intensive forestry (Keisarillinen porolaidunkomisiooni 1914; Table 1). However, there might also be negative impacts of other factors, as evidenced by a strong decrease in the percent cover of reindeer lichen outside the reindeer management area between 1951–1953 and 1995 (Nousiainen 2000). In northern Finland, forestry practices affecting abundance of reindeer lichens include prescribed burning and soil scarification (on fresh and sub-dry sites) (Ferm & Pohtila 1977, Eriksson & Raunistola 1990, Webb 1998, Roturier & Bergsten 2006), cutting residues covering lichen vegetation (Kauppi 1990, Kumpula 2003), in addition to which clear-cutting changes the habitat selection of reindeer during the summer. Before the practice of clear-cutting started, reindeer concentrated in the summer on open mires and fells that provided both food and, due to the wind, relief from blood-sucking insects (Ahti 1973, Haukioja & Heino 1974). Later on, clear-cut areas were commonly mentioned as the sites of summer pastures (Ferm & Pohtila 1977, Helle 1980a, Mäkitalo *et al.* 1998, Kumpula *et al.* 2007). In the summer, the diet of the reindeer contains only very small amounts of reindeer lichens (Helle 1982), whilst trampling by reindeer destroys the fragile lichen vegetation on the driest sites especially (Pegau 1970, Oksanen 1978, Boudreau & Payette 2001).

Development of supplementary/corral feeding

According to our interviewees, the second sharp transition in herd-management was associated with the rapid extension of supplementary/corral feeding from the late 1960s onwards, described in details by Helle and Saastamoinen (1979) and Nieminen and Autto (1989). In comparison with Sweden for instance, it is an exceptional feature in the management of reindeer (Moen & Danell 2003). The Field Reservation Scheme, enacted in 1969, made possible the use of hay. Farmers were paid for leaving their fields uncultivated, but haymaking for reindeer was allowed in these fields. An increasing number of farmer-reindeer herders took advantage of this opportunity, which explains the rapid extension of supplementary feeding. This was costly, but meat production also increased due to the decreased mortality and increased reproduction and carcass weights (Kojola & Helle 1991, Helle & Kojola 1993, 1994).

Our interviewees pointed out that the ultimate reason for the use of hay was the reduction in arboreal lichens, occurring most abundantly in old forests ((Mattila 1979, Esseen *et al*. 1996, Jaakkola *et al*. 2006). Pasture inventories covering the whole reindeer management area indicated that about 60% of the forests were totally lacking in arboreal lichens in the 1970s because of the young stand age (Mattila 1979), while in northern national parks without forestry the proportion is only 2%–5% (Jaakkola *et al*. 2006). In the mid-1970s, 51% of the herding associations, most of them located in the southern half of the reindeer management area, considered the scarcity of old forests rich in arboreal lichens as the minimum factor determining the carrying capacity of winter pastures; an additional 22% suggested that they lacked both arboreal lichens and reindeer lichens (Helle & Saastamoinen 1979).

Arboreal lichens were used in several and variable kinds of occasion. Among our study areas, Hossa-Irni was the only one where “reindeer cuttings” were a normal practice until the beginning of the 20th century (Heikinheimo 1920, Kortesalmi 1996). “Reindeer cuttings” were the only way to keep the reindeer in the herd in areas with restricted lichen pastures and deep snow (Inha 1909); intensive herding with the aid of felled trees was, however, necessary due to predators and the otherwise disappearance of reindeer. Since WWII, arboreal lichens on fallen trees in commercial cuttings were an important food source for reindeer for decades. In 1975 30%, and in 1977 15% of the total reindeer population lived on cutting areas in mid-winter, most commonly in the southern part of the reindeer management area (Saastamoinen 1978, Helle & Saastamoinen 1979). According to our interviewees, reindeer herders themselves cut single trees or knocked down the lower branches of trees still in the 1960s and 1970s in order to keep the reindeer in a given area (extensive herding) or to ensure food availability of freely roaming reindeer (free-ranging system).

Our interviewees also emphasized the importance of arboreal lichens, which reindeer obtained in standing forests or those fallen on the snow in winter storms. In the southern part of the area arboreal lichens were a part of the “normal” winter diet of reindeer, whilst in the northern part they are used in conditions where access to ground forage is limited in early spring or occasionally already earlier by hard or deep snow. Helle and Saastamoinen (1979) found during two winters in the 1970s that during January–March 21%–30% of the reindeer lived mainly on arboreal lichens, the percentage being the highest in the southern half of the reindeer management area.

“The intensification spiral” (Beach 1981: 476), i.e. the development in an opposite direction to “over-extensification”, was clearly observable in our study areas. It was associated with the population decline caused by high winter mortality, which took place in our southern study areas in the late 1960s and in the northern ones in 1972–1974. In the southern half, intensification was due to the rapid extension of supplementary/corral feeding (Helle & Saastamoinen 1979). In the north, the role of feeding was less still in the 1970s, but a combination of extensive herding and supplementary feeding developed in many herding associations, including Hammastunturi, in our study during the following decade (Nieminen & Autto 1989).

The tameness degree of reindeer increased and they were as tame as before the "wild years" of the "snowmobile revolution". Supplementary feeding, an emergent phenomenon, revitalized the old herding methods, including individual recognition of reindeer and pasture rotation. The same happened to a lesser extent in Näkkälä and Kemin-Sompio, without supplementary feeding, due to frequent and peaceful contacts with snowmobile-driving herders. In general, "The intensification spiral" increased the accuracy by witch the reindeer could be gathered for round-ups. Alaruikka (1964) estimated that, before the "snowmobile revolution", about 15% of the reindeer avoided the annual round-ups and were thus missing from the official reindeer statistics. Estimates from the early phases of "the snowmobile revolution" have not been presented, but by the late 1970s and early 1980s the proportion of uncounted reindeer was only 1%–2% (Helle & Kojola 1993).

The "intensification spiral" apparently led to "feeding competition" in conditions where the highest permitted number of reindeer was reached (Helle *et al*. 1985), which was a common feature throughout the whole reindeer management area from the late 1970s onwards until the end of the 1980s (Helle & Kojola 2006). At that time every owner had to reduce his herd by an overall fixed percentage (Reindeer Management Act 1932). The calculations are based on statistics from the previous winter's round-ups. Thus they do not take into account the fact that, on natural pastures, winter mortality may be higher and reproduction lower than in herds fed supplementary or artificially in corrals. Subsequently, maintaining the herd requires the intensification of feeding if the other owners are already doing so, otherwise, the herd starts to decline.

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II

CONSEQUENCES OF FOREST LANDSCAPE CHANGES FOR THE AVAILABILITY OF WINTER PASTURES TO REINDEER (RANGIFER TARANDUS TARANDUS) FROM 1953 TO 2003 IN KUUSAMO, NORTHEAST FINLAND

by

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Consequences of forest landscape changes for the availability of winter pastures to reindeer (*Rangifer tarandus tarandus*) from 1953 to 2003 in Kuusamo, northeast Finland

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Using aerial photographs, we examined the changes in the forest matrix from 1953 to 2003 in the Oulanka National Park and commercial forests in the northern part of the municipality of Kuusamo. The changes concerned the potential winter grazing grounds available to the existing reindeer population. The main changes in the commercial forests took place between 1953 and 1977, during which time the mean forest-patch size shrank by 65%, and the number of patches increased by 78%. From 1953 to 2003, the total area of epiphytic lichens and ground-lichen pastures decreased by 48.6%. The area of ground-lichen pastures decreased by 20%, and the area of common hair grass pastures doubled. The forest matrix transition in the commercial forests changed not only the spatial configuration and areas of different pasture patches, but also the grazing pressure at the remaining pasture sites. In the national park, the changes in grazing pressure were related only to the changes in numbers of reindeer. In general, the conditions of reindeer pastures are a result of interaction between different land-use components.

Introduction

Reindeer husbandry takes place within a large and complex system of pasture environments, in which several factors affect directly or indirectly the state of pastures and the abundance as well as availability of reindeer fodder. Over the past decades, this environment in Finland and Sweden underwent several changes, while the land use intensified and expanded, causing quantity and quality of the most important winter fodder resources to decrease. (Berg *et al*. 2008, Kumpula and Kurkilahti 2010) At the beginning of the 20th century, reindeer in Finland numbered approximately 100 000 (Anon 1934). Due to several factors, the number was doubled by 1984, and in 1992 there were about 265 000 reindeer (data of the Finnish Reindeer Herders' Association). Regardless of the intensification and several changes in the use of pasture environments during the latter part of the 20th century, depletion of lichen ranges (Mattila 1981, 1998, Kumpula *et al*. 1998) was considered to be primarily related to the high numbers of reindeer (Helle and Aspi 1983, Väre *et al*. 1995, Väre *et al*. 1996, Kumpula *et al*. 2000, Moen and Danell

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2003). The most important competing form of land use in the reindeer herding area is forest management, as 75%–80% of the reindeer population graze during the winter in the northern boreal forest zone, an important region for commercial forestry since World War II (Helle *et al.* 1990, Kumpula *et al.* 2007, Helle and Jaakkola 2008). Both the intensity of reindeer grazing and forest management correlate with the condition of winter pastures, making it difficult to separate the effects of forestry from those of reindeer husbandry (Kumpula 2001a, Moen and Danell 2003, Kumpula *et al.* 2008).

During winter, the best fodder for reindeer energy expenditure and digestion consists primarily of ground (*Cladonia* sp. and *Cladina* sp.) and epiphytic lichens (*Alectoria* sp. and *Bryoria* sp.) (Aagnes *et al.* 1995), though reindeer utilise also dwarf shrubs, sedges, hays and grasses, the most important of which is the common hair grass (*Deschampsia flexuosa*) (Helle and Tarvainen 1984, Kojola *et al.* 1991, Kumpula *et al.* 2007). In the habitat selection studies of the Oraniemi herding district in 2002–2005, Kumpula *et al.* (2008) found that the most important habitat in late winter is the mesic logging areas, in which plenty of arboreal lichens are available in tree crowns and logging residues. The second important habitat consists of mature and old-growth mesic epiphytic-lichen-rich forests (Kumpula *et al.* 2008).

Several studies have shown that the effects of forest management on winter pastures for reindeer are for the most part negative (Eriksson and Raunistola 1990, Kumpula 2003, Roturier and Bergsten 2006, Hallikainen *et al.* 2008, Kivinen *et al.* 2010, Kumpula and Kurkilahti 2010). It has been observed that clear-cutting as a forest regeneration method reduces the amount and availability of ground lichens at sub-xeric and xeric sites (Helle *et al.* 1983, Kumpula and Kurkilahti 2010, Kivinen *et al.* 2010). Clear-cutting on mesic and sub-xeric mineral soils frequently gives rise to an abundance of common hair grass, thereby partly compensating for the loss of mature forest due to forestry operations (Colpaert *et al.* 2003). The highest mean biomasses of common hair grass on mesic sites have been found 5–10 years after clear-cutting (Helle 1975). Unlike ground lichens, epiphytic lichens disappear immediately as a result of clear-cutting (Kivinen *et al.* 2010). Because forests that are abundant in epiphytic lichens are usually older than forests at the end of the current rotation period, forest management has significantly reduced the availability of epiphytic lichen pastures (Esseen *et al.* 1996, Jaakkola *et al.* 2006). In addition to affecting the abundance of lichens, clear-cutting also impacts reindeer access to lichens. Reindeer do not like to graze in clearings or in dense young-growth forests for several reasons: litter and logging residues obstruct digging, snow is likely to be packed harder due to strong wind gusts, and predator visibility in dense young-growth forests is poor (Helle *et al.* 1990, Kumpula 2001a, Kumpula *et al.* 2007, 2008). Studies of the interaction between caribou and forestry have shown that caribou may abandon or avoid harvested and partially harvested areas for up to 12 years (Darby and Duquette 1986, Chubbs *et al.* 1993). Studies of the habitat use of semi-domesticated reindeer in Finland and woodland caribou (*Rangifer tarandus caribou*) in Canada have shown a strong preference for old-growth forests and an avoidance of clear-cuts or young stands (Apps *et al.* 2001, Kumpula *et al.* 2007, 2008).

In studying landscape change, five different spatial processes can be distinguished in human-modified landscapes. These produce more or less isolated patches of habitat and cause habitat loss (Forman 1995). The spatial processes take place simultaneously, and therefore they overlap during the period of land transformation (Forman 1995, Jaeger 2000). The most common ways for land transformation to begin are perforation and dissection, and the process continues through sub-division, shrinkage and attrition (Forman 1995, Fahrig 2003). Classical landscape fragmentation studies concentrate on the different parameters describing habitat areas as well as on the spatial arrangement of the fragments within a landscape. Another approach to studying fragmented landscapes looks at the changes in the conditions in and around the habitat fragments. As the spatial structure of the landscape changes, various factors can act to modify the conditions of landscape elements. These are including both the fragments and the matrix, which are the most extensive and connected

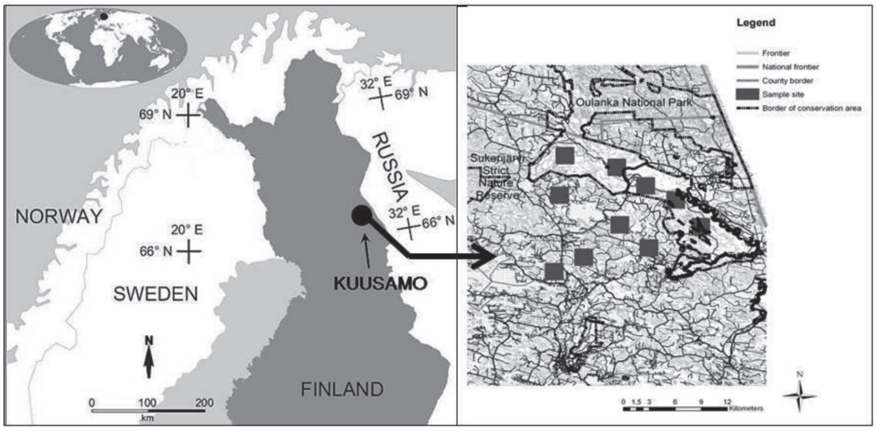

Fig. 1. Location of Kuusamo and the study plots in Oulanka National Park as in the commercial forests (source: National Land Survey of Finland, the Finnish Forest Research Institute, Helsinki; permission number 305/MML/12).

landscape element types (Pickett and Cadenasso 1995, Hobbs 2001). As the degree of modification increases, the land-use intensity in the intact areas increases. Moreover, the remnants of the original vegetation are increasingly influenced by processes originating in modified areas as well as by the original land-use (McIntyre and Hobbs 1999). The decrease in the area of original vegetation may lead to a concentration of moving elements — such as large herbivores in the remaining areas — and changes in temporal and spatial interactions. This is likely to lead to an increase in use of the habitats in the remaining areas (Lovejoy *et al*. 1986).

Our hypothesis suggests that, together with the increase in the reindeer population, the changes in reindeer management methods and the intensification of forest use have resulted in reduced availability of pasture land to reindeer. Simultaneous forest landscape transformation and changes in the numbers of reindeer have together influenced the grazing pressure on the remaining sites of original forest vegetation. In this study, we: (1) defined and quantified the transformation process of the forest landscape in northern part of the municipality of Kuusamo from 1953 to 2003 in the national-park and commercial-forest areas; (2) calculated the mean areas of potential winter grazing grounds for reindeer in the national park and commercial forests during 1953–2003; and (3) related the observed changes in potential winter grazing grounds to the existing numbers of reindeer.

Material and methods

Material used in this study was originally collected for the M.Sc. thesis of the second author (*see* Heiskanen 2009). For the purpose of this paper, we re-analysed the data to clarify the results, which here are based on the re-classified land-use data. In this study, we used a Mann-Whitney *U*-test, Friedman's test and a Wilcoxon signed-rank test instead of a Kruskall-Wallis one-way analysis of variance, which was applied in Heiskanen (2009). Collection of the original material is briefly described below.

Study area

This study was conducted in the northern part of the municipality of Kuusamo, in northeastern Finland (Fig. 1). The area represents the northern boreal zone within the southern Lapland subzone (Kalela 1961). A part of the study area, the Oulanka National Park, became a protected area in 1956. According to the IUCN classification of nature conservation areas, Oulanka belongs to Category II. The Oulanka National Park is located 137–395 m a.s.l. Oulanka is dominated by mature forests of Norway spruce (*Picea abies*) and Scots pine (*Pinus sylvetris*). The birches present in the area are downy birch (*Betula pubescens* var *pubescens*) and silver birch (*Betula pendula*). The mean snow depth in mid-March (1971–2003) is 0.75–1 m (source http://www.ilmatieteenlaitos.fi/lumitilastot [in Finnish]). The human impact on the primeval forests of northern Fennoscandia had been almost nonexistent until the end of the 19th century (Pohtila 1979). With the exception of few patches of slash-and-burn in the coniferous forests, some small-scale selection cutting and felling trees for reindeer, forest use in northern Kuusamo was very limited even at the end of the 19th century; 60.5% of the forests were over 200 years old (Viramo *et al*. 1980, Ruuttula-Vasari and Juvonen 2006). Until the 1950s, most of the forests in Kuusamo were located beyond what was considered to be the economically profitable limit for industrial forestry (Helle and Jaakkola 2008).

The area under study (1055 km^2 in total, of which 965 km^2 are reindeer pastures) belongs to the Alakitka Reindeer Herding Association. The Association maintains 17.6% of the protected area of the Oulanka National Park and the Sukerijärvi Strict Nature Reserve (Nieminen 2008). At the beginning of the 20th century, Alakitka's area was 743 km^2, and the maximum number of reindeer therein was 900 (Anon 1934). In 1953, the number of reindeer was 1200; in 1977 it was 1500; in 1991 it increased to 2600, and in 2003 it decreased to 1600. The pastures of the Alakitka Reindeer Herding Association are mainly on mesic and sub-xeric upland mineral soils. Alakitka is characterised by a low percentage of xeric pastures that are rich in reindeer lichens as well as a rather high percentage of potential epiphytic lichen pastures. The total area of mires spans 323 km^2. Percentages of mineral soil sites, potential reindeer lichen pastures, and potential epiphytic lichen pastures were 66.5%, 0.1% and 18.1%, respectively. The pasture area per reindeer (in 2009, the number of reindeer was 1600), area of mire per reindeer, and area of mineral soil pasture per reindeer were 66.0, 20.2 and 40.1 ha, respectively. Presently, some 90%–95% of the Alakitka Reindeer Herding Association's reindeer are fed in enclosures during winters (November–April) (Nieminen 2008).

Aerial photographs

The landscape change was studied using digital aerial black-and-white photographs obtained from the Topographic Service of the Finnish Defence Forces. The photographs were taken on 11 July 1953, 7 July 1977, and 27 June 2003. Photograph scales were 1:20 000 (1953) and 1:60 000 (1977, 2003). Selection of areas included in the study was based on 90 aerial photographs of northern Kuusamo taken in 1953. In the first phase of sampling, we chose aerial photographs in which the forested areas covered at least ~70% of the picture (estimated visually). We then created two groups of selected photographs based on the primary location (national park *vs*. commercial forest). There were 5 and 18 independent photographs of the national-park area and the commercial forests, respectively, with at least 70% forest cover. From these we randomly chose five non-overlapping photographs (Fig. 1). The photographs were rectified and georeferenced to the Finnish National Grid Coordinate System using ArcGIS 9.3. The aerial photographs from the year 1953 covered an area of 4×4 km. To minimise the distortion of the images close to the edges and the variation of scale-dependent landscape indices, we used the centres of the photographs covering 2×2 km. (Löfman and Kouki 2003). The sample squares were manually digitised to the various land-use classes. The visual classification was conducted by delineation and identification of homogenous patches of certain land-use types (Jennings *et al*. 1999, Paine and Kiser 2003). The digitised classes were mature forest (closed canopy), open forest (canopy cover degree 50%), clear-cut, sapling stand, young forest, seed-tree stand, mire, drained mire, water, roads, open areas (yards), and fields. The original land-use classes were then re-classified into the following new categories: forest (mature forest), open forest (open forest), regeneration area (clear-cut, sapling stands, young forest, seed-tree stand), mire (mire), drained mire (drained mire), water (water), and open area (roads, open areas, fields).

To include in the study the edge effect of the impact of landscape transition on epiphytic lichens, 25- and 50-m edges were created within the forest patches. In Swedish studies, the maximum edge effect extended 25–50 m into the Norway spruce forest at moderately exposed sites (Esseen and Renhorn 1998). By subtracting the edge areas from full areas of the patches, we were able to calculate the relative change in the size of the core forest area.

Potential winter grazing grounds

The potential areas of winter pastures were calculated based on the areas of the different classes of digitised patches. The areas of the forest, open forests, and regeneration classes were divided into mesic (57.0%), sub-xeric (41.6%), and xeric (1.4%) sites, based on the results of the 9th National Forest Inventory (Mattila and Mikkola 2009). According to Mattila and Mikkola (2009), xeric and barren forests are primarily ground-lichen pastures. However, ground lichens are also found in sub-xeric forests (Kumpula *et al*. 1999). The mesic sites make the best epiphytic-lichen pastures, which are also found at sub-xeric sites. The mesic and sub-xeric regeneration sites are rich in common hair grass. In addition, the age and structure of the forest affect the abundance of the most important winter fodder resources (Kumpula *et al*. 1999, Mattila and Mikkola 2008, 2009). However, these factors cannot be estimated reliably from the aerial photographs used in the present study. These calculated areas were then classified into the following types of reindeer pasture: epiphytic lichen (mesic forest areas), epiphytic and ground lichen (sub-xeric forest areas), ground-lichen pastures (sub-xeric forest, xeric forest and xeric open forest areas), and common hair grass (mesic and sub-xeric regeneration areas; Kumpula *et al*. 1999, Mattila and Mikkola 2009). Other classes were considered as having no winter pasture value.

To show the relative impact of landscape change on the grazing pressure, we divided the calculated areas of potential winter pastures (epiphytic lichen, epiphytic and ground lichen, ground lichen and common hair grass) by the number of reindeer for the years 1953, 1977, and 2003. For 1991, when the number of reindeer was at its highest, the areas of potential pasture types were estimated to be between the values obtained in 1977 and in 2003. First, we calculated the percentages of different pasture types per sample area, and with these percentage figures the areas (km^2) of the different pasture types were calculated for the entire herding district. The pasture areas were converted to hectares (ha), and the subsequent value was then divided by the maximum number of reindeer in the herding district in particular years. This calculation was based on the assumption that the pasture-type distribution in the sample squares is similar to that in the entire herding district. Therefore in this study, these results are best applied in comparisons among years and different types of areas.

Statistical analyses

We calculated the landscape spatial pattern statistics using FRAGSTATS (McGarigal *et al*. 2002). In order to define the landscape structure during different periods, and to estimate the change in the reindeer winter pasture resources, we selected the following six most independent variables for the analysis: number of patches (NP), average patch size, edge density (ED), largest patch index (LPI), Shannon's diversity index (SHDI), and landscape shape index (LSI). The variables are presented as mean values calculated over the sample areas located in the national park and commercial forests. These variables were then grouped into four categories: Patch area, Edge and shape, Diversity, and Configuration (Herold *et al*. 2002). The first three variables characterise the composition of the landscape and the last one defines the configuration of the landscape. Edge density (ED) describes the length of edge per hectare (m ha^{-1}). Largest patch index (LPI) refers to the percentage of the landscape accounted for by the largest patch and it is a simple measure of dominance. Shannon's diversity index (SHDI) represents the amount of "information" per patch, and it increases as the number of different patch types (i.e., patch richness, PR) increases. Landscape shape index (LSI) measures the perimeter-to-area ratio for the landscape and quantifies the amount of edge present in a landscape relative to what would be present in a landscape of the same size but with simple geometry. (McGarigal *et al*. 2002).

The data did not meet the assumption of normality, and therefore we applied non-parametric tests to compare results obtained from the national park and commercial forests as well as between among years. A Mann-Whitney *U*-test was used to determine the statistical significance of the observed differences between the areas (national park *vs*. commercial forest). To compare the results for different years, Friedman's test was used to determine the statistical significance of the differences. For comparing the areas of pasture types per reindeer between years, the Wilcoxon signed-rank test was used. In the results, the means and standard deviations are presented. The statistical tests were conducted using PASW Statistics ver. 18.0 (SPSS Inc.). Although the Oulanka National Park was established in 1956, this name is used in this study when referring to the data from 1953 for the area covered later by the park.

Results

Landscape changes

The analysis based on the aerial photographs shows that during the period studied, the forest structure changed significantly within the commercial-forest area.

Patch area

In all the studied years, the average areas of the forest patches were significantly larger in the national park as compared with those in the commercial forests (Table 1). The reduction in the mean forest patch size in the commercial forests from 1953 to 2003 was 77%. However, this difference was not statistically significant (Friedman's test: $\chi^2 = 0.667$, $p = 0.72$). When all the land-use classes were pooled, the mean number of patches increased in both the national park and commercial forests, although the increase was significantly higher in the commercial forests (Fig. 2). In 1953, the average number of patches was slightly higher in the commercial forest than in the national park. In 1977 and 2003, the number of patches in the commercial forest was twice as high as that in the national park. In 1977 and 2003, the difference in the number of patches between the national park and the commercial forests was statistically significant (Mann-Whitney *U*-test: $Z_{both} = -2.6$, $p_{both} = 0.008$). The changes in the number of patches in the commercial forests were statistically significant among the years ($\chi^2 = 7.6$, $p = 0.022$).

Edge and shape

There was a statistically significant difference in edge density between the national park and commercial forests in 1977 and 2003 ($Z_{both} = -2.6$, $p_{both} = 0.008$). In the commercial forests, the edge

Table 1. The average size (ha) of the forest, open forest, and regeneration area patches within the national park and commercial forests in 1953, 1977 and 2003.

Patch type	Year	Mean area (ha) of patch ± SE (*n*)		Mann-Whitney *U*-test
		National Park	Commercial forests	
Forest	1953	92.5 ± 24.2 (17)	53.8 ± 21.2 (27)	$Z = -2.9$, $p = 0.004$
	1977	85.5 ± 25.8 (15)	17.6 ± 5.7 (55)	$Z = -3.0$, $p = 0.003$
	2003	89.4 ± 24.1 (18)	12.4 ± 2.8 (60)	$Z = -4.0$, $p < 0.001$
Open forest	1953	5.0 ± 1.2 (9)	4.8 ± 1.3 (6)	$Z = 0$, $p = 1$
	1977	8.1 ± 4.3 (4)	4.8 ± 1.2 (32)	$Z = 3.0$, $p = 0.003$
	2003	2.6 ± 1.4 (6)	2.5 ± 0.9 (14)	$Z = 0.8$, $p = 0.934$
Regeneration area	1953	13.1 (1)	0.5 (1)	$Z = -1.0$, $p = 0.317$
	1977	–	9.8 ± 2.5 (38)	–
	2003	0.2 (1)	9.5 ± 1.9 (81)	$Z = 1.7$, $p = 0.087$

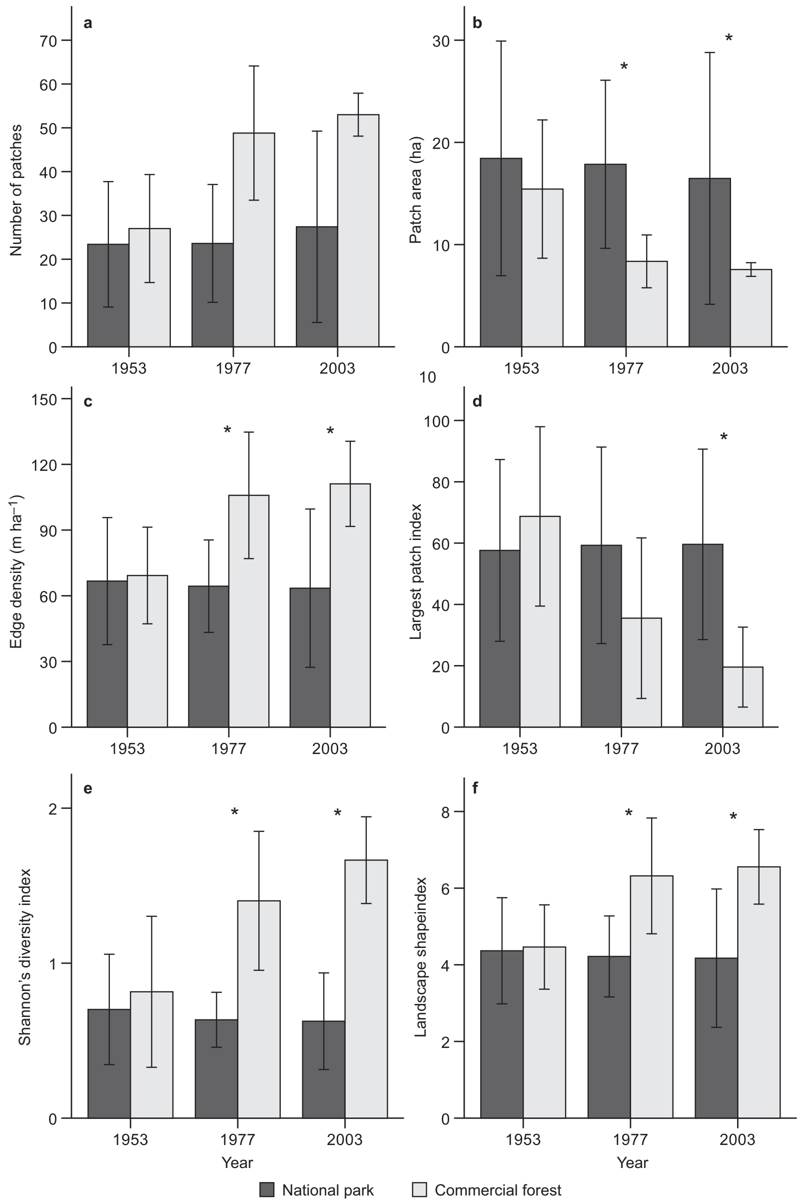

Fig. 2. Comparisons among years (1953, 1977, and 2003) and areas (Oulanka National Park the commercial forest) of (**a**) number of patches, (**b**) area of patches, (**c**) edge density, (**d**) largest patch index, (**e**) Shannon's diversity index, and (**f**) landscape shape index. Vertical lines represent standard deviations. Asterisks indicate significantly different values between Oulanka National Park and commercial forests (Mann-Whitney *U*-test; $p < 0.05$).

density increased by 37.6% from 1953 to 2003 ($\chi^2 = 8.4$, $p = 0.015$) (*see* Fig. 2).

Diversity

There were no significant differences in the Shannon's diversity index (SHDI) in 1953 between the national park and the commercial forests (Fig. 2). During the periods 1953–1977 and 1977–2003, the SHDI increased within the commercial forests by 42.9% and 17.6%, respectively ($\chi^2 = 8.4$, $p = 0.015$). The SHDI for the commercial forests was significantly higher than for the national park in 1977 ($Z = -2.6$, $p = 0.008$) and in 2003 ($Z = -2.6$, $p = 0.008$).

Configuration

In 1953, the largest patch index (LPI) for the national park was 19% lower than that for the commercial forests (Fig. 2). However, in 1977 the LPI was close to being significantly higher for the national park than for the commercial forests ($Z = -2.0$, $p = 0.056$). In 2003, the LPI for the national park was significantly higher than that for the commercial forests ($Z = -2.6$, $p = 0.008$). The differences among the years were statistically significant for the commercial forests ($\chi^2 = 10.0$, $p = 0.007$).

The landscape shape index (LSI) for the commercial forests increased by 47% from 1953 to 2003 ($\chi^2 = 8.4$, $p = 0.015$) (Fig. 2). When compared with the national park figures, LSIs for the commercial forests were significantly higher in 1977 ($Z = -2.6$, $p = 0.008$) and 2003 ($Z = -2.6$, $p = 0.008$), indicating a more fragmented structure within commercial forests.

Potential winter pastures

In 1953, the areas of epiphytic and ground lichen and ground-lichen pastures were significantly larger in the national park than in commercial forests ($Z = -2.6$, $p = 0.008$) (Fig. 3). In 1977 and 2003, the area of epiphytic and ground lichen-pastures was larger in the national park ($Z = -2.6$, $p = 0.008$). Interestingly, the area of epiphytic-lichen pastures was clearly larger in the commercial forests as compared with that in the national park in 1953 and 1977. In 2003, the areas of epiphytic-lichen pastures in the national park and in the commercial forests were the same.

The potential areas of epiphytic-lichen pastures in the commercial forests decreased by 33.0% from 1953 to 1977, and by 23.5% from 1977 to 2003 ($\chi^2 = 8.4$, $p = 0.015$). The corresponding values for potential epiphytic and ground lichen pastures were 33.1% and 23.2%, respectively ($\chi^2 = 8.4$, $p = 0.015$). The area of the ground-lichen pastures in the commercial forests was almost three times larger in 1977 than it had been in 1953, and it decreased by 71% during the second period from 1977 to 2003. These differences were statistically significant ($\chi^2 = 68.4$, $p = 0.015$). As the regeneration areas in mesic and sub-xeric sites are suitable grounds for hair grass, the area of potential hair grass pastures increased by 73% and 109% in 1977 and 2003 respectively. However, the differences were not statistically significant (Fig. 3).

Potential winter pastures per head of reindeer

The available pasture areas per head of reindeer decreased from 1953 to 1977, and further to 1991 (Fig. 4). From 1991 to 2003, the available pasture area per head of reindeer increased in all cases except with regard to the ground-lichen pasture per head of reindeer in the commercial forests. In all the studied years, the areas of epiphytic and ground-lichen pastures per head of reindeer were significantly higher in the national park than in the commercial forests ($Z_{all} = -2.5$, $p_{all} = 0.008$). In 1953, the area of epiphytic-lichen pasture per head of reindeer was significantly higher in the commercial forests than in the national park ($Z = -2.6$, $p = 0.008$). In 1953 and 2003, the area of ground-lichen pastures per head of reindeer was significantly higher in the national park than in the commercial forests ($Z_{all} = -2.6$, $p_{all} = 0.008$).

From 1953 to 2003, the areas of epiphytic and ground-lichen pasture per head of reindeer decreased by 61.5% and 23.4% in the commercial forests and in the national park, respectively.

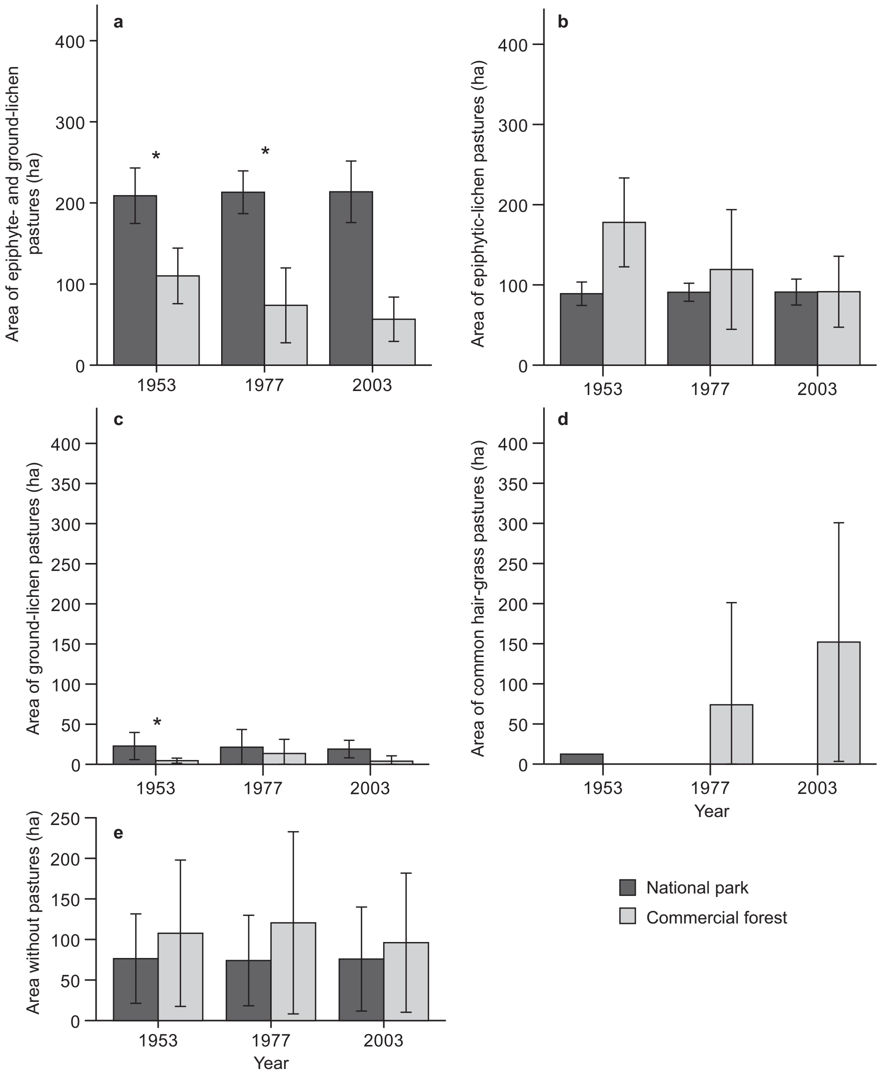

Fig. 3. Total areas of (**a**) epiphytic- and ground-lichen pastures, (**b**) epiphytic-lichen pastures, (**c**) ground-lichen pastures, (**d**) hair-grass pastures, and (**e**) without pastures, per sample square in the Oulanka National Park (national park) and commercial forests in 1953, 1977, 1991 and 2003. Vertical lines represent standard deviations. Asterisks indicate significantly different values between Oulanka National Park and the commercial forests (Mann-Whitney *U*-test; $p < 0.05$).

The decrease was statistically significant both in the commercial forests ($\chi^2 = 14.0$, $p = 0.003$) and in the national park ($\chi^2 = 9.6$, $p = 0.008$). In the national park, from 1953 to 2003 the area of ground-lichen pasture per head of reindeer decreased by 38% ($\chi^2 = 9.8$, $p = 0.02$).

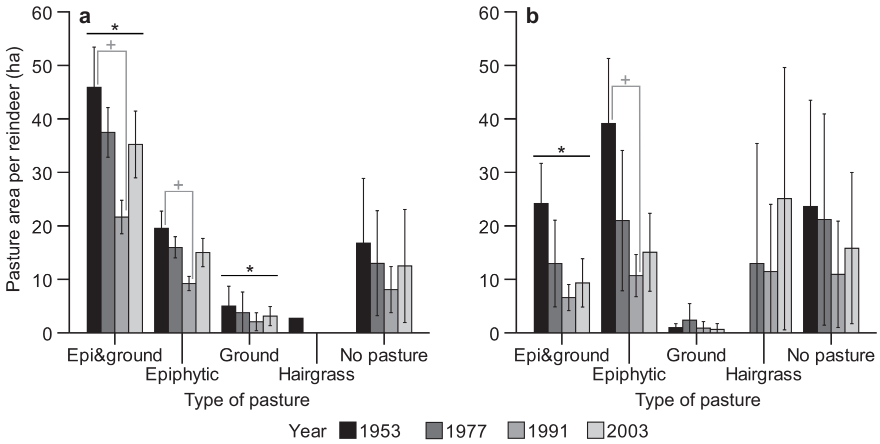

Fig. 4. Areas of different pasture types (epi&ground = epiphytic- and ground-lichen pasture, epiphytic = epiphytic-lichen pasture, ground = ground-lichen pasture, hair grass = hair-grass pasture, and no pasture) per reindeer in 1953, 1977, 1991, and 2003 in (**a**) Oulanka National Park, and (**b**) commercial forests. Vertical lines represent standard deviations. Asterisks indicate statistically significant differences between all the years (Friedman test; $p < 0.05$); plus signs indicate statistically significant differences between the yesr 1953 and 1991 (Wilcoxon test; $p < 0.05$).

In order to estimate the impacts of the changing environment and reindeer numbers on pasture availability, we calculated the pasture availability for the year 1991. In the national park, the area of epiphytic- and ground-lichen pasture per head of reindeer in that year was 23% lower as compared with the corresponding value in 1953 ($Z = -2.0$, $p = 0.043$). From 1953 to 2003, the area of epiphytic-lichen pasture per head of reindeer in the commercial forests decreased by 61.5% ($Z = -2.0$, $p = 0.043$) and in the national park by 23.5% ($Z = -2.0$, $p = 0.043$). During the same period, the area of ground-lichen pasture decreased by 60%.

Edge effects

In 1953, the 25-m and 50-m edges reduced the commercial forest area by an average of 19.9% and 37%, respectively (Table 2). In 2003, the respective values were 35.4% and 57.5%. When comparing the years, between 1953 and 2003 the forest-patch area decreased by an average of 48.5%.

Discussion

After 1950s, even-aged silviculture was an increasingly popular method used for forest regeneration, and this led to an extensive transformation of commercial forest landscape in Fennoscandia in the latter part of the 20th century (Pohtila 1979). In our study area, the middle phase of a typical landscape transition (Forman 1995) was reached during the first 25 years, from 1953 to 1977. A similar pattern, beginning

Table 2. Calculated areas of forest patch, forest core area minus 25-m edge, forest core area minus 50-m edge in 1953 and in 2003 in commercial forests. The areas were calculated from the 400 ha sample plots.

	1953	2003
Forest area (mean ± SE (*n*), ha)	290.3 ± 20.2 (5)	149.3 ± 16.1 (5)
Forest core area minus 25-m edge (mean ± SE (*n*), ha)	232.4 ± 20.8 (5)	96.4 ± 12.2 (5)
Forest core area minus 50-m edge (mean ± SE (*n*), ha)	186.0 ± 21.3 (5)	63.4 ± 8.4 (5)

already in the 1940s, was detected by Löfman and Kouki (2001) in southern Finland. The forest landscape change in the Kuusamo area started later than in many other parts of northern Finland due to land consolidation, which ended in 1955 (Kortesalmi 1960, Pohtila 1979, Heiskanen 2009). During the period under study, the largest patch index (LPI) decreased in the commercial forests from 70% to 20%, which means that the matrix of homogenous, mature forest is lost for the time it takes a clear-cut forest area to become reforested and matured. Löfman and Kouki (2001) found relatively high LPI values for closed-canopy patches in southern Finland in 1941, 1969 and 1997, indicating that the matrix of closed-canopy was maintained. This result is markedly higher than ours; however, Löfman and Kouki (2001) included the development stages of young, middle-aged, mature and old forests in the closed-canopy classes. According to the current knowledge, landscape indices do not directly indicate suitability of an area for reindeer or caribou. However, it is known that the principal factors affecting the winter habitat selection of the *Rangifer* species are food biomass and availability, the latter being affected by the characteristics of the snow cover (Pruitt 1979, Helle 1980, Johnson *et al*. 2002). In addition to high-quality habitat patches, the spatial configuration of habitat in the landscape (i.e. larger clusters of high-quality habitats) is also a strong determinant of the species' winter distribution (O'Brien *et al*. 2006). According to our results, the patch configurations in the present-day Oulanka National Park and in commercial forests differed from each other even in 1953. Our assumption is that the use of those areas had already been "minimised" from the end of the 19th century, when the idea of establishing the Oulanka National Park was first presented (Komiteanmietintö 1910, 1976).

Due to modern forest practices the multi-aged forest matrix has been replaced by a patchwork of forest stands of various ages, most of them being younger than 100 years (Eriksson *et al*. 2000, Axelsson and Östlund 2001, Berg *et al*. 2008, Kumpula *et al*. 2008). The impacts of forest management are only temporary, due to natural and artificial regeneration as well as succession. However, for reasons of economical profitability, the applied rotation times are too short to develop forests that are ideal as winter pastures for reindeer (Esseen *et al*. 1996, Dettki and Esseen 1998). It has also been noted that epiphytic lichens may be strongly affected by the particular environmental conditions of human-induced forest edges (Renhorn *et al*. 1997, Esseen and Renhorn 1998). During the period under study, the edge-affected area in the commercial forests doubled. This may indicate, together with fragmentation of mature and old-growth forest stands, that this development does not support the long-term persistence of epiphytic lichens (Kivinen *et al*. 2010). Forest management efforts have had mainly negative effects on the abundance of ground lichens through direct disturbances such as clear-cutting, timber transportation and soil scarification; however, availability of ground lichen for reindeer have also been affected by logging residues. Berg *et al*. (2008) found that during the 20th century in northern Sweden, forestry has caused the area of potentially good ground lichen pastures — i.e. middle-aged and old pine forests — to decrease by about 30%–50%. This is in accordance with our results: the areas of ground- and epiphytic-lichen pastures decreased by 20%–50%. In addition to forestry, far-reaching pollutants from different emission sources have affected the amount and growth rate of ground and epiphytic lichens (Kumpula and Kurkilahti 2010).

Forest regeneration increased the area of suitable growth sites for common hair grass. Our results agree with those of Mattila and Mikkola (2009), who found that the biomass of common hair grass increased from the 1970s to the 2000s. In January–March 1974 and 1975, the reindeer of the Alakitka herding district were not feeding in common hair grass pastures, but by the end of the 1970s common hair grass was considered, on average, to be more important than lichens as winter food (Helle and Saastamoinen 1979). This change indicates that the large-scale loggings began in our study area during the late 1960s. The common hair grass biomass in the mesic and sub-xeric sites reaches its peak 5–10 years from logging, and the abundance decreases sharply 35–45 years after clear-cutting (Helle 1975).

While estimating the carrying capacity of winter ranges, an important measure is the available area of ground-lichen pasture per head of reindeer, although carrying capacity in itself is a theoretical concept that contains a great deal of oversimplification (Kumpula 2001a, Helle *et al.* 2007). In old estimates, the minimum for moderate-condition lichen pastures was 10–15 ha per head of reindeer (Keisarillisen porolaidunkomissioonin mietintö 1914, Alaruikka 1964). According to Skogland (1986) and Skuncke (1969), with a good pasture rotation system, 7 to 10 ha ground-lichen pastures per animal would satisfy the energy need of reindeer over winter. Compared with these values, our results seem rather high. However, these models can be applied only in conditions, in which alternatives to lichens are not available. Our study area (Alakitka Herding Association), represents a multi-fodder grazing system, in which other pasture types should to be taken into account when calculating carrying capacity (Mattila 1981). According to Mattila and Mikkola (2009), in Alakitka in 2005 the area of epiphytic-lichen pasture per head of reindeer (1600 reindeer in total) was 7.3 ha, and that of ground-lichen pasture 0.1 ha. Respective values in 1995 obtained by Kumpula *et al.* (1999) were 22.2 and 9.1 ha per head of reindeer (1752 reindeer in total). Mattila and Mikkola (2009) included only xeric sites in ground-lichen class. In contrast to this, Kumpula *et al.* (1999) included also sub-xeric sites in the ground-lichen pasture class. Our results are closer to the values obtained by Kumpula *et al.* (1997, 1999), due to similar pasture classification. When comparing the results, it should also be kept in mind that we studied the potential pastures and pasture types per head of reindeer in the national park and commercial forests separately, and the results of Mattila and Mikkola (2009) and Kumpula *et al.* (1997, 1999) are representative of the entire Alakitka Herding Association, which is one reason why direct comparisons are not possible. According to our study, in 1953 and 1977 the areas of epiphytic-lichen pasture in commercial forests were more important than those in the national park. Currently, the Oulanka National Park is considered to be an important epiphytic lichen pasture (Nieminen 2008).

Our results support the hypothesis that the forest matrix transition changed the spatial configuration of patches, the area of reindeer pastures, and — together with the increase in reindeer numbers — the available pasture area per head of reindeer, which decreased. It is likely that the grazing pressure increased at the unaffected sites, decreasing the biomass of ground lichens. However, supplementary winter feeding that began in the late 1960s as a response to exceptionally difficult weather conditions and inadequacy of epiphytic lichen pastures also had an impact on the condition of the winter pastures (Helle and Saastamoinen 1979, Kumpula *et al.* 2001, Helle and Jaakkola 2008). According to Helle *et al.* (1990) and Fischer (2005), the number of winter pellets — an indication of the grazing pressure — at lichen-rich xeric sites in 2004 was only 50% of the value in 1983, and at the same time the mean ground-lichen biomass at xeric sites increased. This is most likely a consequence of the intensive corral feeding (Fischer 2005).

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III

EFFECTS OF FOREST CHARACTERISTICS ON THE ABUNDANCE OF ALECTORIOID LICHENS IN NORTHERN FINLAND

by

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IV

THE CUMULATIVE IMPACTS OF INDUSTRIAL DEVELOPMENT PROJECTS ON REINDEER HABITATS IN FINLAND

by

Jaakkola, L.M. & Vallius, E.M.

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