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Resonance Strategies of Sámi Reindeer Herders in Northernmost Finland during Climatically Extreme Years

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ABSTRACT. This study focuses on the resonance strategies of Sámi reindeer herders in four reindeer-herding cooperatives in northernmost Finland in climatically extreme years, specifically those occurring during the period 1970–2007. "Resonance" is an instinctive and indwelling reaction of a herder to a specific change (in contrast to coping, which is a more general response). The study is based on interviews with herders, field experiences, reindeer population statistics, and weather data. Before the 1960s, herders were able to deal with changing weather conditions by using intensive herding techniques and semi-tame reindeer. After the 1960s, reindeer became wilder because of the use of snowmobiles and more extensive herding techniques. The herders of the fell and forest cooperatives did not have sufficient means to prevent the serious reindeer losses in 1972–74, which resulted from two years of hard snow and ice cover, hot summers, and the free ranging of loose herds. In each of the four cooperatives studied, most of the old *siida* herds were combined, and one solution to handling large, loose herds was to build fences between cooperatives. Since the 1990s, all four cooperatives have used diverse herding and pasture rotation strategies to cope with the critical winter months. The herding techniques and the human-reindeer relationship in the fell cooperatives have differed from those in the forest cooperatives mainly because of differences in pasture types, topography, and microclimate. The contrast can be seen particularly in snow and ice conditions, as open fell regions have a thin and compact snow cover, whereas forest regions typically have deep, soft snow. This research shows that the resonance strategies of Sámi reindeer herders are both heterogeneous and dynamic: herders change them constantly, drawing on both old and new techniques to deal with the variable weather.

Key words: reindeer herding, Sámi, Finnish Lapland, resonance, herding techniques, traditional knowledge, weather, climate change, developmental systems theory, interview, anthropology, biology, multidisciplinary

RÉSUMÉ. La présente étude se penche sur les stratégies de résonance employées par les pasteurs de rennes lapons au sein de quatre coopératives de garde de rennes tout au nord de la Finlande pendant des années extrêmes du point de vue climatique, surtout celles faisant partie de la période allant de 1970 à 2007. La « résonance » est la réaction instinctive et à-demeure d'un pasteur à un changement particulier (par opposition à l'adaptation, qui se veut une réaction plus générale). Cette étude était composée d'entrevues avec les pasteurs, d'expériences sur le terrain, de statistiques relatives à la population de rennes et de données météorologiques. Avant les années 1960, les pasteurs étaient capables de faire face aux conditions climatiques changeantes en recourant à des techniques intensives de garde de troupeaux et à des rennes semi-apprivoisés. Après les années 1960, les rennes sont devenus plus sauvages en raison de l'utilisation des motoneiges et de techniques de garde plus extensives. Les pasteurs des coopératives en abattis et de coopératives en forêts n'étaient pas dotés de moyens suffisants pour prévenir les importantes pertes de rennes qui ont été subies de 1972 à 1974, pertes attribuables à la présence de neige durcie et de couverture de glace pendant deux ans, d'étés chauds et du fait que les troupeaux étaient élevés en liberté. Dans chacune des quatre coopératives ayant fait l'objet de l'étude, la plupart des anciens troupeaux *siida* étaient mis ensemble, et une solution à la présence de gros troupeaux en liberté consistait à installer des clôtures entre les coopératives. Depuis les années 1990, les quatre coopératives ont eu recours à diverses stratégies de garde des troupeaux et de rotation des pâturages pour s'adapter aux mois critiques de l'hiver. Les techniques de garde des troupeaux et la relation qui existe entre l'être humain et le renne dans les coopératives en abattis diffèrent des techniques employées au sein des coopératives en forêts principalement en raison des différences caractérisant les types de pâturage, la topographie et le microclimat. Le contraste se voit particulièrement bien sur le plan des conditions de neige et de glace, les régions d'abattis ayant une couverture de neige mince et compacte, tandis que les régions de forêts ont généralement de la neige épaisse et molle. Cette étude démontre que les stratégies de résonance des pasteurs de troupeaux de rennes lapons sont à la fois hétérogènes et dynamiques : les pasteurs modifient constamment leurs stratégies et ce, en faisant appel à d'anciennes et de nouvelles techniques pour faire face au temps variable.

Mos clés : garde de rennes, lapons, Laponie finnoise, résonance, techniques de garde, connaissances traditionnelles, temps, changement climatique, théorie des systèmes de développement, entrevue, anthropologie, biologie, multidisciplinaire

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INTRODUCTION

In northern Fennoscandia, reindeer herding is practiced in several climatic and vegetation zones. The pasture lands span boreal coniferous forests, subarctic mountain birch woodlands, tundra, barren fells and mountains, peatlands, and river banks (Colpaert et al., 2003; Rees et al., 2003; Sandström et al., 2003; Tømmervik et al., 2004; Heikkilä, 2006; Kumpula, 2006; Kitti et al., 2009). Access to different pasture habitats and the availability of different forage plants can greatly affect the growth rate and survival of reindeer. Reindeer in Norway and Sweden and on the Kola Peninsula in northwestern Russia usually spend the summer on the tundra or in coastal areas foraging on green vegetation. For the winter, they are moved to boreal forests or taiga, where they feed on terricolous lichens. In Finland and in some parts of Sweden, reindeer herds remain primarily within the same forest range throughout the year, but summer and winter grazing usually take place in different areas within the range.

Reindeer herding in northern Fennoscandia is characterized by substantial national differences in herding systems and in the economic, socio-political, cultural, and administrative environments in which the livelihood operates (e.g., Forbes et al., 2006; Heikkilä, 2006; Rees et al., 2008). During the last few decades, reindeer herding and its operational environment have changed in many ways. The livelihood has faced new threats associated with the changing climate and socio-economic challenges. At the same time, it has also had to compete with other actors and forms of land use (Jernslettern and Klokov, 2002; Riseth, 2003; Forbes et al., 2006; Heikkilä, 2006; Kumpula et al., 2008; Rees et al., 2008). Global climate change predictions for the Arctic regions in forthcoming decades indicate increased warming, higher winter precipitation levels, deeper snow cover, and a higher risk of ice formation on the ground (Putkonen and Roe, 2003; ACIA, 2005; IPCC, 2007; Tyler et al., 2007). These changes can have both positive and negative effects on reindeer pastures and reindeer herding (Weladji and Holland, 2006; Moen, 2008; Rattenbury et al., 2009; Turunen et al., 2009). Mechanization of reindeer herding, regulation of meat production, antiparasite medication, supplementary feeding, and other factors have raised the cost of reindeer herding during the past decades (e.g., Heikkinen, 2002, 2006; Jernslettern and Klokov, 2002; Forbes et al., 2006). The response of reindeer herding to changes in both climate and socio-economic circumstances in the four countries of northern Fennoscandia has recently been discussed by Rees et al. (2008).

The reindeer herding area in Finland covers 114 000 km², or 36% of the surface area of the country (Fig. 1). Reindeer herding was organized as far back as the 1700s. The state authorities intervened in 1898 by obliging reindeer owners to set up geographically defined herding cooperatives (Kortesalmi, 1996). Earlier, there were no fences between herding cooperatives; the boundaries of natural grazing regions coincided with fells or rivers (Kortesalmi, 1996).

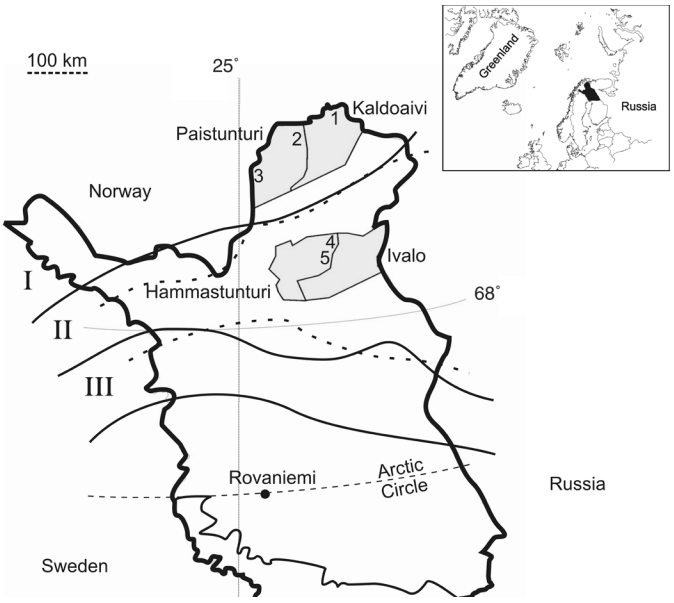

FIG. 1. Location of the fell herding cooperatives (Kaldoaivi and Paistunturi) and the forest herding cooperatives (Ivalo and Hammastunturi). Solid lines indicate vegetation zones (Kalliola, 1973): I. Fell Lapland, II. Forest Lapland, and III. Southern Lapland (Perä-Pohjola). Dashed lines indicate mire zones (Ruuhijärvi, 1988): I. Palsa and oroarctic (alpine) mires, II. Aapa (string bog) mires of Forest Lapland, and III. Aapa mires of Southern Lapland (Perä-Pohjola). Arabic numbers indicate weather stations of the Finnish Meteorological Institute: 1. Utsjoki-Nuorgam, 2. Utsjoki-Kevo, 3. Utsjoki-Karigasniemi, 4. Ivalo-Inari, and 5. Ivalo-Inari airport.

A fence was built along the Finnish-Soviet border already at the beginning of the 20th century, and fences were erected along the Norwegian and Swedish borders in the mid-1950s. In northernmost Finland, most of the herding cooperatives were fenced off during the 1960s (Helle and Jaakkola, 2008). At present, Finland has 56 herding cooperatives or profit-making herding units, each differing in size as defined by surface area and number of reindeer. Each herder in a cooperative has personal rights and obligations according to the number of reindeer he or she owns (Reindeer Herders' Association, 1960–2007; Reindeer Husbandry Act, 1990; Kortesalmi, 1996, 2007). The rights and interests of the cooperatives are protected by the Reindeer Herders' Association, which is administered by the Ministry of Agriculture and Forestry (Reindeer Husbandry Act, 1990). The ministry confirms the largest permissible number of living reindeer for each cooperative once in a decade. In Finland, both Finns and Sámi have similar rights to own reindeer and practice herding, whereas in Sweden and Norway, only the Sámi have the right to practice the livelihood.

The Sámi Home Region (Sápmi) in northernmost Finland (Fig. 1) has eight Sámi herding cooperatives. Reindeer herding in each of these cooperatives is based on Sámi customs and practices and organized in keeping with the *siida* system. A siida (in different Sámi languages: *cearru*, *siida*, *sita*, *kite*) is traditionally defined as an extended family or kin group consisting of economically independent households. The herding success of a siida depends largely on its level of consensus and its members' ability to exchange

information and act on the knowledge and insight gained by regular participation in the daily life of the household (Oskal, 1995; Joks, 2000; Sara, 2001). A siida can also be defined as an open system, transforming in time and according to the socio-economic environment. In Finland, a siida may be either a single family or a certain number of households linked by kinship. In a siida, each member of the family or extended family has personal tasks geared to the success of the siida's herd and the other members of the siida. The number of members in each siida unit can vary flexibly from year to year: siidas might be small during good years and larger during bad ones (Bjørklund, 1990).

The most detailed terminology in reindeer herding in northern Fennoscandia can be found in the Sámi language (Jernslettern, 1997; Tyler et al., 2007; Saijets and Helander, 2009). In this article, we use "reindeer herding" (North Sámi: *boazodoallu*; Finnish: *porotalous*, *poronhoito* and *bohccostallat*; *porostelu*) to refer to the work done by reindeer herders. According to Paine (1964), "herding" is the day-to-day activity with the reindeer carried out by the herders/siida (short-term decisions), whereas "husbandry" (*boazudilli*; *poronhoito*, *porotila* and *boazobargu*; *porotyö*) is the work of a household relating to individual animals (slaughter, etc.), done only by the owner, in order to realize the production potential of the herd (Ingold, 1978:121; Riseth, 2003). The term "husbandry" in our article does not include breeding. "Extensive herding" means that reindeer range or graze (*guohtu, laiduntaa*) by themselves in free-ranging or loose herds (*guohtut*, *vapaa laidunnus*) without any supervision by the reindeer herder; the herds gather freely, forming mixed or combined herds (*eallu, poroelo*) that consist of animals belonging to many owners and siidas. "Intensive herding" (*guođohit*, *paimennus*) is quite the opposite (Helle and Jaakkola, 2008): it is a technique by which the reindeer herd is kept under the control of the herder. For example, herding with hay during springtime (*siiddastallat*, *heinillä paimennus*) means that a herd is moved by spreading hay from one place to another and kept together by checking its tracks every day. "Reindeer management," in turn, can be seen as an administrative system, such as that operated by the Reindeer Herders' Association or the Ministry of Agriculture and Forestry.

The theoretical framework of this research draws on three corpora of knowledge with similar epistemologies and ontologies: traditional ecological knowledge (TEK), biology, and anthropology. In light of this choice of disciplines, we use developmental systems theory, which views both development and evolution as processes of construction and reconstruction; in this perspective, an organism—including the human being—functions as a resource for its own future development. This type of a system is open, implying that organisms and their ecological niches are constructions of their own lives (Ingold, 2000, 2001; Griffiths and Gray, 2001; Lewontin, 2001; Oyama et al., 2001). In fact, a developmental system can be regarded as a system of constructing mutual organism-niche relations that are reconstructed not only through heredity, but also by a process of incorporation in which generative potentials and capacities remain within one's life world or environment. In this sense, a niche is not a pre-existing environment that an organism can adopt; rather, organisms actively change and construct the world in which they live (Lewontin, 1983; Ingold, 2001; Oyama et al., 2001; Olding-Smee et al., 2003).

As a frame of reference, we consider both human beings and reindeer amid continuous change: they are both transforming and being transformed within their environment. Changes in the short term can be described using the concept of "resonance," which means the dynamics of action that is based on knowledge, skills, and behavior in response to various changes in the weather and environment. "Resonance" is defined here as an immediate, immanent, and continuous reaction of a herder to a change. In comparison to "coping," which is regarded as a response on a more general level, "resonance" is considered to be a comparatively specific reaction to a specific change. In the cooperatives examined in this research, resonance can be seen as changes in herding techniques or the human-reindeer relationship in response to weather extremes. When considering a longer time frame, we describe reindeer herding as a holistic, adjustable system (Ingold, 2000, 2001).

This research aimed to characterize the climatically extreme years that occurred between 1970 and 2007, which have proven critical for reindeer herding in northern Finland. We interviewed reindeer herders and considered their experiential knowledge in the context of climatic variables (FMI, 1970–2007) and reindeer numbers (Reindeer Herders' Association, 1960–2007). We focused on the period 1970–2007 because most systematic statistics for the cooperatives are available only from 1970 onwards. Finally, we analyzed the herders' activity during climatically extreme years such as 1972–74, outlined the resonance strategies they used in reindeer herding, and compared these results to those of other recent studies.

METHODS

Study Area

Four Sámi reindeer herding cooperatives in northernmost Finland were selected for this research: Kaldoaivi, Paistunturi, Hammastunturi, and Ivalo (Fig. 1, Table 1). Because of their location, climate, and vegetation, the Kaldoaivi and Paistunturi cooperatives are designated fell cooperatives, while Hammastunturi and Ivalo are forest cooperatives. Kaldoaivi and Paistunturi belong to the municipality of Utsjoki, the only municipality in Finland where the Sámi are a majority. Most of the Sámi there belong to families whose livelihood is based on reindeer-herding and salmon-fishing traditions and who speak northern Sámi. Hammastunturi and Ivalo belong to the municipality of Inari, and the Sámi in these cooperatives belong to either the Inari Sámi or the Fell Sámi. Each of these two cooperatives has some Finnish herders as well.

TABLE 1. Characteristics of the herding cooperatives studied.

Herding cooperative	Kaldoaivi	Paistunturi	Hammastunturi	Ivalo	Reference
Total surface area (ha)	241 274	297 066	251 732	286 319	Kumpula et al. (2008)
Bedrock	Bedrock gneiss	Granulite region	Granulite region	Granulite region	Manner and Tervo (1988)
Vegetation zone	Fell Lapland	Fell Lapland	Forest Lapland	Forest Lapland	Kalliola (1973), Oksanen and Virtanen (1995)
Largest permissible number of reindeer	5300	6300	5500	6000	Reindeer Herders' Association (1960–2007)
Number of reindeer (2006–07)	5533	6388	5018	5592	Reindeer Herders' Association (1960–2007)
Reindeer/km^2 land area	2.38	2.17	2.51	2.35	Kumpula et al. (2008)
Calf percentage (%; 2006–07)	76	77	52	67	Reindeer Herders' Association (1960–2007)
Lichen pasture (ha/reindeer)	11.07	12.50	12.20	12.06	Kumpula et al. (2008)
Arboreal lichen pasture (ha/reindeer)	0.86	0.73	16.02	18.17	Kumpula et al. (2008)
Shrub, deciduous, and herb pasture (ha/reindeer)	19.89	22.37	11.89	12.16	Kumpula et al. (2008)
Fells	10.0	12.1	1.2	0.5	Kumpula et al. (2008)
Peatland (ha/reindeer)	6.31	4.64	4.66	5.25	Kumpula et al. (2008)
Area of impact by infrastructure of the total land area (%)	4.57	3.10	6.65	13.26	Kumpula et al. (2008)

The characteristics of the focal cooperatives are presented in Table 1. Kaldoaivi belongs principally to the poor bedrock gneiss region of northernmost Lapland, which is 2.8–3 billion years old, and Paistunturi, Hammastunturi, and Ivalo to the granulite region of Lapland (Manner and Tervo, 1988). Both Kaldoaivi and Paistunturi (the fell herding cooperatives) are located in Fell Lapland, where the vegetation zone is characterized by subarctic mountain birch woodlands (*Betula pubescens* subsp. *czerepanovii*), treeless heaths, and barren fell tops. Hammastunturi and Ivalo (the forest herding cooperatives) are located in Forest Lapland, where the vegetation zone has mainly boreal coniferous forests dominated by Scots pine (*Pinus sylvestris* L.) (Kalliola, 1973; Oksanen and Virtanen, 1995). Reindeer densities in these cooperatives range from 2.17 to 2.51 reindeer per km^2, and the area of lichen pasture per reindeer ranges from 11.07 to 12.50 hectares. In the forest cooperatives, the impact of infrastructure on the total surface area is 13.26% (Ivalo) and 6.65% (Hammastunturi), whereas in the fell cooperatives it is only 3.10% (Paistunturi) and 4.57% (Kaldoaivi) (Kumpula et al., 2008) (Table 1).

The vegetation and topography vary from one region to another so that each herding cooperative in this study has its natural weaknesses and strengths when it comes to practicing reindeer herding—a situation clearly recognized by the herders. Herders commonly demonstrate knowledge not only of their own region, but of other herders' environments as well. The reindeer herders describe the areas in terms of the mobility of workers and reindeer. The two northernmost cooperatives—the fell cooperatives Kaldoaivi and Paistunturi—have fewer trees and are referred to as areas of easy terrain, where open ground and thinner snow cover enable easier snowmobile driving and herd gathering. However, icy fells, which sometimes thaw and re-freeze, are problematic for winter pasturing and a threat to reindeer welfare. The Ivalo cooperative is known as a favorable area for reindeer herding because the influence of the large Lake Inarijärvi results in a later fall and an earlier spring. The region's relatively mild climate and large forest areas have also contributed to its becoming a site of intensive forestry and tourism.

Interviews and Data Collection

Interviews with reindeer herders, field experiences, statistics on reindeer numbers, and weather information provided the data for this research.

We interviewed 32 reindeer herders to detemine the kinds of resonance strategies that they used in response to changing weather and climatic conditions. Seven to nine interviews were conducted in each of the cooperatives. The informants (80% men and 20% women, with ages ranging from 20 to 76 years) all spoke both Sámi and Finnish. In 1995–96, the interviews were carried out by anthropologist Terhi Vuojala-Magga, who lives permanently in one of the herding communities in the study area and participates in daily reindeer herding work; in 2007–08, they were conducted in cooperation with biologist Minna Turunen. Excerpts from 11 interviews are quoted in the text.

The biology-oriented questions in the interviews concentrated on the effects of weather and climate changes on reindeer pastures, with a particular focus on the availability and quality of forage plants. The anthropology-oriented questions related primarily to the behavior of reindeer and reindeer herders at different times in different situations and herding districts. The interviews were thematic rather than structured, enabling discussion of the matters that herders found important. The researchers sought to understand not only the data, but also herders and their work: that is, the basics of different herding techniques, which provided insights into how something is done and why. The interviews usually ended with a discussion between researchers and herders about the changes associated with weather and climate. The interviews were conducted in Finnish, tape-recorded, transcribed, and analyzed thematically. The structure of this multidisciplinary research was developed to reflect the focal themes and understandings of the practice of reindeer herding.

Data were obtained from the Finnish Meteorological Institute (FMI, 1970–2007) for the weather stations Utsjoki-Kevo, Utsjoki-Karigasniemi, Utsjoki-Nuorgam, Ivalo-Inari airport, and Ivalo-Inari (Fig. 1). The data on reindeer numbers were provided by the Reindeer Herders' Association (1960–2007). The software used for statistical analysis was SPSS 15.0 for Windows (SPSS, Inc., Chicago, Illinois). We used regression analysis to study the relationships between calving percentages and mean July temperature, cumulative thickness of snow cover (a sum of mean daily values from 1 December to 30 March), and snowmelt onset. The calving percentage is the number of calves born per 100 females as calculated during the summer or autumn calf markings. The figure thus reflects the production and survival of calves from birth until marking. Several factors affect this percentage. In many Finnish herding cooperatives, for example, the calving percentage has risen since the 1980s because of supplementary feeding, antiparasite medication, decreased reindeer density, and increased pasture rotation (see, for example, Oksanen et al., 1992; Nieminen et al., 1998; Helle and Kojola, 2008).

HISTORY OF CHANGES IN THE HERDING SYSTEM

The Legacy of World War II

Before the Second World War (1939–45), two herding systems were used in Inari: the Fell Sámi system, which represented the western herding tradition, and the Inari Sámi system, from the eastern tradition (Heikkinen, 2006:187; Helle and Jaakkola, 2008). Some of the Fell Sámi siidas originated from nomadic Norwegian Sámi families that settled in Inari after the Russian-Norwegian border was closed in 1852. Finland was under Russian rule at that time and remained so until 1917. The Fell Sámi and the Inari Sámi systems differed in two respects. First, the Fell Sámi had big herds, which they moved around the large areas of fells and pine forests south of the Norwegian border, whereas the Inari Sámi had fewer reindeer, which they herded intensively close to the home area of the siida. Second, the Fell Sámi marked their calves on the fells in mid-summer, with the aid of mosquito smoke, while the Inari Sámi earmarked the calves on tether-calving sites in May. In tether-calving, pregnant female reindeer were tied to a tree in early spring. These reindeer were moved to another place for fresh snow each day until the birth of their calves, which were then earmarked by the herders (Hannula, 2000; Kortesalmi, 2007; Helle and Jaakkola, 2008).

> Tether-calving was a very hard job. If 200 hinds were tethered, it meant that each of the two herders had to move 100 hinds every day to a new place. (male 4)

> Because of the two different practices, the calves earmarked earlier and the intensively herded reindeer of the Inari Sámi were not mixed up with those of large Fell Sámi herds (female 1, male 4).

According to the elderly informants (female 1, male 1), reindeer were rather tame earlier in history, as only a few herders, with the help of a leading bull on a leash and dogs, were able to move the herds from one grazing area to another (Itkonen, 1948; Paulaharju, 1962). As the herders and the dogs were able to manage the reindeer so well, the animals must have become accustomed to the herding techniques, and the calves learned by imitating the behavior of the hinds and leading bulls. The Inari Sámi described their reindeer as being so tame that they would even come to the house. "I would call my reindeer from the door, and after a while they were in the yard" (female 1).

People were able to regulate the dynamics of a herd by giving individual animals the chance to learn desirable behavior. The main idea was to have a herd with a large phenotypic diversity. Thus, the proportion of bulls was kept at approximately 40% of the herd because of their specific tasks, which included breaking the hard snow cover for hinds and calves and protecting them from predators (Tyler et al., 2007). In spite of their different operational models, the Fell Sámi and the Inari Sámi coexisted relatively peacefully.

During hard winters with thick snow cover, the Fell Sámi had to let their reindeer free into the southern forests and onto the Inari Sámi pastures. The losses in large herds were often more extensive than those in small herds. The Inari Sámi were able to keep most of their reindeer by dropping arboreal lichen from trees and breaking the hard snow cover. Niche construction among the Fell Sámi varied from one year to another according to weather and snow patterns, whereas the Inari Sámi adjusted their herding techniques to the varying niche constructions of the Fell Sámi.

Reindeer herding in northernmost Finland suffered serious setbacks as a result of World War II. The old system declined over the first 10 years after the war. The behavior of reindeer had become wilder because of the bombing, shooting, and lack of intensive herding, and the destruction caused by landmines continued to disturb animals for several years after the conflict ended. In addition to all the disorder, the number of predators increased. In northernmost Finland, the war reduced the number of reindeer by more than 44 000 animals in 1939–40, and more than 200 000 animals were slaughtered in 1941–44, many as food for troops (see also Hukkinen, 2008). In addition, 78 000 reindeer were lost in the period 1939–45. In the 1950s, difficult times were partly caused by hard winters, as around 1952 there was a winter with particularly deep snow. The Inari Sámi herders had no possibility to tether hinds because the fell herds moved into the forests (Reindeer Herders' Association, 1960–2007). The war years were destructive to niche construction for all living species, reindeer and humans alike.

The modernization of the reindeer herding system—particularly the introduction of snowmobiles at the beginning

of the 1960s—ultimately brought the end of intensive herding techniques, which were replaced by extensive herding practices (Pelto et al., 1968, Ingold, 1978; Helander-Renvall, 2008; Helle and Jaakkola, 2008). In most areas, the siidas' herds became mixed with one another, and the intensive siida system changed into the extensive or loose system of many siidas with combined herds. Constructing fences between cooperatives was the only solution to keep reindeer from becoming mixed up with those from different regions; niches thus became corral-controlled. By the 1980s, the old traditions of tether-calving and mosquito smoke—elements of the old open herding system and niche construction—seemed to be finished for good. During the period 1970–80, rapid changes took place with the advent of a monetary economy as well as new technology and permanent housing (Reindeer Husbandry Act, 1990). In addition, reindeer herding had to face new competing forms of land use, such as forestry, industrial development, building, mining, tourism, and the electricity industry (Jernsletten and Klokov, 2002; Riseth, 2003; Forbes et al., 2006).

The Disastrous Years of the 1970s

Before World War II, the reindeer herders and reindeer in the four study cooperatives resonated to hard winters or hot summers by changing their niche construction; herders drew on their special skills. Things changed radically at the beginning of the 1970s. Reindeer numbers were at their lowest in all four cooperatives during 1974–75 (Fig. 2a). The calving percentage (calves per 100 females) in 1973–74 was only 7% for Paistunturi, 23% for Kaldoaivi, 12% for Ivalo, and 6% for Hammastunturi (Fig. 2b), compared to mean values for the period 1964–2006 of 53% to 57% (Reindeer Herders' Association, 1960–2007).

These losses of reindeer coincided with the exceptionally high mean January temperatures (over -8˚C) that occurred in 1972, 1973, and 1974 (FMI, 1970–2007) (Fig. 3a). In these years, January was characterized by many days with mean temperatures exceeding +1˚C. (FMI, 1970–2007) (Fig. 3b), creating suitable conditions for ice formation on top of the vegetation and the ground, as well as on and within the snow cover. Ice layers, as well as crusted and deep snow, may greatly decrease the availability to reindeer of winter forage, particularly terricolous lichens (see reviews by Moen, 2008; Turunen et al., 2009). This lack of forage can be particularly critical for pregnant hinds, which have the largest nutritional requirements in winter. A thick snow cover or ice layers, or both, may result in deterioration of reindeer condition, lowering the calving percentage and decreasing the body weight of calves (Lee et al., 2000; Solberg et al., 2001; Kumpula and Colpaert, 2003; Helle and Kojola, 2008).

The reindeer losses in 1972–74 were further exacerbated by the exceptionally high mean July temperatures (over +16˚C) that occurred in 1972 and 1973 (Fig. 3c). A significant relationship ($r^2 = 0.276$, $p = 0.001$, df = 37) between the July temperature and calving percentage was found for the Hammastunturi reindeer-herding cooperative: the higher the July mean temperature, the lower the calving percentage (Fig. 4). This result coincides with the positive correlation between mosquito abundance and ambient temperature and the negative correlation with solar irradiance and wind speed found by Hagemoen and Reimers (2002). Weladji et al. (2003) used an insect harassment index, based on a midday ambient temperature of 13˚C or higher, a wind speed of under 6 m/s and cloud cover below 40%. They found that insect harassment has a negative impact on the autumn weight of reindeer calves, most probably through reduced grazing time and increased energy expenditure, but also indirectly by negatively influencing milk production of the hind (Weladji et al., 2003).

The bad years of 1972–74 were the consequence of late winters with difficult snow conditions combined with hot summers that brought insect harassment. This interpretation is borne out in the interviews with the reindeer herders. They told us about the hard snow cover in the late winter of 1972, which weakened reindeer before calving in May by decreasing the availability of winter forage. The winter was not very unusual in itself, but the following hot summer of 1972 with insect harassment made the reindeer restless, and the spring calves of that year suffered most from the heat and insects. The dramatic developments followed one upon the other. After the hot summer, the dry soil produced hardly any mushrooms, which are an important reindeer forage source for winter. All in all, reindeer, and particularly calves, were abnormally weak as they faced the oncoming winter. In the following spring of 1973, the reindeer again struggled for survival because of a hard snow cover. Herds had not yet recovered from the ordeal of the previous year, and the resulting reindeer losses were considerable. The sight and smell of dead reindeer are still clearly remembered. "There were dead reindeer everywhere on the fells" (male 4). "Reindeer came to our yards to search for food from garbage containers" (female 3). "All over again, the hard spring of 1973 changed into a hot summer" (female 2). "Reindeer went into the rivers and lakes trying to get rid of the mosquitoes" (male 2).

In both the forest and fell cooperatives, people had very few means to help reindeer because the animals were no longer intensively herded. Hence, the disaster was severe. People had given up on their active cooperation with reindeer, and thus the animals had a lesser chance of survival in those years. The three worst years (1972–74) saw the most serious threats to reindeer: a hard snow cover, a hot summer with insect harassment, and a lack of mushrooms in the fall. Calves were born during the first year of the disaster (1972), but they were the first animals to die during the following winter (1972–73). Furthermore, after the second bad year, the adult animals died or had miscarriages, and their calves were too weak to survive; the increased mortality rate of the herd was due to losses from all age groups. In spite of these serious losses, some positive consequences ensued. Empathy arose among many herders, and future cooperation between herders was strengthened; the small owners

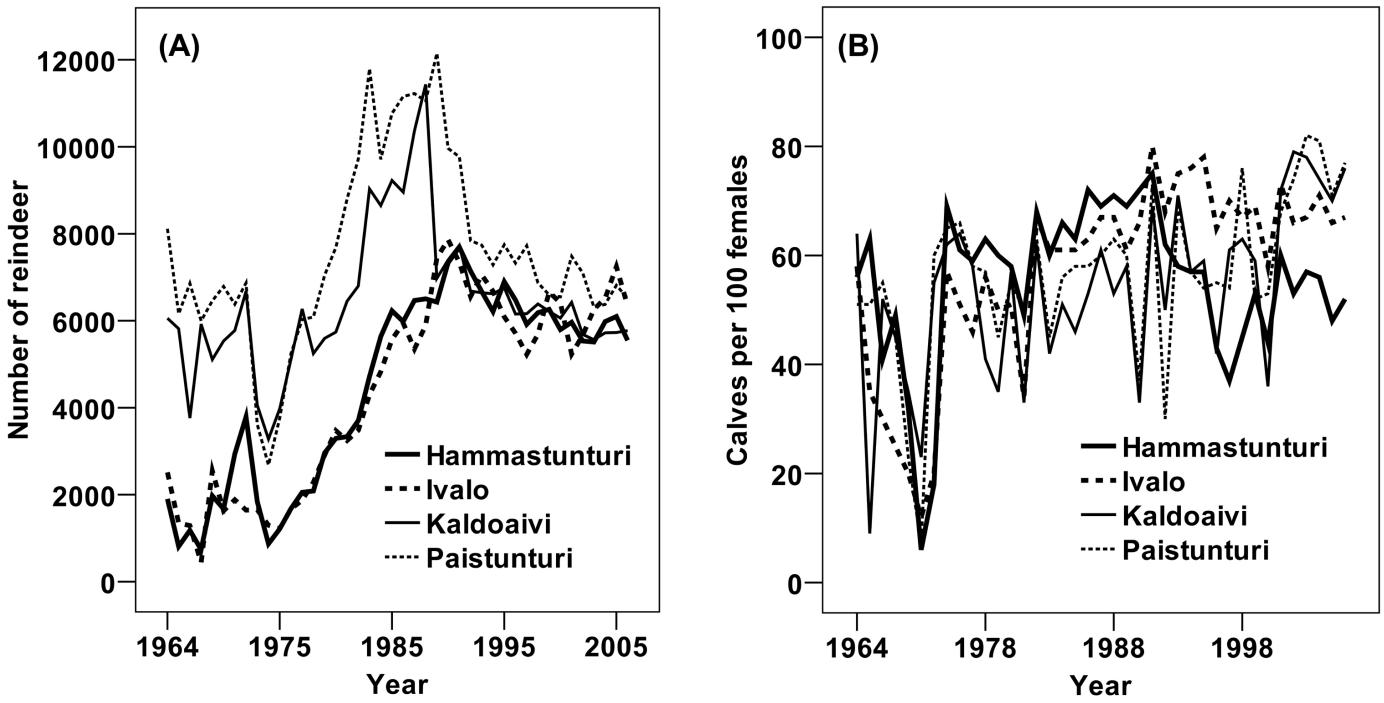

FIG. 2. (A) Number of reindeer and (B) calving percentages (calves per 100 females) during 1964–2006 in the four herding cooperatives (Reindeer Herders' Association, 1960–2007).

were encouraged to carry on for the future. "We shared the same sorrow" (male 1). There was a strong will to recover, and by the end of the 1970s, the number of reindeer had started to increase (Fig. 2a, b).

One of the reindeer herders remembered the disastrous years of the 1970s as follows:

> Reindeer herders have always survived even if there have been bad years. If we now think when reindeer were starving and died—in large numbers—the people gaining their livelihood from subsistence economies did not have bills to pay; they did not need to think about the cost of living…. They were flexible and not poor in the sense that they needed money from the bank. They were independently able to get food and keep their home cottage warm. Today if there is a bad year, the reindeer herders do not have a chance; they are in deep trouble…. There must be feelings of hopelessness if it [reindeer herding] does not provide any income to live on. The reindeer herder must think of other options. (male 4)

Resonance Strategies from the 1980s to 2007

In the 1980s, herd sizes grew in all four herding cooperatives because of favorable climate (Fig. 3) and a good market price for meat (Reindeer Herders' Association, 1960–2007; Heikkinen, 2006:193). Herders recovered from the 1970s collapse (Fig. 2a, b). They became motivated to achieve new success in their herding areas, or niches, and experimented by trial and error with different herding techniques. In the 1980s and 1990s, neither the mean temperatures nor precipitation values indicated any significant trend of climate change in the region (Fig. 3). However, there were differences in microclimates between and within the herding cooperatives due to latitude, proximity to relatively large water bodies (e.g., the Arctic Ocean, Lake Inarijärvi), topography, and vegetation. Thawing and refreezing processes occurred commonly in the fell herding cooperatives of Kaldoaivi and Paistunturi (Fig. 3b). Sub-zero temperatures within 24 hours of a rainfall produce an icy cover on the surface of the ground. Once the ground vegetation becomes encased in ice, reindeer have no access to lichen during the winter months. In 1981, 1990, 1992, and 2000, calving percentages were below 40% in at least one of the herding cooperatives (Fig. 2b). A herder describes the effect of difficult snow conditions as follows:

> Let's say that in a region where snow has fallen in the autumn and then melted away, large areas stay icy; the ice hinders us, and we have to herd in a smaller area. We have been circling around with our herd in a small area, and very big icy areas have not been used for the past two years… I mean that reindeer are very scattered. It increases moving and expenses. It is bad for reindeer, but not for wolverine; now there are 50 reindeer missing, I just wonder how many animals we have lost. (male 4)

According to the interviewees (males 3, 6, 7, female 4), Sámi herders in the fell cooperatives—Kaldoaivi and Paistunturi—resonated to thawing and freezing by changing their herding techniques in three different ways from the 1980s onwards. The older, post-war technique involving

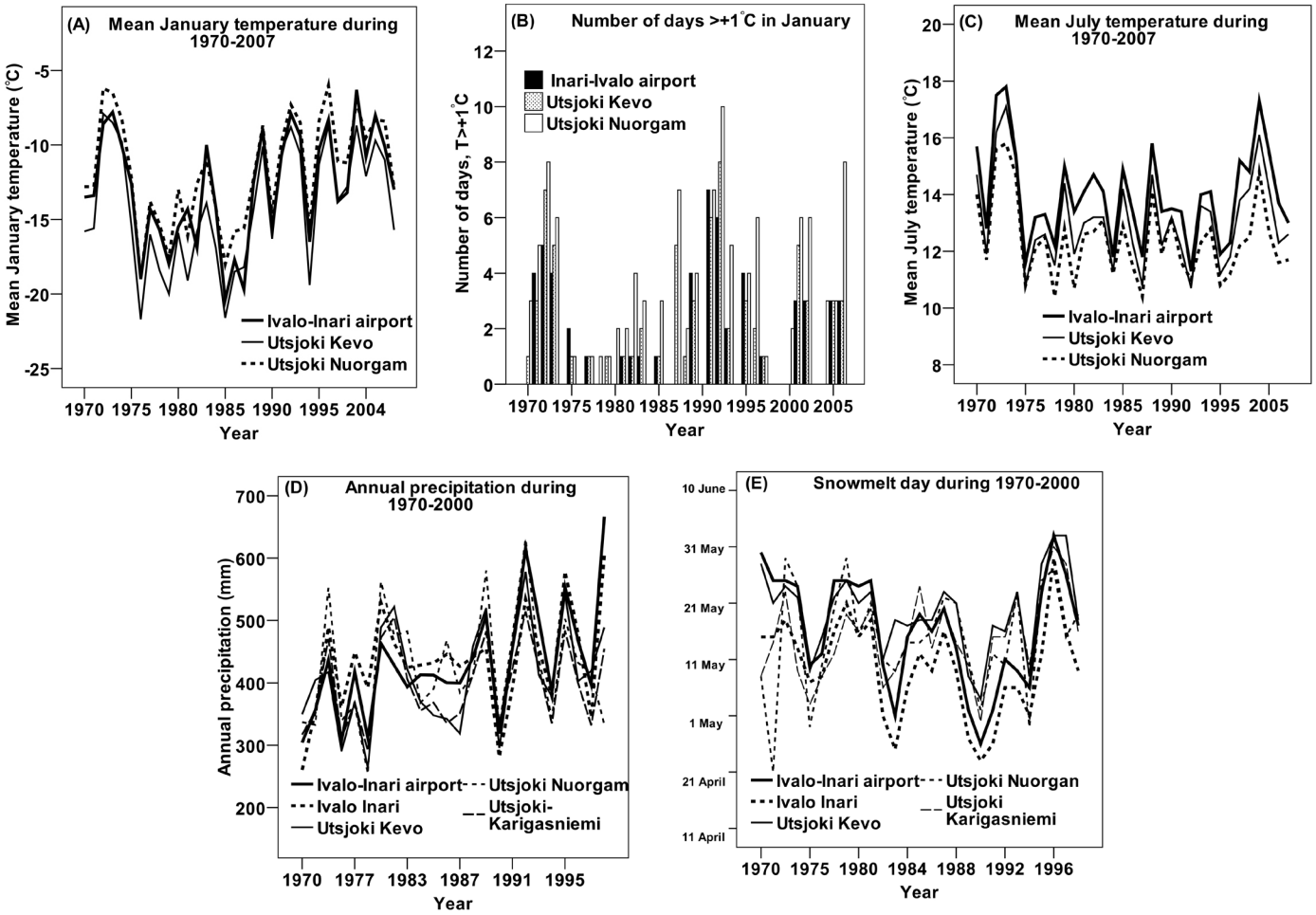

FIG. 3. Weather data for the study area. (A) Mean January temperature, (B) number of days with mean temperature above 1°C in January, (C) mean July temperature, (D) annual precipitation, and (E) snowmelt onset (FMI, 1970–2007). Locations of the weather stations are shown in Figure 1.

large combined herds and loose ranging throughout the year was discontinued. First, a new herding technique with free and controlled pasture rotation was started. From summer to midwinter, reindeer were loose, but in late winter they were herded. In this technique, a mixed herd is separated into smaller herds according to the old siida system, and reindeer are intensively herded with hay and thus moved from one place to another from February to April, prior to the calving season. The change from combined to small herds happened as follows:

> It changed naturally without anyone noticing it in particular. Everyone wanted it; no decisions were made, but everyone wanted to take care of his or her own reindeer, just like in the olden days…. It came little by little, with everyone taking care of his or her own siida. (male 8)

The second resonance strategy in Kaldoaivi and Paistunturi, at the beginning of the 1990s, was to discontinue the round-up of calves for ear marking. This change facilitated free ranging and growth during the insect harassment period in the summers and thus improved meat production (through higher carcass weights) in the fall. It has generally been regarded as a successful solution.

The third important resonance strategy in the fell herding cooperatives in the 1990s was to reduce the reindeer numbers. Two reindeer herders (male 3, female 4) pointed out that smaller reindeer numbers directly decrease grazing pressure on pastures and lead to improved meat production. Lowering the reindeer numbers is not a simple matter, however, because it affects the number of workers, the cost of technology, and other modern expenses (Stammler and Beach, 2006). “Intensive herding techniques are based on labor, and once the number of reindeer declines, those people working with small herds in the fells and forests can easily find themselves with no reindeer herding to do” (male 6). The informants describe the situation at the end of 1980s and 1990s as involving a specific mixture of old and new, intensive and extensive techniques; with this system, reindeer were once again tamer during the spring months (see also Helle and Jaakkola, 2008).

Projections for northern Fennoscandia indicate a 2–3°C increase in mean annual temperature and up to a 10% increase in precipitation by the end of the century. Current models predict deeper snow cover, increasing rainfall,

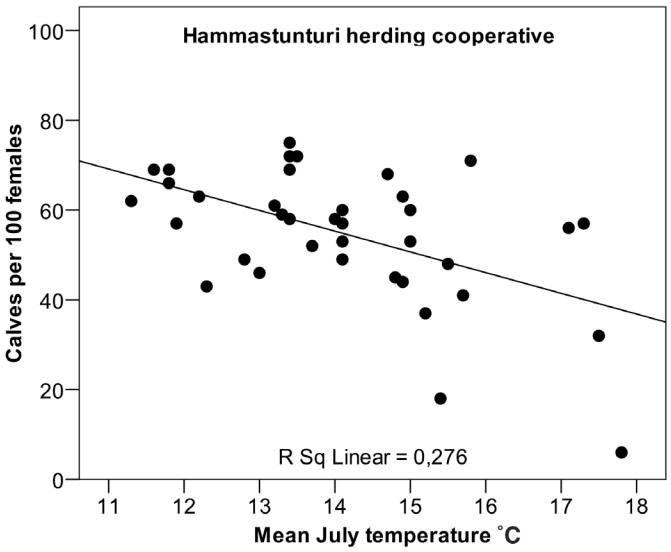

FIG. 4. Relationship between mean July temperature measured at Ivalo-Inari airport (FMI, 1970–2007) and calving percentage (calves per 100 females) (Reindeer Herders' Association, 1960–2007) in the Hammastunturi forest herding cooperative during 1970–2007.

warm spells, thawing-freezing cycles, and a higher risk of ice encasing bare ground or ice layers forming within the snow pack during the winters of the forthcoming decades (Putkonen and Roe, 2003; ACIA, 2005; IPCC, 2007; Tyler et al., 2007). Figure 3 shows that in the region of the herding cooperatives studied, the mean January (Fig. 3a) and July temperatures (Fig. 3c) have increased slightly (FMI, 1970–2007), but do not indicate any statistically significant warming trend over the period 1970–2007. It can be expected, however, that longer and warmer growing seasons will increase the net production of many summer and winter forage plant species. Prolonged snow-free periods in both spring and fall will improve the availability of forage for reindeer (see the review by Turunen et al., 2009). In 2008, reindeer herders from all four cooperatives said that longer falls and earlier springs have been contributing to good reindeer condition. As one of the herders in the Kaldoaivi fell herding cooperative said:

> I'm not at all afraid of climate change; for reindeer, it signals a good direction. Until now, we have got benefits, but we cannot be sure about the future. (male 7)

Herders have noticed lately that the late fall winds dry the surface of the soil and vegetation before the permanent snow cover, which seems to improve the availability of winter forage for their reindeer and inhibit the formation of molds (microfungi) on the pastures (see also Kumpula et al., 2000). Herders also said that reindeer have had improved access to forage because winter winds have become more common, causing thinner snow covers.

In the forest herding cooperatives of Ivalo and Hammastunturi, annual precipitation increased during 1970–2007 (FMI, 1970–2007) (Fig. 3d). Precipitation most probably

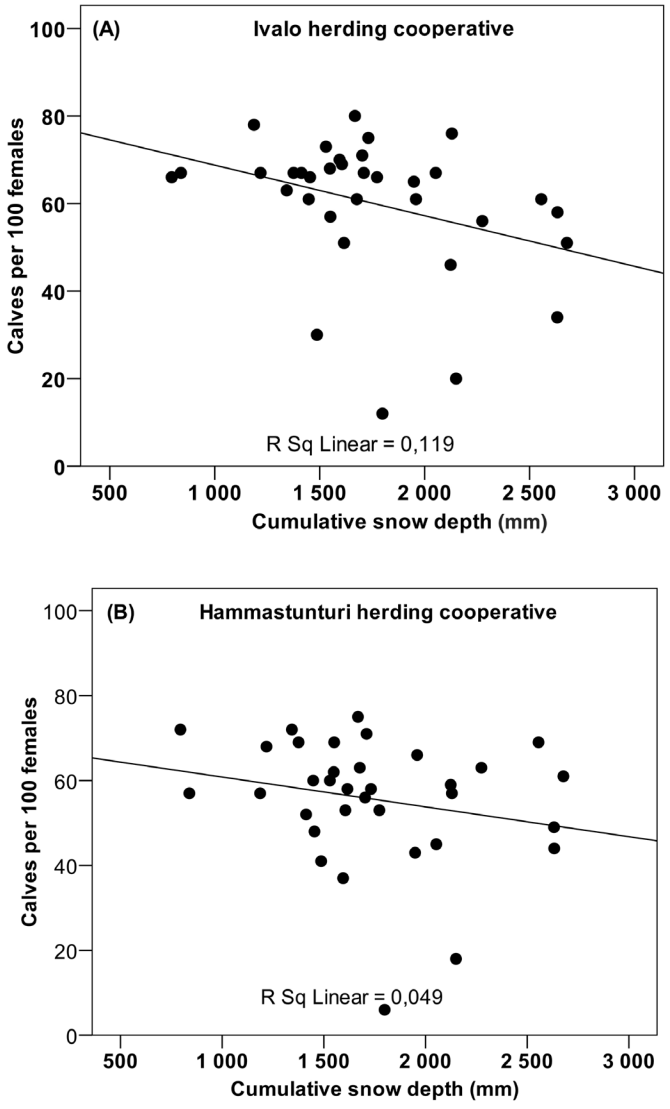

FIG. 5. Relationship between the cumulative thickness of snow cover (Dec, Jan, Feb, March) measured at Ivalo-Inari weather station (FMI, 1970–2007) and calving percentage (calves per 100 females) (Reindeer Herders' Association, 1960–2007) in the (A) Ivalo and (B) Hammastunturi forest herding cooperatives during 1970–2007.

increased in the form of rain, since different variables describing the thickness of the snow cover indicate decreasing trends. For example, the December snow cover has become thinner. In the Ivalo herding cooperative, the cumulative thickness of the snow cover (Dec, Jan, Feb, March) and the calving percentage were significantly related (r^2 = 0.119, p = 0.046, df = 33), but in the Hammastunturi herding cooperative, the relationship between snow cover and the calving percentage during the same period was not clear (r^2 = 0.049, p = 0.206, df = 33) (Fig. 5a, b). A thick snow cover decreases the availability of winter forage and may thus regulate the reproductive rate of reindeer, particularly within the boreal coniferous forest zone.

The thickness of the snow cover in the spring can vary between cooperatives—Ivalo and Hammastunturi are adjacent—and even within the same cooperative:

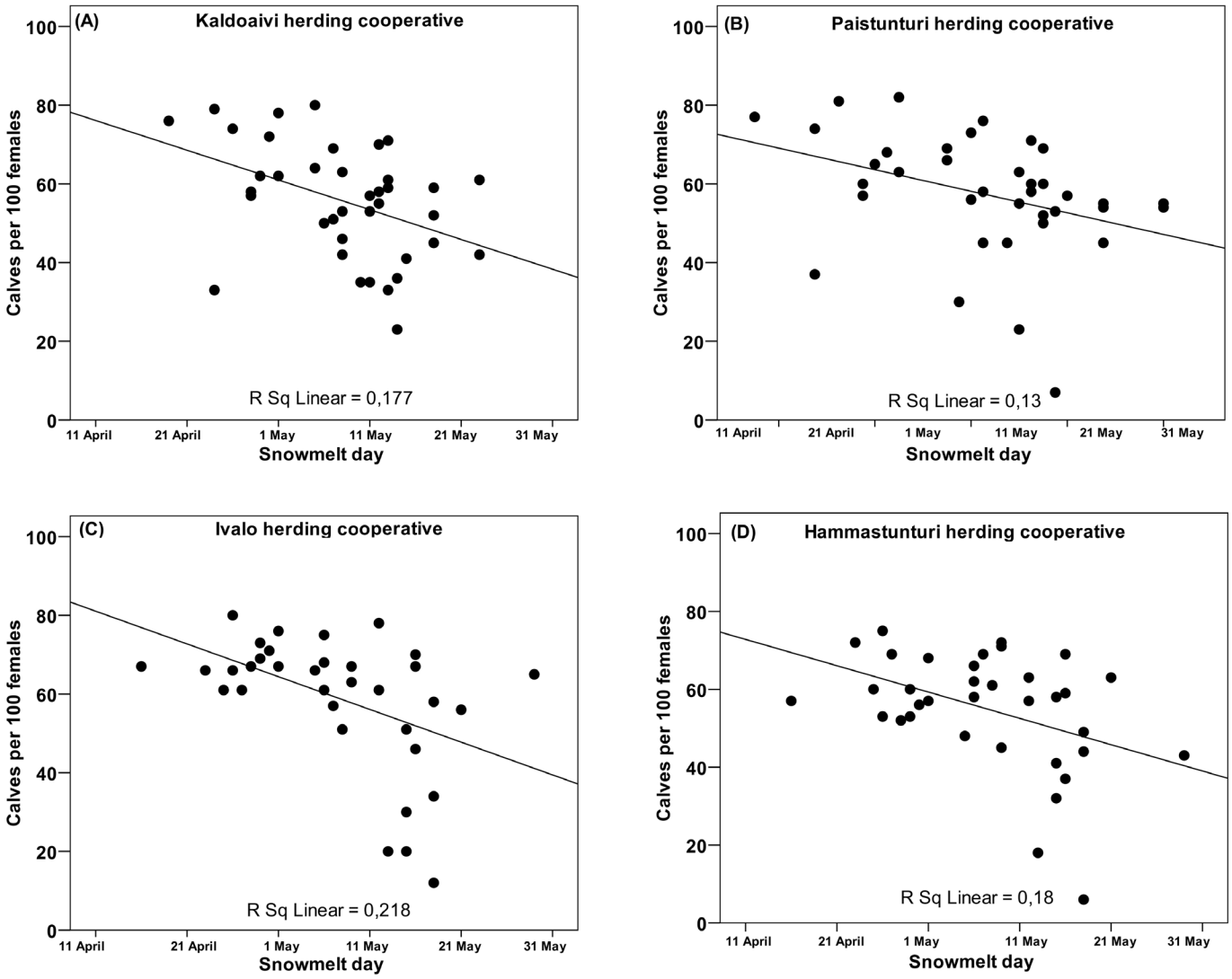

FIG. 6. Relationship between the snowmelt onset date and calf percentage (calves per 100 females) (Reindeer Herders' Association, 1960–2007) in fell herding cooperatives (A) Kaldoaivi and (B) Paistunturi and forest herding cooperatives (C) Ivalo and (D) Hammastunturi during 1970–2007. Snowmelt onset was observed at the Utsjoki-Kevo (A, B) and Inari-Ivalo (C, D) weather stations (FMI, 1970–2007).

> I know that there is this different microclimate in the Kuttura area of the Hammastunturi herding cooperative; they do have thicker snow cover that lasts longer there. It is normally colder in the upper course of the Ivalojoki River than in the village of Ivalo, because most of the upstream precipitation most probably comes in the form of snow there. (male 4)

After the 1980s, the calving percentage decreased in the siida of Kuttura (Fig. 2b). Reindeer herders therefore started the corral calving system in 1996 (see also Ruotsala, 2002). The start of a new system was dramatic, because the thick snow cover in March meant that reindeer were already weak when they were moved into corrals. Many reindeer either died or had miscarriages, and many calves perished on the snow and in waterholes. Through intensive spring herding during the following 12 years, herders of the Kuttura siida learned the corral-calving and feeding system, and they noticed that reindeer in this region became more docile (tame) during the spring months. Whereas fell cooperatives have benefited with better availability of forage from the long, warm falls with late onset of permanent snow cover, in the forest cooperatives the long falls have postponed the fall round-ups in the Kuttura siida until the rivers freeze up for the winter. On the other hand, snow containing layers of ice has caused problems, particularly in keeping the herds together: once the icy snow allows animals to move better, young reindeer tend to get separated from their mothers. Although the intensive herding technique using hay in the Ivalo forest herding cooperative is similar to that in the fell herding cooperatives, the structure of the herds is different. Herds are not separated by siida and by owner; herders may take care of other herders' reindeer in each location.

The average snowmelt onset advanced in all four herding cooperatives during 1970–2007 (Fig. 3e). Snowmelt onset and the calving percentage were negatively related:

the earlier the onset of snowmelt, the higher the calving percentage ($r^2 = 0.130–0.218$, $p = 0.005–0.026$) (Fig. 6). As the snow melts earlier in the spring, the key phenological events for reindeer summer pasture plants, such as leaf bud burst, may occur earlier, increasing the availability of newly emergent, highly nutritious and easily digestible forage (see Turunen et al., 2009). In the forest herding cooperatives, the springs of the 21st century have been early and brief, and the early snowmelt has improved the foraging conditions for calves and female reindeer. As a result of early springs, the corral-calving system became useless in the Kuttura siida of the Hammastunturi herding cooperative. Since 2008, Kuttura herders have started making more extensive use of the system whereby the reindeer are led from one place to another by spreading hay, aiming to use a system similar to that used in the Ivalo herding cooperative. In 2009, the herders began using the free calving system, in which they let the female reindeer have hay in the forest during March and April.

DISCUSSION

In terms of developmental systems theory, the reindeer herding system and techniques are used in a constantly changing, dynamic process, and the changes in niche constructions and behavior of reindeer have taken place within this process (Ingold, 2000, 2001). Our study shows that the resonance strategies among the Finnish Sámi reindeer herders of these four herding cooperatives have been both heterogeneous and dynamic. Herders working with their reindeer change their strategies and techniques constantly and include both old and new ways to cope with the changing weather and climatic conditions, such as the snow and ice conditions that critically determine the availability of winter forage (see Turunen et al., 2009 and references).

The widely described extensive and loose reindeer herding technique introduced after the war (e.g., Helle and Jaakkola, 2008)—a result of modernization in the 1960s—is vanishing in the four herding cooperatives. Intensive herding practices are coming back, slightly transformed from the old days. This long-term, continuous process of changes in herding techniques is based on special skills of knowing and coping with the environment, people, and animals. In this process, the old type of traditional, semi-domesticated reindeer became a loose-ranging, semi-wild reindeer. By the 1990s, however, the semi-wild reindeer seem to have changed back into semi-domesticated reindeer (see also Vuojala-Magga, 2010).

Daily herding work in the four cooperatives includes modern innovations, such as using snowmobiles for transportation to the reindeer herd and back home within one day, or using mechanically packed hay or pellets as extra forage for reindeer to facilitate managing the herd. Feeding reindeer with hay or pellets secures the survival of reindeer during winters with exceptional weather conditions, and thus their number and condition can be kept stable. Supplementary feeding can also reduce grazing pressure on pastures (Nieminen et al., 1998; Helle and Jaakkola, 2008). It increases herding costs, but may still be profitable in cooperatives that have their own agricultural land. However, in the herding co-operatives studied, the old means of moving the herd from one place to another is still in use. From day to day, reindeer herders move reindeer to new grazing pastures with the aid of hay. Reindeer voluntarily follow the snowmobile in the same way as they used to follow herders and their trained reindeer in earlier times. Everything changes, both in herding techniques and in reindeer behavior, indicating that the reindeer herding system is open, resonating continuously to changes.

Short-term weather changes have had both positive and negative effects on reindeer herding in the four cooperatives, and each cooperative has used various strategies to resonate sensitively to weather changes. These resonance strategies have been adopted on the basis of the reindeer herders' knowledge of past practices and experiences, the mistakes of the 1970s, reindeer behavior, and the special features of each herding district. In the fell herding cooperatives, the herding techniques differ from those in forest herding cooperatives mainly because of their different pasture types, topography, and microclimates, particularly snow and ice conditions. Open fell regions are characterized by a thin, compact snow cover, whereas deep, soft snow is more typical of forest regions. For example, the reindeer herders carry out controlled pasture rotation and herding each year by analyzing the snow conditions, including the structure, depth, and duration of the snow cover. The essential precondition for change is thus the reindeer herders' ability to master the necessary skills and their individual actions connected to knowledge of their herding district, or niche, and reindeer behavior.

This study showed that in 1972–74, the losses of reindeer in the Finnish Sámi herding cooperatives were a combined result of two years of hard snow cover, hot summers with insect harassment, and the use of free-ranging loose herds. The result of using extensive herding techniques and practices was that the herders did not have sufficient means to prevent the reindeer losses. This period was also the first time that people had modern expenses from housing and technology. In reality, modernization of the economies had bound the reindeer herders to the monetary system; the losses of the 1970s hit the new economic system of individual households hard. Therefore, the key change factors are not only climatic, but also socio-economic (see also Rees et al., 2008). There were no alternative solutions in the 1980s other than to increase the number of reindeer, which was facilitated, in turn, by antiparasite medication (e.g., Oksanen et al., 1992) and a new slaughter system focusing on calves. The Chernobyl nuclear power plant accident in 1986 tarnished the image of reindeer meat, and the market became glutted. During the next two years, the number of reindeer increased quickly and caused overgrazing in large areas (Heikkinen, 2006:193–194). All in all, the wild years of extensive herding with high reindeer numbers and loose

herds increased grazing pressure and decreased the amount of lichen on the pastures, making niche construction less favorable for reindeer.

The adaptive capacity, vulnerability, and resilience of reindeer herding to global change have been studied in northern Fennoscandia, northwestern Russia, and Alaska in various interdisciplinary and intercultural projects (e.g., Weladji and Holand, 2003; Beach and Stammler, 2006; Stammler and Beach, 2006; Tyler et al., 2007; Moen, 2008; Rees et al., 2008; Forbes et al., 2009; Rattenbury et al., 2009; Turunen et al., 2009; Hovelsrud and Smit, 2010). It has been shown that reindeer herders' traditional responses to changes are greatly dependent on flexibility in herding practices. These practices are currently being eroded by several non-climatic factors that vary greatly in different reindeer-herding countries or regions. These factors include inter-linked constraints that are social, legal (e.g., state regulations on reindeer densities), administrative (e.g., institutional structure of reindeer herding), economic (e.g., meat prices, equipment costs, labor, subsidy policy), and environmental (e.g., predators) (Beach and Stammler, 2006; Stammler and Beach, 2006; Tyler et al., 2007; Rees et al., 2008; Forbes and Stammler, 2009; Rattenbury et al., 2009). A recent study by Rattenbury et al. (2009), for example, reported that the long-term adaptability of reindeer herders to weather variability on the Seward Peninsula, Alaska, is greatly affected by a number of interacting factors, including the mixing of reindeer with migrating caribou, reduced herd sizes, difficulties in affording snowmobile maintenance or crew assistance, and dwindling market opportunities.

The geographical dimensions of niches (herding areas) within the herding cooperatives may vary considerably, and they depend very much on boundaries, both natural (e.g., water bodies) and man-made (e.g., reindeer fences, construction, mining, and forestry activities). Sámi reindeer herding in Norway, which is based on large niches and extensive tracts of land with long pasture rotation routes extending from the Finnish border (winter grazing area) to the Barents coast (summer grazing area), has faced various threats, the most serious being difficult ice and snow conditions (e.g., Tyler et al., 2007). Sámi herding in Finland, characterized by micro-scale niches and smaller herding cooperatives, may not have as much difficulty resonating to constantly changing weather conditions, because the herders have detailed traditional knowledge—including familiarity with microclimatic and edaphic factors—that covers not only their own, but also others' herding districts. There seems to be a strong relationship between the knowledge of herding techniques, changes in these techniques based on niche structure, and reindeer behavior in the context of weather changes. Future threats and challenges to Sámi reindeer herding in northern Fennoscandia will most probably be related not only to difficult snow and ice conditions, but also to the increasing numbers of hot summers with insect harassment—one extreme condition following another.

CONCLUSIONS

The resonance strategies among the Sámi reindeer herders of the four focal herding cooperatives in northernmost Finland have been both heterogeneous and dynamic. Herders working with their reindeer change their strategies and techniques constantly and include both old and new ways to respond to changing weather and climatic conditions. In this study, niche construction is seen as a continuous process of changes within the human-reindeer relationship, one of the key drivers being the changing weather. During the free-ranging period (extensive herding) of the 1960–80s, substantial losses of reindeer took place in the period 1972–74. This loss was followed in the 1980s by a rapid increase of reindeer numbers, which degraded lichen pastures. Together with new technology, the old resonance strategies seem to offer a rather stable way of constructing niches within Finnish Sámi reindeer herding. It seems clear that as long as people are continuously working with reindeer in intensive ways (intensive herding), the human-animal relationship will provide diverse strategies for reducing or preventing the negative effects of climate change and using its positive effects.

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