Available online at www.sciencedirect.com
ScienceDirect
Global Environmental Change 17 (2007) 191–206
Global Environmental Change
www.elsevier.com/locate/gloenvcha

Saami reindeer pastoralism under climate change: Applying a generalized framework for vulnerability studies to a sub-arctic social–ecological system ☆

N.J.C. Tyler[a,*], J.M. Turi[b], M.A. Sundset[c], K. Strøm Bull[d], M.N. Sara[e], E. Reinert[f,g], N. Oskal[e], C. Nellemann[h], J.J. McCarthy[i], S.D. Mathiesen[e,j], M.L. Martello[k], O.H. Magga[e], G.K. Hovelsrud[l], I. Hanssen-Bauer[m], N.I. Eira[n], I.M.G. Eira[e], R.W. Corell[o]

[a]*Centre for Saami Studies, University of Tromsø, Tromsø N-9037, Norway*
[b]*Association of World Reindeer Herders, N-9520 Guovdageaidnu, Norway*
[c]*Department of Arctic Biology and Institute of Medical Biology, Faculty of Medicine, University of Tromsø, N-9037 Tromsø, Norway*
[d]*Centre for Human Rights, Faculty of Law, University of Oslo, Norway*
[e]*Saami University College, N-9520 Guovdageaidnu, Norway*
[f]*Norwegian Institute of Strategic Studies (NORISS), Youngstorget 5, N-0181 Oslo, Norway*
[g]*Tallinn University of Technology, Sütiste 21, Tallinn, Estonia*
[h]*UNEP GRID-Arendal /NINA, Fakkelgaarden, Storhove, N-2624 Lillehammer, Norway*
[i]*Department of Organismic and Evolutionary Biology, Harvard University, Cambridge, MA 02138, USA*
[j]*Section of Arctic Veterinary Medicine, Department of Food Safety and Infection Biology, Norwegian School of Veterinary Science, N-9292 Tromsø, Norway*
[k]*Kennedy School of Government, Harvard University, Cambridge, MA 02138, USA*
[l]*CICERO—Centre for International Climate and Environmental Research-Oslo, P.O. Box 1129, Blindern, N-0318 Oslo, Norway*
[m]*Norwegian Meteorological Institute, P.O. Box 43, Blindern, N-0313 Oslo, Norway*
[n]*Fossbakken, N-9357 Tennevoll, Norway*
[o]*American Meteorological Society, 1120 G Street, NW, Suite 800, Washington, DC 20005-3826, USA*

Received 26 January 2006; received in revised form 8 June 2006; accepted 12 June 2006

Abstract

A generalized vulnerability framework was used to structure an interdisciplinary and intercultural examination of factors that influence the ways in which reindeer pastoralism in Finnmark (northern Norway) may be affected by climate change. Regional and local (downscaled) climate projections included scenarios that can potentially influence foraging conditions for reindeer. None of the projections were without precedent; several climate change events in Finnmark during the last 100 years were at least as great as those projected in the next 20–30 years. Herders' traditional responses to changes in both the natural and the socio-economic environments have depended on a flexibility in herding practice that is currently being eroded by several non-climate factors. The reduced of freedom of action resulting from loss of habitat, predation and aspects of governance (especially economic and legal constraints) potentially dwarves the putative effects of projected climate change on reindeer pastoralism. It may, however, also lead to situations in which new climatic conditions threaten the system in unprecedented ways. Developing appropriate methodologies for assessing the adaptive capacity, the vulnerability and the resilience of social–ecological systems to global changes remains a challenge. Recognition of the knowledge systems of Arctic cultures and the full engagement of local people throughout the process are key elements of the solution.

Keywords: Climate change; Downscaling; Finnmark; Pastoralism; Reindeer; Saami; Traditional knowledge; Transhumance; Vulnerability

Terminology

In this paper we distinguish between the terms reindeer 'husbandry' and reindeer 'herding' (cf. Paine, 1964). We

☆This paper is an expanded version of 'Case 3: Reindeer nomadism in Finnmark, Norway' included in McCarthy et al. (2005).

*Corresponding author. Tel.: +47 77 64 47 88/+47 90 57 72 98; fax: +47 77 64 63 33.
E-mail address: nicholas.tyler@ib.uit.no (N.J.C. Tyler).

0959-3780/$ - see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.gloenvcha.2006.06.001

use husbandry as a general, inclusive term that refers to the possession, maintenance and management of the herd which is the harvestable resource of its owners (Saami *báikedoallu*; Norwegian *hushold*). Herding is a subset of this and the term refers to the gathering and moving of herds to pasture (closest equivalent in Saami *guođotit* (Nielsen, 1962); Norwegian *gjeting*). Herding frequently involves the combined herds of several husbandry groups (Saami *siida*) and is characteristically collective/co-operative, although an individual herder may have to undertake it alone from time to time. Common to both herding and husbandry, responses to sporadic and unpredictable changes in the physical environment are frequently discretionary (Paine, 1994, p. 102). In deference to convention, we refer to reindeer pastoralists as 'herders', irrespective of the distinction between husbandry and herding.

Currency

Values in Norwegian kroner have been converted to US dollars at a rate of NOK 7.0 = US$ 1.00.

1. Introduction

1.1. Vulnerability of social–ecological systems to change

Climate variability, climate change and the societal/cultural transformations associated with globalization have been, and continue to be, responsible for major changes in the physical environment, biota and cultures of indigenous and other communities in the Arctic (ACIA, 2005). Moreover, social–ecological systems in the Arctic are both subject to unprecedented environmental and social changes (Ullsten et al., 2004) and may be particularly sensitive to change, perhaps more than in many other regions (Nuttall, 2000). This is due in part to the variability of the Arctic climate and to the characteristic ways of life of indigenous Arctic peoples and, in particular, of their local communities (Freeman, 2000). To gain an understanding of the potential impact of climate change on coupled social–ecological systems in the North is, therefore, a major priority.

High sensitivity notwithstanding, little is known about the vulnerability of such systems to change. Vulnerability is a product of the susceptibility to, and coping capacity of, systems to the integrated effects of the many forces that act on them. It is, thus, a function of not only the character, magnitude and rate of change of the factors that act on systems but also of the sensitivity and coping and adaptive capacities of those systems. Sensitivity, in this regard, is the degree to which a system is affected (adversely or beneficially) by a particular factor while adaptive capacity refers to the ability of the system to adjust, to ameliorate potential harm, to realize opportunities and to cope with consequences (IPCC, 2001).

Understanding and measuring vulnerability therefore requires assessment of at least three separate aspects. These include real or potential impacts on the system, the systems' ability to cope and adapt to these impacts and the extent to which coping capacity may be constrained by environmental or societal conditions (Turner et al., 2003a, b). Techniques for the analysis and synthesis of such a disparate mass of data may include historical narratives, contextual analyses, case studies, statistical analyses, application of Geographic Information Systems and the development of vulnerability indices (e.g., Cutter, 1996; Downing et al., 2001). Every case is unique and the particular methodologies adopted may, therefore, vary from case to case. The novel feature of vulnerability assessments, however, is not which specific techniques are used but the integration of different techniques across a wide variety of different intellectual domains (McCarthy et al., 2005). This plurality of approaches, moreover, enhances rather than compromises the ability to generalize between studies.

This paper describes an interdisciplinary and intercultural examination of Saami reindeer pastoralism in Finnmark in northern Norway (Fig. 1) in relation to projected climate change in the North. Reindeer pastoralism is an ancient form of animal husbandry which has major economic and cultural significance for the indigenous peoples of northern Eurasia (Slezkine, 1994). Its economy, however, is in many cases weak. The principal commercial product of Saami reindeer pastoralism in Norway is meat. Production, though substantial, is highly variable: in the period 1994–2003, for instance, total annual production here varied between 1200 and 2700 tons and income (wholesale value) varied correspondingly between US$ 9 and 17 million (Reindriftsforvaltningen, 2004; St.prp.nr. 63, 2004–2005). Herders' income, already relatively low (mean annual income in 2004 = US$ 19,000 for herders compared to US$ 42,000 for industrial workers in Norway;

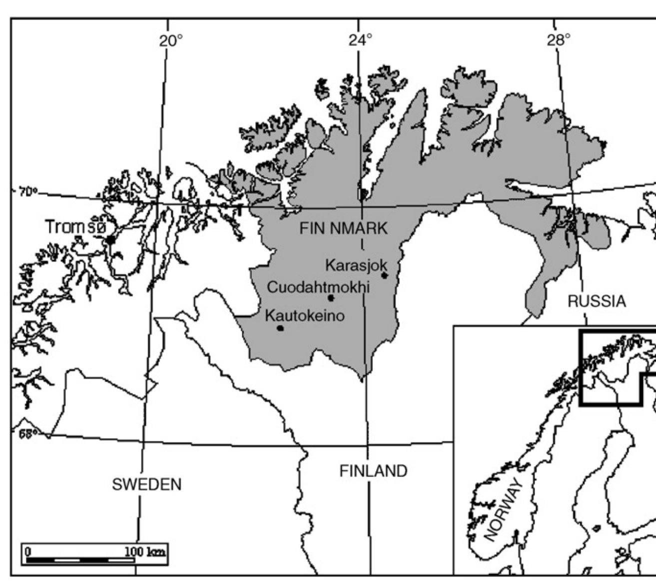

Fig. 1. Map of Finnmark, the northernmost, largest and least populated county in Norway, showing place names mentioned in the text.

Budsjettnemda for Jordbruket, 2005; Lars-Johan Rustad, personal communication) is also highly variable (range 2000–2004 from US$ 11,000 to US$ 23,000; St.prp.nr. 63, 2004–2005) and their private economy is precarious as a direct result. Where income is uncertain and cash (as opposed to capital) is scarce, people are especially vulnerable to factors that perturb the basis of the production upon which they depend. The study, therefore, used a vulnerability framework (Turner et al., 2003a) to structure an examination of the multiple and interacting forces that may influence the ways in which reindeer pastoralism is affected by climate change.

1.2. Developing a conceptual framework: local participation

A vulnerability study must be built on a conceptual framework that reflects the attributes of the case under investigation. The first step towards such a study, therefore, is to develop a framework tailored to the characteristics of the system of interest, in this case reindeer pastoralism in Finnmark. Reindeer, reindeer herders and the natural and social environments of which they are a part represent a coupled social–ecological system consisting of many components which, though only distantly related, are closely and functionally linked. Herders' livelihoods, for example, depend in large part on the level of production of their herds. Production, in turn, depends on the size of herds and on the productivity of individual reindeer in them which depends, again in turn, on the quantity, quality and availability of forage. The level of feeding the animals enjoy is determined in the short-term by prevailing weather conditions in summer, which affect the growth and nutritional quality of forage plants (e.g. Lenart et al., 2002), and by weather conditions in winter, in particular a combination of precipitation, temperature and wind, which affect the quality of the snow-pack and, hence, the availability of the forage beneath it (Pruitt, 1959; Skogland, 1978; Forchhammer and Boertmann, 1993). In the medium and long term, however, feeding levels are also determined by a suite of non-climate factors and these, and others, have a major influence on the level of production and, completing the circle, on herders' livelihoods. Such factors include the quality of pasture (in terms of the species composition and biomass of forage and the availability of other important natural resources), the existing area of pasture, herders' rights of access to it, the level of competition between reindeer and other grazers (chiefly free-ranging domestic sheep), the level of predation to which herds are subjected, the size of the market and the monetary value of reindeer products and so on. Reindeer pastoralism, therefore, is influenced by a range of variables in both the natural and the social environments in which it is practiced. Moreover, not only are several of the non-climate factors that impinge on it determined by political decisions and the policies of institutions far removed from Finnmark but also the perception of the vulnerabilities of reindeer pastoralism itself differs widely across political and managerial hierarchies, economic sectors and cultures, not least with increasing distance from Finnmark. Ultimately, however, the vulnerability of any coupled social–ecological system is a function of local conditions and the identification of the factors that influence it

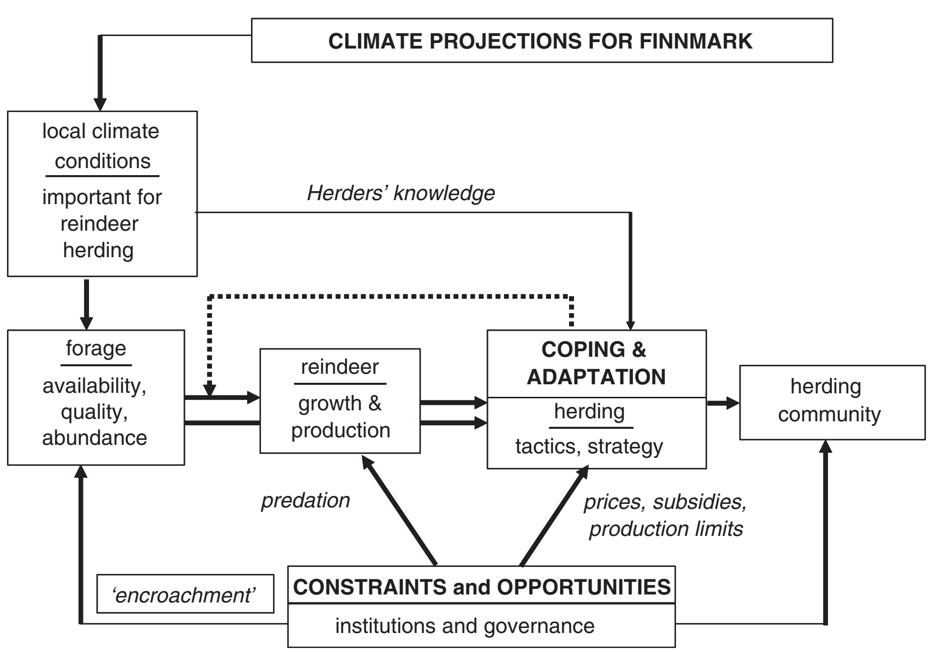

Fig. 2. Conceptual framework for the study developed in collaboration with reindeer herders. The framework describes the perceived relationships through which (i) climate change influences the growth and productivity of herds of reindeer, (ii) herders cope with climate related changes in the supply of forage and in the level of production of their herds and (iii) herders' ability to cope with climate related changes is constrained by extrinsic anthropogenic factors collectively called 'institutions and governance' (These include 'predation', the level of which is influenced through legislation designed to protect populations of predators).

requires knowledge of the priorities and perspectives of local people. Their involvement in the design, implementation and the dissemination of research results from studies of this kind is therefore not only an ethical imperative but also scientifically indispensable.

The adaptive capacity of reindeer pastoralism, which has been demonstrated repeatedly throughout history (e.g. Pedersen, 2006), is based on the knowledge and experience of individual herders and is embodied in their language and the institutions of their husbandry (Nielsen, 1962). Recognizing this, in August 2002 the Association of World Reindeer Herders convened a meeting in Tromsø at which natural and social scientists, administrators and reindeer herders together developed a conceptual framework for an analysis of reindeer pastoralism in Finnmark based on the generalized scheme of Turner et al. (2003a). The resulting scheme (Fig. 2) consisted of three main parts: (i) climate projections and the ecological consequences of climate change, (ii) coping and (iii) constraints on coping. Superficially, this model bore little resemblance to the general framework from which it evolved, yet key elements, including social and environmental driving forces, human and societal conditions, impacts, responses and adaptation, all remained.

2. Study area

Finnmark (Fig. 1) is the northernmost, largest and least populated county in Norway. Populations in 2004 of 165,000 reindeer and approximately 2000 registered reindeer owners in Finnmark represented 73% and 75% of semi-domesticated reindeer and Saami reindeer owners in Norway, respectively (Reindriftsforvaltningen, 2004). Reindeer here are managed in a transhumant manner (Skjenneberg, 1989; Paine, 1994). Herds of mixed age and sex varying in size from 100 to 10,000 animals are maintained on natural mountain pasture all year round and typically are moved between coastal summer pastures and inland winter pastures (Fig. 3). The pattern of migration is clearly an adaptation to climatic conditions. Feeding conditions for reindeer in winter are determined chiefly by the qualities of the snow pack. In particular, recurring cycles of thawing and re-freezing increase the density and the hardness of the snow pack throughout winter and can make it progressively more difficult for the animals to dig down to the plants beneath. Such cycles are much more frequent at the coast, where winters are mild and wet than inland, where conditions are colder and drier. Consequently, grazing (snow) conditions for the animals are generally better inland which is why they move there in winter.

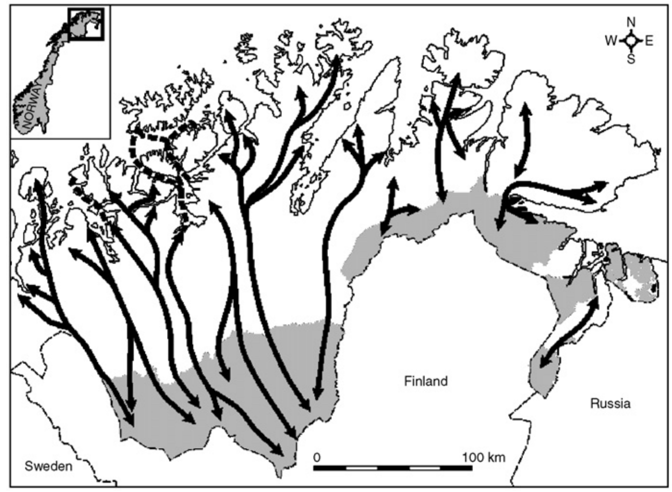

Fig. 3. The general pattern of migration of semi-domesticated reindeer in Finnmark. Herders here typically make two migrations with their animals each year, moving between geographically separate summer and winter pastures. In spring (April and May), they and their animals generally move to the mountainous coastal region where the reindeer are left on peninsulas or are swum or ferried across to islands where they feed throughout the summer, eating highly nutritious parts of dwarf shrubs, birch, willows, sedges and grasses. In September they are typically gathered and taken inland to winter pastures (shaded grey) characterized by open, upland plains of tundra and taiga birch scrub. For clarity, only a selection of migration routes (black arrows) and ferry routes (heavy dotted lines) are shown.

3. Potential effects of, and projections for, climate change in Finnmark

Large-scale climate changes in the Arctic may influence local climate (e.g. Bamzai, 2003) which, in turn, is likely to affect foraging conditions for reindeer, the productivity of herds and, ultimately, herders' income and livelihood. The ecological impact of large-scale climate variability and recent climate change on temperate species of plants and animals is well documented (Ottersen et al., 2001; Post and Stenseth, 1999; Post et al., 2001; Stenseth et al., 2002; Walther et al., 2002). Among northern ungulates, variation in growth, body size, survival, fecundity and population rates of increase, correlate with large-scale atmospheric phenomena including the North Atlantic (Forchhammer et al., 1998, 2001, 2002; Post and Stenseth, 1999) and Arctic Oscillations (Aanes et al., 2002). Putative causal mechanisms underlying these correlations involve the climatic modulation of grazing conditions for the animals. The effects may be either (i) direct, through the influence of climate on the animals' thermal environment or the availability of their forage beneath the snow in winter (e.g. Forchhammer et al., 2001; Mysterud et al., 2000) or (ii) indirect, through modulation, by late lying snow, of the phenological development and nutritional quality of forage plants in summer (e.g. Mysterud et al., 2001). The consequences for the animals may, in turn, be either direct, involving the survival of the current year's young or indirect, whereby climate-induced variation in early growth influences the survival and breeding performance of the animals in adulthood (e.g. Forchhammer et al., 2001).

Projections for northern Fennoscandia indicate an increase in mean annual temperature during the next 20–30 years of as much as 0.3–0.5 °C per decade

(Christensen et al., 2001; Benestad, 2004a). The trend in mean annual temperature for the period 1970–2000 generated retrospectively by the models corresponds reasonably well with empirical observations (Hanssen-Bauer et al., 2003). The models do not, however, capture the observed changes in the variability of ambient temperature and it is not yet possible, therefore, to project temperature variability for the next 50–100 years with any degree of confidence.

Global projections for the next 70 years indicate increased precipitation at high latitudes (Räisanen, 2001). These projections seem robust and are qualitatively consistent with the expected intensification of the hydrological cycle caused by increased temperatures. Regional models for Fennoscandia project an increase in annual precipitation of between 1% and 4% per decade (Hellström et al., 2001; Christensen et al., 2001; Hanssen-Bauer et al., 2003). Decadal scale trends in precipitation are, however, very sensitive to changes in atmospheric circulation. Projections vary considerably between different climate models (Chen et al., 2006) and none reproduce the observed trends in precipitation during the last few decades very well.

Increases in temperature and precipitation can affect the pastures in a variety of ways that may influence conditions for reindeer. For instance, increased temperature in autumn can delay both the arrival of snow, as a result of which the reindeer tend to disperse and the herds become less easy to control, and also the formation of thick, safe ice over rivers and lakes, consequently impeding the movement of herds inland. Increased precipitation in winter can result in greater accumulation of snow on winter pastures resulting in a general reduction in the availability of forage. The scenarios indicate that though the average winter temperature in Finnmark will remain well below zero in the foreseeable future, the frequency of warm spells in winter will most probably increase and this, in turn, may influence the structure and quality of the snow pack. Increased temperatures in spring might advance the date of the melt but the flush of new vegetation might be delayed where snow cover is deeper (e.g. Mårell et al., 2006). No projections for snow conditions have yet been made for Finnmark. Their development would require an integration of the projections for temperature and precipitation both of which are currently available only at a coarse scale of resolution. To be meaningful, Global Climate Models would have to be downscaled to relevant local scales and would need to incorporate data on the physical structure of the landscape, especially altitude which influences local temperature profiles and, hence, the transition of precipitation from rain to snow (e.g. Mysterud et al., 2000).

The spatial resolution of the projections for temperature and precipitation over northern Fennoscandia is still coarse and useful for projecting local trends only in general terms. Downscaled climate scenarios (Hanssen-Bauer et al., 2003; Benestad, 2004b) have been developed for several stations, including Karasjok close to the winter pastures in eastern Finnmark (Figs. 1 and 3). Hanssen-Bauer et al. (2003) developed temperature and precipitation scenarios (Figs. 4 and 5) based on one global scenario, using a regional scaling technique and multiple regression. Benestad (2004a) developed a tentative probabilistic temperature scenario by downscaling output from 17 different global climate models using canonical correlation analysis and the software package CLIM.PACT (Benestad, 2004b). The scenarios do show the main characteristics of the regional scenarios for Fennoscandia identified by Hanssen-Bauer et al. (2005), including larger warming in winter than in summer and inland compared to the coast. In order to produce sufficiently detailed local scenarios for evaluating possible impacts, a denser network of stations and/or improved spatial interpolation will, however, be needed.

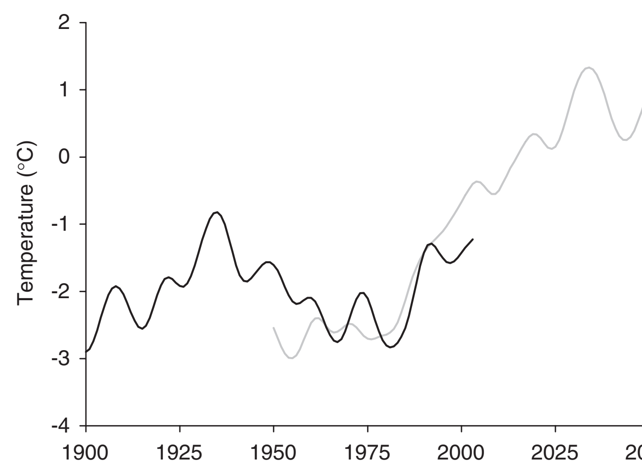

Fig. 4. Low-pass filtered series of observed (black line) and projected (grey line) annual mean temperature in Karasjok. The projected temperature is downscaled from the ECHAM4/OPYC3 global climate model, run with the IS92a emission scenario (updated in August 2005 from Hanssen-Bauer et al., 2003).

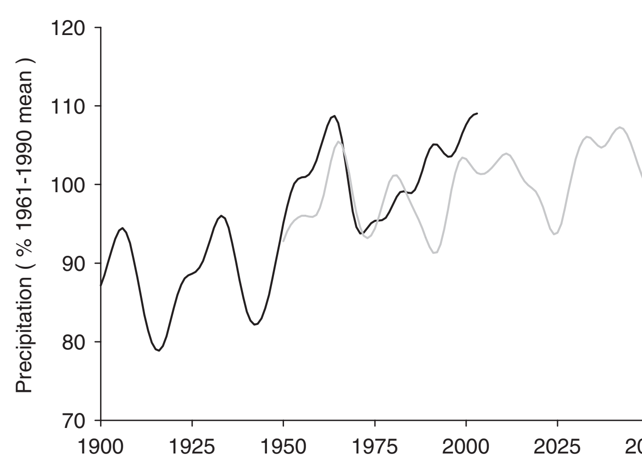

Fig. 5. Low-pass filtered series of observed (black line) and projected (grey line) annual precipitation in Karasjok. The projected precipitation is downscaled from the ECHAM4/OPYC3 global climate model, run with the IS92a emission scenario (updated in August 2005 from Hanssen-Bauer et al., 2003).

It may also be necessary to apply non-linear downscaling techniques in order to capture the climate variability. Weather patterns over reindeer pastures are complex: they display enormous variation and, consequently, are difficult to project at local scales even using the most robust downscaling methods. During the last century, for example, the winter (December–February) temperature in Karasjok varied from more than 6 °C below the 1961–1990 average (1966) to more than 7 °C above it (1930), while the winter precipitation varied from about 30% (1911) to almost 200% (1952) of the 1961–1990 average (Fig. 6). Even between successive years, mean winter temperature varied by more than 9 °C (1902/1903), and precipitation by 140% (1951/1952). Likewise, in the period 1968–2005 the date each year on which the last snow melted at the meteorological station in Tromsø varied by 45 days (from 29 April to 14 June; median date = 20 May; data from the Norwegian Meteorological Institute, Oslo). The situation, however, is more complicated than even these simple examples indicate owing to the multitude of ways in which weather varies. Almost every year in Finnmark is exceptional in the sense that every year one or other parameter exceeds all previous records (Table 1). There are, in effect, no 'normal' years in Finnmark; instead, in herders' parlance, 'One year is not another's brother' (*Jahki ii leat jagi viellja*).

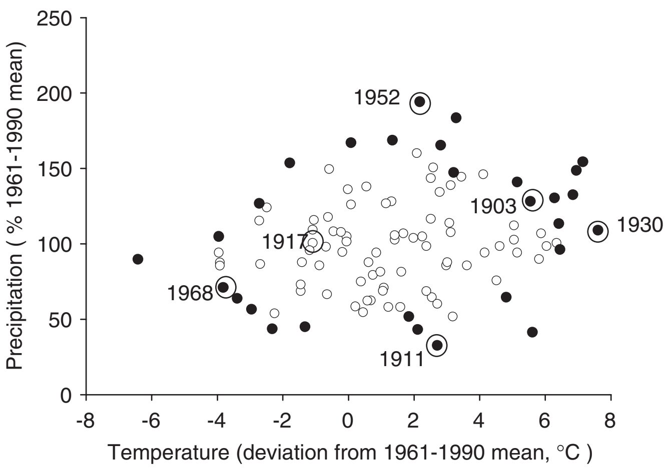

Fig. 6. Scatterplot of average temperature and precipitation during the winters (December, January and February) from 1900 to 2004 in Karasjok. Extraordinary winters (filled circles) mentioned in the text are identified with the year in which they ended. Temperatures are given as anomalies from the 1961–1990 mean (−16 °C) and precipitation is given as a proportion (%) of the 1961–1990 mean (48 mm).

4. Coping with climate variability and change

Climate variability and change is not a new phenomenon in Finnmark even over the time-scale of human memory. Though the mean annual temperature at Karasjok displayed no statistically significant trend across the last century (Fig. 4), inner Finnmark experienced two substantial periods with generally increasing temperatures. Between 1900 and 1935 and again between 1980 and 2000

Table 1
Climate complexity: the winter weather in the mountains of northern Norway is highly variable and there are consequently no 'normal' years. Data from two weather stations in eastern Finnmark (at Karasjok and Cuodahtmokhi, Fig. 1) show that virtually every year is a record year with respect to one parameter or other. In herders' parlance, 'One year is not another's brother' (*Jahki ii leat jagi viellja*)

Station and period		Parameter	Data
Karasjok 1960–2000	1965	Lowest minimum temperature	Nov., Dec., Jan., Feb., March = −43.6° C
Karasjok 1960–2000	1965	Lowest maximum temperature	Nov., Dec., Jan., Feb., March = −1.1° C
Karasjok 1960–2000	1966	Earliest snow	2 October
Karasjok 1960–2000	1967	Latest snow free	30 May
Karasjok 1960–2000	1971	Highest number of days with snow	226
Karasjok 1960–2000	1971	Highest maximum temperature	Nov., Dec., Jan., Feb., March = 5.6° C
Karasjok 1960–2000	1974	Lowest number of days with snow	181
Karasjok 1960–2000	1980	Most snow	cumulative 13.4 m
Karasjok 1960–2000	1981	Least snow	cumulative 2.6 m
Karasjok 1960–2000	1983	Deepest snow	mean 64 cm
Cuodahtmokhi 1985–2000	1986	Lowest minimum temperature in Dec.	−39.8° C
Karasjok 1960–2000	1986	Latest arrival of snow	3 Nov.
Cuodahtmokhi 1985–2000	1988	Lowest minimum temperature in Nov.	−33.1° C
Karasjok 1960–2000	1989	Earliest snow free	21 April
Cuodahtmokhi 1985–2000	1991	Lowest minimum temperature in April	−21.7° C
Cuodahtmokhi 1985–2000	1994	Greatest snow depth in November	39 cm
Karasjok 1960–2000	1994	Highest minimum temperature	Nov., Dec., Jan., Feb., March = −11.6° C
Cuodahtmokhi 1985–2000	1997	Greatest snow depth in January	49 cm
Cuodahtmokhi 1985–2000	1997	Greatest snow depth in March	74 cm
Cuodahtmokhi 1985–2000	1998	Lowest minimum temperature in Feb.	−41.8° C
Cuodahtmokhi 1985–2000	1998	Lowest minimum temperature in March	−34.8° C
Cuodahtmokhi 1985–2000	1999	Greatest snow depth in December	45 cm
Cuodahtmokhi 1985–2000	1999	Lowest minimum temperature in Jan.	−48.2° C
Cuodahtmokhi 1985–2000	2000	Greatest snow depth in April	80 cm

the mean annual temperature increased by about 0.5 °C per decade. This rate of increase in temperature is at the upper end of the range projected for northern Fennoscandia over the next 20–30 years (above). Similarly, the modest mean increase in precipitation of 1.6% per decade across the last century belies three periods of considerable increase (Fig. 5). Between 1945 and 1965, for example, annual precipitation at Karasjok increased by 20%; this is between 2.5 and 10 times the current projection (above). Thus, during the last century Saami reindeer pastoralism was exposed to climate change events at least as great as—and in some cases much greater than—those projected for northern Fennoscandia during the next 20–30 years. That reindeer pastoralism survived these events is unquestionable: a priority for predicting the effects of, and herders' responses to, future climate change, therefore, is to explore what herders registered, how they were affected and what responses they displayed to these events. This will require the codification not only of herders' knowledge and analysis of their responses to weather-related changes in foraging conditions but also of their perception and assessment of the risks and opportunities associated with the different options for coping with such changes.

Undesirable effects—real or potential—of climate variation and change on the productivity of herds have historically been ameliorated by strategic decisions and tactical manoeuvres. Herders' responses representing coping (*birgehallat*) are indicated by the dotted line in Fig. 2. The conceptual framework proposes that responses are triggered at two levels. Ultimately, the herders respond to climate related changes in the performance of their animals. They also respond directly to the kinds of weather conditions that they recognize as important for successful pastoralism. This proximal response is indicated by the line marked 'herders' knowledge' in Fig. 2.

4.1. Strategic responses

Pastoral nomadism and transhumance reflect pastoralists' responses to temporal and spatial heterogeneity in the distribution of key resources for their animals, usually forage, whether these be sheep, goats or cattle on a tropical savannah (where water is also a key resource; Behnke et al., 1993) or reindeer on the taiga/tundra (Behnke, 2000). Movement is adaptive in the sense that, by moving his herd, the pastoralist gains or averts what he anticipates will be the advantages or undesirable consequences of his doing or not doing so, respectively (below).

Aboriginal production systems in variable and unpredictable climates are often based on the sequential utilization of a large number of ecological or climatic niches (e.g. Murra, 1975). The essence of such systems is flexibility and the distribution of risk through diversity. In reindeer pastoralism the challenges posed by climate variation are met through herders' skill in exploiting options presented by the diversity of the landscape and the phenotypic diversity of the animals in their herds:

> The more landscape types one has—that is, alternatives with which to meet different situations – the more secure reindeer pastoralism will be over a longer period of time. Contrariwise, in a uniform landscape without alternatives, one is left helpless when faced with natural changes [within a season, between years] (Mikkel Nils Sara quoted in Paine, 1992).

Reindeer herders, moreover, have traditionally maintained high levels of phenotypic diversity in their herds with respect, for example, to the age, sex, size, colour and temperament of their animals (Oskal, 2000). Their concept of a 'beautiful' herd of reindeer (*čappá eallu*) is the antithesis of the homogeneity of a pure bred herd of livestock developed by selection for the requirements of modern, high yielding agricultural production systems.

The traditionally high level of diversity of the reindeer in herds reflects a coping strategy aimed at reducing vulnerability to the consequences of unfavourable—and unpredictable—conditions (e.g. Nilsen, 1998; Oskal, 1999). Hence, even apparently 'non-productive' animals have particular roles which contribute to the productivity of the herd as a whole. For example, in the 1960s reindeer herds in Finnmark typically comprised between 25% and 50% adult males, perhaps half to two-thirds of which were castrated (Paine, 1994). Large numbers of large males were required for traction, to help keep the herd gathered and to keep the general level of activity of the females low: in modern jargon, they contributed to increasing net energy gain in the herd. The males' strength, moreover, enabled them to break crusted snow and ice, opening the snow pack and providing access to the plants beneath to the benefit of themselves and—incidentally—also of females and calves. Agronomists have considered adult males unproductive and today few herds in Finnmark comprise more than 10% large bulls (Nilsen, 1998; Reindriftsforvaltningen, 2002). Their role as draft animals and in controlling the herd has been superseded by snowmobiles—albeit at substantial cost both financially and in terms of reduced manoeuvrability early in winter in years when snow arrives late. But old ways die slowly. When asked recently (2002) why he kept several heavy, barren females in his herd, herder Mattis Aslaksen Sara from Karasjok replied 'I have few big males now—so who else will break the ice?' The increased proportion of females in herds reflects agronomists' translation of modern high yield production practices to reindeer pastoralism. The reduced heterogeneity of herds represents a reversal of the traditional approach; its consequences, in terms of the performance of the animals, remain largely unknown. The pattern of dispersion of female dominated herds over the landscape is said to be different but the consequences of this for the vulnerability of the pastoral system to the vagaries of the environment have yet to be identified.

4.2. Tactical responses

4.2.1. Movement

In Saami transhumance, the principal feature of the natural environment that influences the pattern of movement of herds into, within, and out from the winter pastures is the condition of the snow pack. Snow determines the availability of forage (crusted snow is bad) and, in late winter, the mobility of herds (crusted snow is good). Herders observe how the snow settles, drifts and packs and decide how and when to move after assessing its physical quality in relation to topography, vegetation, time of year and condition of the animals. Sometimes snow conditions can have a major impact on the pattern of herding. So extreme were ground ice conditions in the winter of 1917/18, for example, that some Saami herders in Finnmark abandoned, or never even entered, the winter pastures and took their herds out to summer pastures at the coast where the same mild conditions that created the ice had left the ground bare. Likewise, when in the warm, wet winters of the 1930s (Figs. 4 and 5) conditions became difficult owing to heavy precipitation, herds were spread out and moved to summer pastures at the coast earlier than normal in spring. Today, neighbouring cooperative herding partnerships (*siida*) may 'trade snow' in the sense that one *siida* may allow another to exploit an area of undisturbed snow (good grazing) in the former's range. In each of these examples, success was and is contingent on freedom to move.

4.2.2. Feeding

Reindeer are adaptable 'intermediate ruminants' with specialized digestive mechanisms that enable them to cope with the very large seasonal changes in the nutritional quality and availability of forage that are a characteristic of northern habitats (Mathiesen et al., 2005). Reindeer pastoralism in Norway is virtually wholly based on the sustainable exploitation of natural pasture from which the animals select a large number of species of vascular plants and lichens (e.g. Mathiesen et al., 2000) but some feed may be provided for them, especially in winter, when access to forage is restricted by crusted snow or ice. Herders also provide small amounts of lichen to reward animals they tame and as a feed supplement for draft animals. Gathering lichens, however, is laborious and locally produced grass converted into hay or silage and commercially available pelleted feeds may be used instead (Aagnes et al., 1996; Sletten and Hove, 1990). The provision of small amounts of supplementary feed can improve survival in winter (especially for calves) and increase the degree of tameness of the herd. Negative effects include increased frequency of disease (Tryland et al., 2001) and economic cost. The use of pellets, hay and silage has increased throughout of Fennoscandia, especially since the accident at Chernobyl in 1986. In Sweden, for example, production of pelleted reindeer feed increased from 356 tons in 1986 to some 4200 tons per year in 1988–2003 (Anders Hamnes, personal communication). In Finland, between 10,000 and 12,000 tons of reindeer feed are produced annually and, reflecting the high demand for it, many petrol stations in the reindeer husbandry areas of northern Finland and Sweden now stock sacks of reindeer feed during winter. The use of pellets is less widespread in Norway where less than 200 tons are produced per year. The low level of feeding pellets here is in part due to its high cost; the grain products in pelleted ruminant feeds are heavily taxed and the cost of reindeer feed is up to seven times greater in Norway than in Finland and Sweden. Consequently, in Norway feeding pellets is generally restricted to periods of acute difficulty. This pattern might alter should the incidence of unfavourable snow conditions increase, not least because of the need herders themselves have expressed for improving the public perception of animal welfare in their industry (Ballari, 2005). The consequences of an increased use of expensive feed for the vulnerability of the system have yet to be identified.

5. Constraints on coping

The strategic and tactical decisions herders make in response to changes in pasture conditions represent aspects of coping. The success of the kinds of responses outlined in the previous section, however, depends to a large extent on herders' freedom of action, yet Saami reindeer pastoralism in Norway takes place in a complex institutional setting that is heavily influenced by various forms of governance ('human conditions' in the generalized model of Turner et al., 2003a) that limit herders' options. Constraints include the loss of habitat, predation (where the abundance of predators and, hence, the rates of mortality due to predation, is influenced by legislation) and the governmental regulation of pastoralism (including the regulation of rights of pasture, of the ownership of animals, of the size and structure of herds; below) and of market- and price-controls. Of course, not all forms of governance and far from all institutions obstruct pastoralism: central administration also provides important protection and opportunities for the industry and has supported both education and research. One major development in government support for reindeer pastoralism was actually precipitated by an extreme climatic event. The autumn (September, October and November) of 1967 remains among the 20% wettest ever recorded in eastern Finnmark. Following this, the temperature sank resulting in the formation of an extensive layer of ground ice which, owing to prolonged cold, persisted throughout winter. The difference between the mean temperature in autumn and winter (December, January and February) at Karasjok of −20.8 °C is the largest recorded there during the 20th century. Severe icing of the pasture from the start of the winter of 1967/68 resulted in considerable loss of reindeer (Norges Offentlige Utredninger, 1994). The government responded in an unprecedented manner and provided a fund, part of which was intended as compensation, equivalent, in today's monetary terms, to US$ 7 million (Berg, 1997). This action led to debate among the Saami regarding the payment and distribution of government funds within reindeer industry which continues, in one form or another, to this day (Nils Oskal, unpublished data).

The effects on reindeer pastoralism of the non-climate factors that these three constraints represent potentially overwhelm the putative effects of climate change of the kinds outlined above. Loss of habitat, institutions and governance, in particular, have in the past two decades substantially reduced the degree of freedom and the flexibility of operation under which reindeer herders have traditionally acted. The challenge remains to identify and quantify the impact of this on reindeer pastoralism and to identify and understand its effects on herders' ability to cope with and adapt to changing environmental conditions. The following section outlines four key areas where government policy (state, regional and municipal) and present institutional arrangements appear to influence herders' ability to respond creatively to environmental change. The points included are those highlighted at the Tromsø meeting (above): the legitimacy and relevance of this selection lies in the fact that it is based on herders' evaluation of their own situation.

5.1. Loss of habitat

Reindeer pastoralism is a highly extensive form of land use. Roughly 40% (136,000 km^2) of Norway's mainland is designated reindeer pasture and within this area Saami herders have—at least in principle—the right to graze their animals on uncultivated ground irrespective of its ownership. Herders' rights of usufruct, however, afford them neither exclusive access to the land nor protection from the interests of other land users. Conflicts of interest are common. For herders the principle issue is generally the securing of pasture on which to graze their reindeer. Indeed, the progressive and effectively irreversible loss of the uncultivated land which reindeer use as pasture is probably the single greatest threat to reindeer pastoralism in Norway today. Preservation of rangeland is, likewise, perhaps the single greatest priority for sustaining the resilience of reindeer pastoralism confronted by changes in the natural and the socio-economic environment.

Habitat loss occurs principally in two ways: (i) through physical destruction and (ii) through effective, though non-destructive, loss (i.e., through loss of grazing rights and through reduction in its value as a resource). Physical destruction of habitat occurs chiefly as a result of the development of infrastructure, including the construction of artillery ranges, buildings, hydro-electricity facilities, oil and gas installations, pipelines, railways, roads, etc. The magnitude of such losses is normally relatively small except where associated with large hydro-electricity projects (e.g. Mahoney and Schaefer, 2002, Nellemann et al., 2003) or other extensive operations such as logging (Saami Council, 2005).

Of far greater concern is the gradual abandonment by reindeer of previously high-use areas as a result of disturbance caused by human activity (Nellemann et al., 2001; UNEP, 2001, 2004). A range of studies have documented a reduction in the use of rangeland by reindeer of between 48 and 96% compared with pre-development distributions along a band ranging from 2.5 to 5.0 km from cabins, dams, power lines and roads (Vistnes and Nellemann, 2001; Nellemann et al., 2003; Vistnes et al., 2004). Approximately 25% of reindeer range in the Barents Region has effectively been lost during the last 50 years owing to disturbance resulting from infrastructure development; in some of the productive coastal ranges of Finnmark the figure is as high as 35% (Jernsletten and Klokov, 2002; UNEP, 2004). Projections for infrastructure development along a 20 km deep coastal belt indicate that by 2050 up to 78% of calving and summer ranges may fall into disuse through avoidance (UNEP, 2004; Fig. 7). Other factors resulting in the effective removal of habitat include increased grazing pressure by potentially competing species (e.g. sheep; Colman, 2000) and loss of rights of access either locally (Strøm Bull et al., 2001) or as a result of the closure of regional or international borders (Hætta et al., 1994; Pedersen, 2006). These factors, singly and in combination, pose a major threat to the sustainability of reindeer pastoralism by reducing production directly, by reducing the area of available range, and by eroding the flexibility of movement that in the past enabled herders to cope with climate and other variation.

5.2. Predation

Fennoscandia is home to the last remaining sizeable populations of large mammalian predators in Western Europe including bear (*Ursus arctos*), lynx (*Lynx lynx*), wolf (*Canis lupus*) and wolverine (*Gulo gulo*). All of these species are capable of killing medium sized ungulates like reindeer. In Norway very large numbers of domesticated animals range freely in the mountains in summer, including approximately 2 million sheep and 230,000 reindeer (which remain at pasture both in summer and winter) and these, not surprisingly, are all potential prey. Reindeer herders in Finnmark, the county with the highest losses, estimate that between 30% and 65% of their calves are taken as prey each year (Anon., 2002); in some herds losses exceed 90% (Mathis Oskal, reindeer herder, personal communication). Predation on this scale dwarfs all other reported causes of mortality including climate related deaths (Reindriftsforvaltningen, 2005) and is, therefore, probably a major determinant of levels production in herds.

Norway's mountain pastures are a major renewable natural resource: their value, however, is clearly compromised by the presence of predators. Intervention designed to ensure their sustained usefulness as pastures, by reducing the density of populations of predators to levels at which they no longer represent a threat to the livelihood

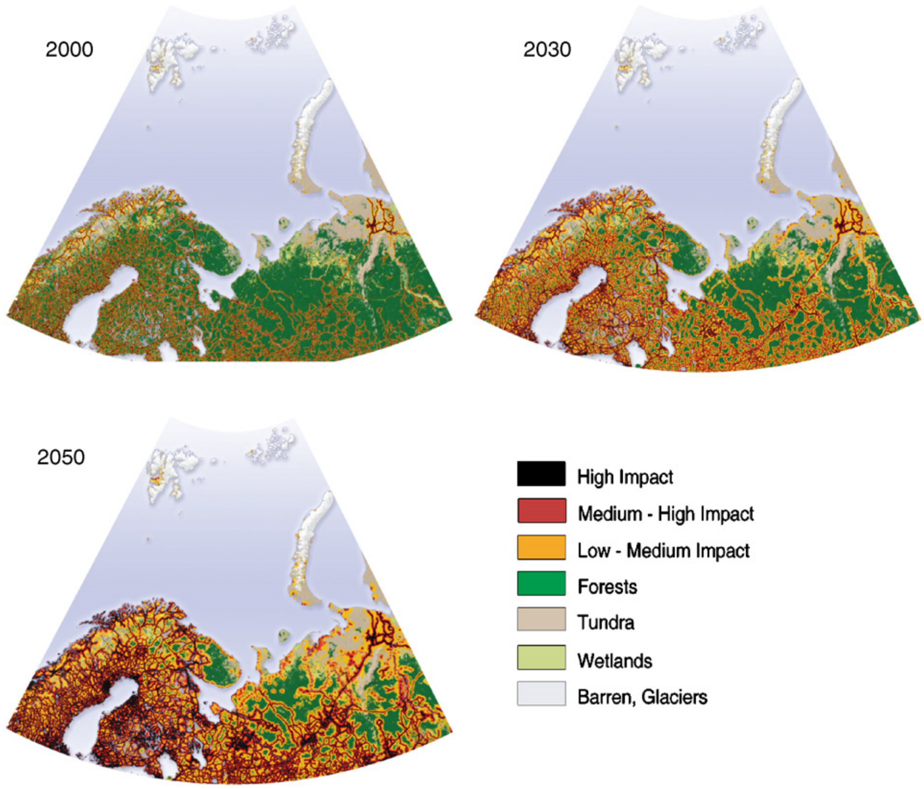

Fig. 7. Projected development of infrastructure (including roads, houses, military training areas) in the Barents Euro-Arctic region 2000–2050. The scenario illustrated here is based on the historical development of infrastructure, distribution and density of the human population, existing infrastructure, known location of natural resources, distance from coast and vegetation type (*Source*: http://www.globio.info/press/2002-08-13.cfm).

of the sheep farmers and reindeer herders alike, must select among several unsatisfactory alternatives. Potential strategies range from implementing a general reduction in numbers of predators to establishing 'predator-free zones', where grazing can continue uninterrupted, while leaving the predators elsewhere undisturbed. Any course adopted must be commensurate both with Norway's commitment to the conservation of viable populations of mammalian predators under the terms of the *'Convention on the conservation of European wildlife and natural habitats'* (the Bern Convention) and other international conservation agreements and, at least as far as reindeer are concerned, by the country's commitment to safeguarding the interests of Saami people. This commitment is enshrined in the terms of the International Labour Organization (ILO) Convention No. 169 on Indigenous and Tribal Peoples. The nation's obligations with respect to the intentions of this Convention appear to take precedence over those of the Bern Convention (Schei, no date; Uggerud, 2001) and reindeer herders accordingly press for the establishment of 'predator-free zones'.

In practice, however, the situation remains unclear. No predator-free zones have been created and although the culling of predators has been instituted on a limited scale, the herders–who usually have the best local knowledge—are not normally involved. Instead, the government offers financial compensation for reindeer lost to predators. Compensation is set at the sale value of animals at slaughter (based on the mean body mass of reindeer of different age and sex classes) plus, for an adult female, the value of 2.6 calves (representing her future production) and an additional sum (equivalent to between 15 and 100% of the resulting total figure) where losses exceed 2% of the herd (Directorate for Nature Management, 2001). Compensation is only paid, however, where claims are substantiated by unequivocal direct evidence of a kill, such as *post-mortem* examination of fresh carcasses, or where, in the opinion of the local authority, there is compelling indirect evidence. Herders, however, normally determine losses by observing the absence of particular animals and are rarely able to support their claims by producing a fresh carcass; the gathering, transport and delivery of carcasses from remote mountain pastures is rarely practicable. Consequently, their claims are mostly unsubstantiated and usually rejected. In the production year 2004–2005, for example, of 58,600 semi-domesticated reindeer lost, 47,600 were claimed killed by predators but compensation, worth US$ 3.8 million, was paid for just 11,400 of these (including 650 confirmed and 10,750 likely kills; Directorate for Nature Management, 2006). Thus, across the country, herders were compensated for 24% of reindeer claimed lost. Under these circumstances, it is inevitable that a significant number of losses go unreported for the herders feel that the small likelihood of their claim being accepted hardly justifies the paperwork. Thus loss of reindeer, chiefly through predation but possibly exacerbated by increased snow, remains a major constraint on production and the herders remain largely powerless to tackle the situation owing to legislation that runs counter to their immediate interests.

5.3. Economic and socio-political environment

Reindeer pastoralism in Norway is highly regulated. In 2000, the annual cost of its administration was US$ 21 million, which was more than twice the amount paid to reindeer herders for the carcasses of the animals they sent to slaughter (Reinert, 2006). The current level of regulation stems from the Reindeer Husbandry Act of 1978 when Saami reindeer pastoralism was brought more closely under the management of The Royal Norwegian Ministry of Agriculture and Food. This development reflected a desire to improve the economic basis of Saami reindeer pastoralism and to help herders achieve the economic stability indispensable in modern society. Its immediate consequence, however, was that central government became one of the most potent forces shaping the development of the industry. Economic planning and development of modern, agricultural food-production systems remained the Ministry of Agriculture and Food's policy-makers' paradigm; increases in the numbers of reindeer and reindeer herders were one immediate result (Anon., 1992). Today, policies established by central administration influence virtually every aspect of reindeer pastoralism, from the granting of licenses to own reindeer and the allocation of grazing rights, to the monitoring and regulation of the size, age-, sex- and weight-structure of herds, the setting of production quotas, the influencing of both the age and sex composition of animals selected for slaughter, the timing of slaughtering and the determining of to which slaughterhouses herders sell their animals. A recent decision by the Reindeer Husbandry Board, the industry's highest national authority, to reduce the number of reindeer in western Finnmark by 30% before the end of the 2004/5 season was an obvious manifestation of central control. Though the legal basis for this decision was apparently sound, it proved ambiguous and barely workable. The 1978 Reindeer Husbandry Act empowers the Board to set an upper limit for the number of animals at pasture but this relates to numbers in summer districts while the purpose of the policy was to reduce numbers on the winter pastures. Many herds, however, are divided in autumn and join different *siida* for winter, yet no guidelines were provided for how the burden of reduction in summer districts was to be divided between the different winter groups. A further complication arose when, in contradiction of the resolution of the Reindeer Husbandry Board, the then Minister of Agriculture and Food spoke of achieving reduction through compulsory slaughter (Solvang, 2005). Though this initially provoked furore, the threat subsequently withered owing to the absence of guidelines detailing the extent to which the authorities' were actually empowered to impound and slaughter reindeer in cases where herders declined to co-operate. In the event, the level of voluntary slaughter was substantially increased during the winter of 2004/5 and the number of reindeer in western Finnmark was reduced by the specified date, although only by approximately 5%. This result was nevertheless considered satisfactory because the summer of 2004 had been a good one with the high rates of both production and survival of calves. Consequently, in the absence of increased rates of slaughter the total number of reindeer would undoubtedly have increased substantially (H. R. Christiansen, personal communication).

The centralized regulation of the price of reindeer meat provides another example of intervention in reindeer pastoralism. In this case, the immediate consequence has been stagnation in herders' economy. The position of reindeer meat as a luxury culinary product in Norway historically provided a solid economic basis for the Saami herders who have virtually a legal monopoly on the ownership of reindeer. Beginning in the late 1970s, however, new government policies weakened the economic position of the herders through the creation of a powerful oligopoly group of slaughterhouses outside their economic control. This creation eroded both the market power and the profitability of reindeer pastoralism. Increased mechanization (e.g., snowmobiles and terrain vehicles), combined with a gradual shift away from the herders' traditional economy to full integration with the Norwegian cash and credit economy, further increased the economic stakes and herders' economic vulnerability. Political and market power was lifted from their hands by the 1978 Act and consolidated 12 years later in an alliance between *Norsk Kjøtt* (a meat farmers' co-operative which controls 75% of slaughtering in Norway) and two large, private, reindeer slaughterhouses neither of which are Saami owned. In 2002 an estimated 20% of reindeer in Norway were slaughtered by Saami-owned enterprises compared with approximately 80% in both Sweden and Finland (Reinert, 2006). Norwegian government legislation and practice effectively reduced the Saami role in the total value chain to that of providers of raw materials to an oligopoly controlled by ethnic Norwegians. Import tariffs and pricing policies have been used to promote the interests of agricultural meat production at the expense of the interests of reindeer pastoralism. Market mechanisms have been eliminated from price setting; instead, the value of reindeer carcasses is negotiated annually by the herders' organization (the Saami Reindeer Herders' Association of Norway; NRL) and the government. In reality, the herders' negotiating power is minimal because *Norsk Kjøtt* is responsible both for the marketing and the regulation of the reindeer meat market. The consequences can be staggering: from 1976 to 1991, for example, the net price paid to herders for the carcasses of animals delivered for slaughter, corrected for inflation, fell by 49% (from approximately US$ 11.7/kg to US $ 6/kg) largely in response to an increase in the level of production. In the following decade the trend was reversed: the level of production was halved yet the real price paid to herders hardly changed (Reinert, 2006). The market mechanisms that normally would have increased prices were not allowed to work and the Saami herders in Norway saw their incomes almost halved while the government allowed imports of reindeer meat from Sweden and Finland to fill the gap in the market (Reinert, 2006). The fall in the value of reindeer carcasses during the last 30 years exemplifies the influence wielded over the economic development of reindeer pastoralism by agricultural meat producers with vested interests. Lacking direct control over the slaughtering and marketing of reindeer meat, the reindeer Saami of Norway became *de-facto* an internal colony (Reinert, 2006). This development reflects the term 'Welfare Colonialism' coined by Paine (1977) to characterize culturally destructive developments in the Arctic.

Central government administration, therefore, remains responsible for key aspects of the economic and socio-political environment in which pastoralism exists and to which herders are obliged to cope and adapt. The traditional fluidity and flexibility of practice that developed to meet the vagaries of the natural environment of the North has been seriously eroded. The exploration of the consequences of this for the adaptive capacity and vulnerability of Saami reindeer pastoralism in the face of potential climate change remains, therefore, an important area of research.

5.4. Law

The elaborate legal structure upon which the regulation of reindeer pastoralism is based is another aspect of the complex institutional setting in which Saami reindeer pastoralism is practiced in Norway. The law is comprehensive, complex and, occasionally, liberal to the point of ambiguity (Strøm Bull et al., 2001). It represents, therefore, a fourth non-climate factor which has a major influence on reindeer pastoralism and which, by constraining herders' options, influences their ability to cope with changes in the natural environment.

Legislation governing reindeer pastoralism is of considerable antiquity. A treaty agreed in 1751 between the respective joint kingdoms of Denmark/Norway and Sweden/Finland included the division, along a common national border, of hitherto undefined northern land. This same border divides Norway and Finland today. The 18th century legislators realized that the creation of a border would potentially disrupt the lives of people whose movements had hitherto been unrestricted. An addendum was, therefore, included in the treaty confirming agreement between the two nations that Saami reindeer herders' customary utilization of the land should remain undisturbed, notwithstanding either the creation of a common border or the herders' obligation to adopt one or other nationality. This document, the Lapp Codicil, is the first formal legislation in reindeer pastoralism (Pedersen, 2006). Crucially, it was built upon the principle by which the division of resources was achieved by local self-government (Hætta et al., 1994).

The legislation of reindeer pastoralism has evolved and increased in complexity since 1751. Successive statutes have been revised and new ones created to meet the challenges of change in the economic and political climate, culminating in the Reindeer Husbandry Act of 1978 and its revision in 1996. Today's law includes provisions for the regulation of a wide range of issues. Section 2 alone includes rules for the designation of husbandry areas, the duration of grazing seasons within them, the size of herds and the body mass of the animals in them. The level of detail of the legislation contrasts sharply with the lack of detail in the guidelines for its implementation. The Act is built on the premise that the organization of reindeer pastoralism is best placed in the hands of public administration. No *siida* has protected rights of usage. Instead, successive levels of the legislature—including the Ministry of Agriculture and Food, the Reindeer Husbandry Board, Regional Boards and Area Boards—determine, virtually unimpeded by legal barriers—the division of grazing districts, the allocation of husbandry franchises and reindeer numbers. Regulation is achieved through rules, not statutes. Consequently there remains considerable uncertainty among administrators and herders alike over the scope of the Act and considerable limitation of any opportunity for individual herders to challenge administrative decisions.

The fact that current legislation is built around the alien concepts of the 'husbandry unit' (Norwegian: *driftsenhet*) and the 'pasture district' (Norwegian: *beitedistrikt*) represents an inherent weakness. Both concepts are new legal constructions related specifically to the internal regulation of reindeer pastoralism. The husbandry unit (a reindeer herd, owned and managed by one person or by spouses in partnership, which may include animals belonging to their close relatives: 1978 Reindeer Husbandry Act, §4), a legal creation introduced in 1978, is especially problematical. Herders, their families and their animals do not operate as independent units; instead, they join and act in *siida*. Each *siida* maintains its integrity for a season (summer or winter) or perhaps throughout the year, moving and migrating in a complicated temporal and spatial pattern determined in part by the activity of neighbouring *siida. Siida* are stable compositions, usually bonded in kinship, which represent a form of organization deeply rooted in Saami custom and practice. No regulatory legal framework which ignores this ancient organization, as the 1978 Reindeer Husbandry Act does, is likely either to receive widespread acceptance within reindeer pastoralism or to provide a satisfactory basis for effective resource management. In its report, the Reindeer Husbandry Act Revision Committee (*Reindriftslovutvalget*) recommended adopting the *siida* as a central element in a revised Reindeer Husbandry Act (Norges Offentlige Utredninger, 2001) but this suggestion has not yet been acted upon by the Ministry of Agriculture and Food.

The prevailing uncertainty is compounded by the fact that reindeer pastoralism is regulated *de facto* by a Convention on Husbandry rather than through the provisions of the 1978 Act. The Convention is negotiated annually between the government represented by the Ministry of Agriculture and Food and the herders represented by NRL. The two parties are far from equal. The Ministry is responsible both for drafting the regulations contained in each Convention, albeit in consultation with the NRL, and also ultimately for the interpretation and implementation of the final agreement. The regulations contained in the Convention are more flexible than the Act but lack the legal checks and balances that the Act contains. The regulations agreed at each Convention, moreover, are frequently changed which only increases the level of uncertainty. Clearly, the complexities and ambiguities of the law contribute to the unpredictability of the administrative environment within which reindeer pastoralism is practiced and therefore represent an important constraint on herders' ability to cope with environmental change.

6. Discussion

We used a general conceptual framework for vulnerability studies (Turner et al., 2003a) to structure an examination of factors that influence Saami reindeer pastoralism in Finnmark and which might potentially influence its sensitivity and adaptive capacity to projected climate change. The study was not a full analysis of the vulnerability of reindeer pastoralism but rather used reindeer pastoralism as a vehicle with which to test the versatility of a conceptual framework for studies of coupled social–ecological systems in the North. It demonstrated, in this way, not only how such studies can be profoundly empirical, place based and interdisciplinary but also, crucially, the value of working closely with local people, in this case reindeer herders, in a co-production of knowledge.

Herders played a key role in modifying the general framework into one suited to their situation. The resulting scheme (Fig. 2) made plain the diversity of the kinds of information needed for assessing the vulnerability of a social–ecological system in the Arctic (see also Kasperson and Kasperson, 2001). Thus, both institutional and ecological constraints including governance, socio-economic conditions, law, habitat, predation and snow were drawn into a conceptual model that, because it contained just a few selected elements, provided a means of reducing great complexity to manageable proportions. The flow chart captured the dynamic character of the social–ecological system, potentially treating vulnerability as a process (see Leichenko and O'Brien, 2002), without becoming overburdened with details. In this way the study not only showed how the general conceptual framework of Turner et al. (2003a) is flexible and lends itself to modifications that capture the characteristics of a particular situation but it also demonstrated the value of local knowledge for understanding the processes that potentially shape and determine the vulnerability of the system to change.

The validity and legitimacy of reducing a complicated system to something simple and, therefore, amenable to assessment was wholly dependent on the participation at the outset of herders themselves. It is they, rather than outsiders, who can best decide what factors, or what suites of factors, influence reindeer pastoralism: nobody, save herders themselves, can legitimately make the selection. Despite its orthodox format, therefore, the resulting conceptual model, developed through an interdisciplinary and intercultural effort that continued throughout the study and the preparation of this paper, represented an integration of empirical data and herders' knowledge.

The integration of different ways of knowing, referred to as the 'co-production of knowledge' (e.g. Kofinas et al., 2002) or 'partnership in research' (Magga, 2005), has not been widely applied in research on coupled social–ecological systems though it is increasingly recognized as crucial for success (Ludwig, 2001; Berkes, 2002; ICARPII, 2005). Aboriginal knowledge often does not conveniently lend itself to reductionist analysis and hypothesis testing. However, herders' knowledge of the impact of something so relatively specific as climate variation on their way of life is based on an understanding founded on generations of experience accumulated and conserved in husbandry practice and herders' specialized vocabulary. Herders integrate bodies of knowledge gathered over time spans that far exceed significant periods of climate change. It would not be possible, using the traditional methods of the natural sciences, to gather comparable bodies of knowledge by direct observation at less than exorbitant cost. The success of the approach outlined here was evident from the logical design and the evident usefulness of the resulting conceptual model (Fig. 2) however rudimentary it appears.

One of the striking features of this work was that, though the study originated primarily in consideration of the vulnerability of reindeer pastoralism in Finnmark specifically to the effects climate change, it quickly became apparent that pastoralism is affected by a great deal more than just change in climate. This in itself is not new but, based our synthesis, we feel confident that the effects on reindeer pastoralism of the non-climate factors introduced into the model probably dwarf the putative effects of climate change on the system. Hence, the potential consequences of a phenomenon such as the projected increase in the average annual temperature at Karasjok over the next 20–30 years (Fig. 4) cannot meaningfully be considered independently of concurrent anthropogenic changes in the environment for which, in some cases, clear predictions are already available (e.g. Fig. 7). Our approach, therefore, is wholly consistent with the general conclusion that studies of the resilience and vulnerability of northern regions must integrate across intellectual domains and consider the multiple factors responsible for social and environmental change (Chapin et al., 2004: Robards and Alessa, 2004).

We focussed on the type and character of factors that impinge on the coupled social–ecological system that reindeer pastoralism represents and have to date barely examined either the magnitude and frequency of different perturbations or the types of interaction between them. Likewise, we have as yet made only rudimentary analysis of the sensitivity and adaptive responses of the system to perturbation and have, therefore, drawn no specific conclusions about the adaptive capacity of reindeer pastoralism to the projected changes. These tasks remain yet some prognosis is possible. Clearly, reindeer pastoralism has been resilient to past change. The continued existence of nomadic reindeer pastoralism by Saami and other northern peoples in Eurasia today is evidence that all these have, through the centuries, coped with the vagaries and transitions of the socio-economic environment of the North (see also Krupnik, 2002). On one hand, the fact cannot be overlooked that, if the marginalization of reindeer nomadism continues and if constraints on the freedom of action of the herders increase, new climatic conditions might threaten the resilience and increase the vulnerability of reindeer pastoralism in ways that truly are without precedent. On the other hand, action provokes reaction: changes in climate and in the socio-economic environment might also create new opportunities for sustainable development in reindeer peoples' societies. Herders can be expected to grasp new opportunities, wherever they arise, and to take the initiative in improving the economy of their industry thereby reducing the vulnerability of their society. Developing appropriate methodologies for assessing the adaptive capacity, the vulnerability and the resilience of social–ecological systems remains a challenge (Carpenter et al., 2005; McCarthy et al., 2005). Recognition of the knowledge systems of Arctic cultures and the full engagement of local people throughout the process are key components in the solution.

Acknowledgments

The Association of World Reindeer Herders' workshop in Tromsø was funded by the Reindeer Husbandry Research Fund. We thank Per Erik Bjørnstad and Jan Petter Holm for assistance with Figs. 1 and 3; Ingunn Vistnes and Hugo Ahlenius for their work on the background to, and production of, Fig. 7; Anders Hamnes for providing data on the production and sale of reindeer pellets; Robert Paine and Hans Roar Christiansen for critically reading parts of the text; and three anonymous referees for their criticism and helpful suggestions.

References

Aagnes, T.H., Blix, A.S., Mathiesen, S.D., 1996. Food intake, digestibility and rumen fermentation in reindeer fed baled timothy silage in summer and winter. Journal of Agricultural Science (Cambridge) 127, 517–523.

Aanes, R., Sætre, B-E., Smith, F.M., Cooper, E.J., Wookey, P.A., Øritsland, N.A., 2002. The Arctic Oscillation predicts effects of climate change in two trophic levels in a high-arctic ecosystem. Ecology Letters 5, 445–453.

ACIA, 2005. Arctic Climate Impact Assessment Scientific Report. Cambridge University Press, Cambridge, pp. 1–1042. ISBN: 10052186509. 〈http://www.acia.uaf.edu/pages/scientific.html〉.

Anon., 1992. En bærekraftig reindrift St. meld. nr. 28 1991–1992: Landbruksdepartementet, Oslo, Norway, 134pp. (in Norwegian).

Anon., 2002. Rapport fra Reindriftens Rovviltutvalg: 〈http://odin.dep.no/filarkiv/164512/Reindriftens_rovviltutvalg_sluttrapp.pdf〉 (in Norwegian).

Ballari, A., 2005. Kjøper seg bedre rykte. Nordlys 16 November 2005. 〈http://www.nordlys.no/nyheter/Innenriks/article1827182.ece〉 (in Norwegian).

Bamzai, A.S., 2003. Relationship between snow cover variability and Arctic oscillation index on a hierarchy of time scales. International Journal of Climatology 23, 131–142.

Behnke, R.H., 2000. Equilibrium and non-equilibrium models of livestock population dynamics in pastoral Africa: their relevance to Arctic grazing systems. Rangifer 20, 141–152.

Behnke, R.H., Scoones, I., Kerven, C. (Eds.), 1993. Range Ecology at Disequilibrium: New Models of Natural Variability and Pastoral Adaptation in African Savannahs. Overseas Development Institute, London, 248pp.

Benestad, R.E., 2004a. Tentative probabilistic temperature scenarios for northern Europe. Tellus 56A, 89–101.

Benestad, R.E., 2004b. Empirical statistical downscaling in climate modelling. EOS 85 (42), 417–422.

Berg, B.A., 1997. Næring og Kultur: Norske reindriftsamers Landsforbund 50 år 1947–1997. Davvi Girji OS, Karasjok (in Norwegian).

Berkes, F., 2002. Epilogue: making sense of arctic environmental change? In: Krupnik, I., Jolly, D. (Eds.), The Earth is Faster Now: Indigenous Observations of Arctic Environmental Change. Arctic Research Consortium of the United States, Fairbanks, Alaska, pp. 335–349.

Budsjettnemda for Jordbruket, 2005. Resultatkontroll for gjennomføringen av landbrukspolitikken. Utredning No. 3. 〈http://www.nilf.no/PolitikkOkonomi/Bm/2005/Utredning2005-3-1.pdf〉.

Carpenter, S.R., Westley, F., Turner, M.G., 2005. Surrogates for resilience of social–ecological systems. Ecosystems 8, 941–944.

Chapin III., F.S., Peterson, G., Berkes, F., Callaghan, T.V., Angelstam, P., Apps, M., Beier, C., Bergeron, Y., Crépin, A.-S., Danell, K., Elmqvist, T., Folke, C., Forbes, B., Fresco, N., Juday, G., Niemelä, J., Shvidenko, A., Whiteman, G., 2004. Resilience and vulnerability of Northern regions to social and environmental change. Ambio 33, 344–349.

Chen, D., Achberger, C., Räisänen, J., Hellström, C., 2006. Using statistical downscaling to quantify the GCM-related uncertainty in regional climate change scenarios: a case study of Swedish precipitation. Advances in Atmospheric Sciences 23, 54–60.

Christensen, J.H., Räisänen, J., Iversen, T., Bjørge, D., Christensen, O.B., Rummukainen, M., 2001. A synthesis of regional climatic change simulations: a Scandinavian perspective. Geophysical Research Letters 28, 1003–1006.

Colman, J.E., 2000. Behaviour patterns of wild reindeer in relation to sheep and parasitic flies. Dr. Scient. Thesis, University of Oslo.

Cutter, S.L., 1996. Vulnerability to environmental hazards. Progress in Human Geography 20, 529–539.

Directorate for Nature Management, 2001. Erstatning for tap tamrein. Retningslinjer til forskrift 4. mai 2001. 〈http://www.naturforvaltning.no/archive/attachments/01/28/Ersta018.pdf〉 (in Norwegian).

Directorate for Nature Management, 2006. 〈http://www.dirnat.no/wbch3.exe?d = 10306&sec = Hoveddel&secnr = 1#utvikling〉 (in Norwegian).

Downing, T.E., Butterfield, R., Cohen, S., Huq, S., Moss, R., Rahman, A., Sokona, Y., Stephen, L., 2001. Climate change vulnerability: linking impacts and adaptation. Report to the Governing Council of the United Nations Environment Programme. United Nations

Environment Programme and Oxford: Environmental Change Institute, University of Oxford, Nairobi.

Forchhammer, M.C., Boertmann, D.M., 1993. The muskoxen *Ovibos moschatus* in north and northeast Greenland: population trends and the influence of abiotic parameters on population dynamics. Ecography 16, 299–308.

Forchhammer, M.C., Stenseth, N.C., Post, E., Langvatn, R., 1998. Population dynamics of Norwegian red deer: density-dependence and climatic variation. Proceedings of the Royal Society (London) B 265, 341–350.

Forchhammer, M.C., Clutton-Brock, T.H., Lindström, J., Albon, S.D., 2001. Climate and population density induce long-term cohort variation in a northern ungulate. Journal of Animal Ecology 70, 721–729.

Forchhammer, M.C., Post, E., Stenseth, N.C., Boertmann, D.M., 2002. Long-term responses in arctic ungulate dynamics to changes in climatic and trophic processes. Population Ecology 44, 113–120.

Freeman, M.M.R. (Ed.), 2000. Endangered Peoples of the Arctic: Struggles to Survive and Thrive. Greenwood Press, Westport, Connecticut, 279pp.

Hætta, J.I., Sara, O.K., Rushfeldt, I., 1994. Reindriften i Finnmark: Lovgivning og Distriktsinndeling. Reindriftsadministrasjonen, Alta, 124pp (in Norwegian).

Hanssen-Bauer, I., Førland, E.J., Haugen, J.E., Tveito, O.E., 2003. Temperature and precipitation scenarios for Norway: comparison of results from dynamical and empirical downscaling. Climate Research 25, 15–27.

Hanssen-Bauer, I., Achberger, C., Benestad, R.E., Chen, D., Førland, E.J., 2005. Statistical downscaling of climate scenarios over Scandinavia. Climate Research 29, 255–268.

Hellström, C., Chen, D., Achberger, C., Räisänen, J., 2001. A comparison of climate change scenarios for Sweden based on statistical and dynamical downscaling of monthly precipitation. Climate Research 19, 45–55.

ICARPII, 2005. Conference Statement. 〈http://www.icarp.dk/ICARP_Statement.pdf〉.

IPCC, 2001. In: Canziani, O.F., Dokken, D.J., Leary, N.A., McCarthy, J.J., White, K.S. (Eds.), Climate Change 2001: Impacts, Adaptation, and Vulnerability—Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, New York, NY, USA, pp. 1–1005.

Jernsletten, J.-L., Klokov, K., 2002. Sustainable Reindeer Husbandry. Arctic Council 2000–2002. University of Tromsø, 157pp.

Kasperson, J.X., Kasperson, R.E., 2001. SEI Risk and Vulnerability Programme Report 2001–01. Stockholm Environment Institute, Stockholm.

Kofinas, G., The communities of Aklavik and Fort McPherson, 2002. Community contributions to ecological monitoring: knowledge co-production in the US–Canada arctic borderlands. In: Krupnik, I., Jolly, D. (Eds.), The Earth is Faster Now: Indigenous Observations of Arctic Environmental Change. Arctic Research Consortium of the United States, Fairbanks, AL, pp. 54–91.

Krupnik, I., 2002. Arctic Adaptations. University Press of New England, pp. 375.

Leichenko, R.M., O'Brien, K.L., 2002. The dynamics of rural vulnerability to global change: the case of Southern Africa. Mitigation and Adaptation Strategies for Global Change 7, 1–18.

Lenart, E.A., Bowyer, R.T., Hoef, J.V., Ruess, R.W., 2002. Climate change and caribou: effects of summer weather on forage. Canadian Journal of Zoology 80, 664–678.

Ludwig, D., 2001. The era of management is over. Ecosystems 4, 758–764.

Magga, O.H., 2005. Reindriftsnæringen i partnerskap med forskningen. In: Seminar manuscript: Reinkjøtt 2005—en positiv framtid for reinkjøtt med fokus på kvalitet, 25–26 May 2005, Saami University College, N-9520 Guovdageaidnu, Norway.

Mahoney, S.P., Schaefer, J.A., 2002. Hydroelectric development and the disruption of migration in caribou. Biological Conservation 107, 147–153.

Mårell, A., Hofgaard, A., Danell, K., 2006. Nutrient dynamics of reindeer forage species along snowmelt gradients at different ecological scales. Basic and Applied Ecology 7, 13–30.

Mathiesen, S.D., Haga, Ø.E., Kaino, T., Tyler, N.J.C., 2000. Diet composition, rumen papillation and maintenance of carcass mass in female Norwegian reindeer (*Rangifer tarandus tarandus*) in winter. Journal of Zoology (London) 251, 129–138.

Mathiesen, S.D., Mackie, R.I., Aschfalk, A., Ringø, E., Sundset, M.A., 2005. Microbial ecology of the digestive tract in reindeer: seasonal changes. In: Holzapfel, W.H., Naughton, P.J. (Eds.), Microbial Ecology in Growing Animals. Elsevier, Edinburgh, pp. 75–100.

McCarthy, J.J., Martello, M.L., Corell, R.W., Eckley, N., Fox, S., Hovelsrud-Broda, G.K., Mathiesen, S.D., Polsky, C., Selin, H., Tyler, N.J.C., Strøm Bull, K., Siegel-Causey, D., Eira, I.G., Eira, N.I., Eriksen, S., Hanssen-Bauer, I., Kalstad, J.K., Nellemann, C., Oskal, N.,
Reinert, E., Storeheier, P.V., Turi, J.M., 2005. Climate Change in the Context of Multiple Stressors and Resilience Arctic. Arctic Climate Impact Assessment (pp. 945–988). Cambridge University Press, pp. 1–1042. ISBN:10052186509. 〈http://www.acia.uaf.edu/pages/scientific.html〉.

Murra, J.V., 1975. Formaciones Economicas y Politicas del Mundo Andino. Instituto de Estudios Peruanos, Lima, 340pp (in Spanish).

Mysterud, A., Stenseth, N.C., Yoccoz, N.G., Langvatn, R., Steinhelm, G., 2001. Nonlinear effects of large-scale climatic variability on wild and domestic herbivores. Nature 410, 1096–1099.

Mysterud, A., Yoccoz, N.G., Stenseth, N.C., Langvatn, R., 2000. Relationships between sex ratio, climate and density in red deer: the importance of spatial scale. Journal of Animal Ecology 69, 959–974.

Nellemann, C., Vistnes, I., Jordhøy, P., Strand, O., 2001. Winter distribution of wild reindeer in relation to power lines, roads and resorts. Biological Conservation 101, 351–360.

Nellemann, C., Vistnes, I., Jordhøy, P., Strand, O., Newton, A., 2003. Progressive impact of piecemeal infrastructure development on wild reindeer. Biological Conservation 113, 307–317.

Nielsen, K., 1962. Lappisk (samisk) Ordbok, vols. I–V. Universitetsforlaget, Oslo. ISBN:82-00-14201-9 (in English, Latin, Norwegian and Saami).

Nilsen, Ø., 1998. Flokkstrukturen i Varanger-reindrifta på sluten av 1800-tallet og i dag. Varanger årbok 1998. pp. 107–115. ISBN:82-90417-18-7 (in Norwegian)

Norges Offentlige Utredninger. 1994. Bruk av land og vann i Finnmark i historisk perspektiv. NOU 1994, 21 Statens Forvaltningstjeneste, Oslo. ISBN:82-583-0297-3 (in Norwegian).

Norges Offentlige Utredninger 2001. Forslag til endringer i reindriftsloven. Norges offentlige utredninger 2001, 35, Statens forvaltningstjenste Informasjonsforvaltning, Oslo (in Norwegian).

Nuttall, M., 2000. Indigenous peoples, self-determination and the Arctic environment. In: Nuttall, M., Callaghan, T.V. (Eds.), The Arctic: Environment, People, Policy. Harwood Academic Publishers, Amsterdam, pp. 377–410.

Oskal, A.I., 1999. Tradisjonelle vurderinger av livdyr. Rangifer Report 3, 121–124 (in Norwegian).

Oskal, N., 2000. On nature and reindeer luck. Rangifer 2-3, 175–180.

Ottersen, G., Planque, B., Belgrano, A., Post, E., Reid, P.C., Stenseth, N.C., 2001. Ecological effects of the North Atlantic Oscillation. Oecologia 128, 1–14.

Paine, R., 1964. Herding and husbandry: two basic distinctions in the analysis of reindeer management. Folk 6 (1), 83–88.

Paine, R., 1977. The path to welfare colonialism. In: Paine, R. (Ed.), The White Arctic: Anthropological Essays on Tutelage and Ethnicity, pp. 7–28. Newfoundland Social and Economic Papers No. 7, Institute of Social and Economic Research, Memorial University of Newfoundland, 420pp. ISBN:0-919666-14-0.

Paine, R., 1992. Social Construction of the 'Tragedy of the Commons' and Saami Reindeer Pastoralism. Acta Borealia B 2, 3–20.

Paine, R., 1994. Herds of the tundra: a portrait of Saami reindeer pastoralism. Smithsonian Institution Press, Washington, London, 242pp.

Pedersen, S., 2006. Lappekodisillen i nord 1751–1859. Fra grenseavtale og sikring av samenes rettigheter til grensesperring og samisk ulykke. Dr. Philos Thesis, University of Tromsø (in Norwegian).

Post, E., Stenseth, N.C., 1999. Climate variability, plant phenology, and northern ungulates. Ecology 80, 1322–1339.

Post, E., Forchhammer, M.C., Stenseth, N.C., Callaghan, T.V., 2001. The timing of life-history events in a changing climate. Proceedings of the Royal Society (London) B 268, 15–23.

Pruitt, W.O., 1959. Snow as a factor in the winter ecology of the barren-ground caribou (*Rangifer arcticus*). Arctic 12, 158–179.

Räisanen, J., 2001. Intercomparison of 19 Global Climate Change Simulations from an Arctic Perspective. In: Källen, E., Kattsov, V., Walsh, J., Weatherhead, E. (Eds.), Report from the Arctic Climate Impact Assessment Modelling and Scenario Workshop, Stockholm, Sweden. ACIA Secretariat, Fairbanks, pp. 11–13.

Reindriftsforvaltningen, 2002. Ressursregnskap for reindriftsnæringen for reindriftsåret 1. April 2000—31 March 2001. Reindriftsforvaltningen, Alta, 144pp (in Norwegian).

Reindriftsforvaltningen, 2004. Totalregnskap for Reindriftsnæringen. Økonomisk Utvalg, Alta/Oslo, 143pp (in Norwegian).

Reindriftsforvaltningen, 2005. Ressursregnskap for reindriftsnæringen for reindriftsåret 1 April 2003—31 mars 2004. Reindriftsforvaltningen, Alta, 133pp (in Norwegian).

Reinert, E.S., 2006. The economics of Reindeer herding: Saami entrepreneurship between cyclical sustainability and the powers of state and oligopolies. British Food Journal 108, 522–540.

Robards, M., Alessa, L., 2004. Timescapes of community resilience and vulnerability in the circumpolar north. Arctic 57 (4), 415–427.

Saami Council, 2005. Saami Council Reported to the Environmental Audit Committee of the British Parliament about Human rights Violations in Finland. Saami Council Press Release: 8 December 2005.

Schei, A., no date. Norsk rovviltforvaltning og folkeretten. Norwegian Ministry of the Environment. 〈http://odin.dep.no/md/rovviltmelding/hvaskjer/utredninger/099001-990034/index-dok000-b-n-a.html〉 (in Norwegian).

Skjenneberg, S., 1989. Reindeer husbandry in Fennoscandia. In: Hudson, R.J., Drew, K.R., Baskin, L.M. (Eds.), Wildlife Production Systems. Cambridge University Press, Cambridge, pp. 206–222, 469pp.

Skogland, T., 1978. Characteristics of the snow cover and its relationship to wild mountain reindeer (*Rangifer tarandus tarandus* L.) feeding strategies. Arctic Alpine Research 10, 569–580.

Sletten, H., Hove, K., 1990. Digestive studies with a feed developed for realimentation of starving reindeer. Rangifer 10, 31–38.

Slezkine, Y., 1994. Arctic Mirrors: Russia and the Small Peoples of the North. Cornell University Press, Ithaca, NY, 456pp.

Solvang, O., 2005. Vil tvangsslakte tusenvis av rein. Nordlys 28 May 2005 (in Norwegian).

St.prp.nr. 63, 2004–2005. Om reindriftsavtalen 2005/2006, om dekning av kostnader vedrørende radioaktivitet i reinkjøtt, og om endringer i statsbudsjettet for 2005m.m. 〈http://odin.dep.no/filarkiv/246513/STP0405063-TS.PDF〉 (in Norwegian).

Stenseth, N.C., Mysterud, A., Ottersen, G., Hurrell, J.W., Chan, K.-S., Lima, M., 2002. Ecological effects of climate fluctuations. Science 297, 1292–1296.

Strøm Bull, K., Turi, J.M., Buljo, K.M.E., Oskal, N., Smuk, I.A., Meløy, J., Eira, J.H., Arnesen, G., Kappfjell, B., Keiserud, E., 2001. Forslag til endringer i reindriftsloven. Norges Offentlige Utredninger 2001, 35. Statens Forvaltningstjeneste; Informasjonsforvaltning, Oslo, 218pp. ISBN:82-583-0628-6 (in Norwegian)

Tryland, M., Josefsen, T.D., Oksanen, A., Ashfalk, A., 2001. Contagious ecthyma in Norwegian semi-domesticated reindeer (*Rangifer tarandus tarandus*). Veterinary Record 149, 394–395.

Turner II., B.L., Kasperson, R.E., Matson, P., McCarthy, J.J., Corell, R.W., Christensen, L., Eckley, N., Kasperson, J.X., Luers, A., Martello, M.L., Polsky, C., Pulsipher, A., Schiller, A., 2003a. A framework for vulnerability analysis in sustainability science. Proceedings of the National Academy of Sciences 100, 8074–8079.

Turner II, B.L., Matson, P., McCarthy, J.J., Corell, R.W., Christensen, L., Eckley, N., Hovelsrud-Broda, G., Kasperson, J.X., Kasperson, R.E., Luers, A., Martello, M.L., Mathiesen, S., Naylor, R., Polsky, C., Pulsipher, A., Schiller, A., Selin, H., Tyler, N., 2003b. Illustrating the coupled human–environment system for vulnerability analysis: three case studies. Proceedings of the National Academy of Sciences 100, 8080–8085.

Uggerud, K., 2001. Wild Fauna Protection and Human Rights in Reindeer Husbandry Regions. 〈http://www.nrl-nbr.no/pdf/Utredning-Engelsk.pdf〉.

Ullsten, O., Speth, J.G., Chapin, F.S., 2004. Options for enhancing the resilience of northern countries to rapid social and environmental change: a message to policy makers. Ambio 33, 343.

UNEP, 2001. GLOBIO—global methodology for mapping human impacts on the biosphere. In: Nellemann, C., Kullerud, L., Vistnes, I., Forbes, B.C., Kofinas, G.P., Kaltenborn, B.P., Grøn, O., Henry, D., Magomedova, M., Lambrechts, C., Larsen, T.S., Schei, P.J., Bobiwash, R. (Eds.), United Nations Environment Programme, UNEP/DEWA/TR.01-3, 47p. 〈www.globio.info〉.

UNEP, 2004. Arctic environment: European perspectives—why should Europe care. UNEP and European Environment Agency, Environmental Issue Report No. 38, EEA, Copenhagen, 58p.

Vistnes, I., Nellemann, C., 2001. Avoidance of cabins, roads, and power lines by reindeer during calving. Journal of Wildlife Management 65, 915–925.

Vistnes, I., Nellemann, C., Jordhøy, P., Strand, O., 2004. Barriers to wild reindeer migration. Journal of Wildlife Management 68, 101–108.

Walther, G.-R., Post, E., Convey, P., Menzel, A., Parmesan, C., Beebee, T.J.C., Fromentin, J.-M., Hoegh-Guldberg, O., Bairlein, F., 2002. Ecological responses to recent climate change. Nature 416, 389–395.