Regional effects of climate change on reindeer: a case study of the Muotkatunturi region in Finnish Lapland

Susan E. Lee, Malcolm C. Press, John A. Lee, Tim Ingold & Terhi Kurttila

Few studies have investigated current climate changes for high latitude regions, and the impact of such changes on reindeer and indigenous people. Previous work by other authors has identified snow and ice conditions in winter as being critical in determining the availability of forage for reindeer. Deep snow makes it difficult to access food. Lack of food weakens the herd and can reduce the allocation of nutrients to the development of the foetus in the female deer. Climate data for Lapland, northern Finland, and Karasjok, northern Norway, are examined, together with reindeer calf numbers for the period 1977 to 1994 for the Muotkatunturi region (68°N 25°30′E). Between 1883 and 1993, precipitation increased but temperatures showed no clear warming or cooling trend. However, since the late 1980s, temperatures have increased. A regression analysis on the climate and reindeer data found that the warmer the winter prior to the rut, the fewer the live calves recorded the following year ($r = 0.529$, $p < 0.05$). Also, the wetter the winter prior to the rut, the fewer the calves recorded ($r = 0.427$, $p < 0.10$). In contrast, the warmer the autumn prior to their birth, the greater the number of calves recorded ($r = 0.474$, $p < 0.10$). These results suggest that as climate changes and winters become warmer and wetter with increased snowfall, calf numbers will decline. These findings have important implications for the Saami people who are heavily dependent on the reindeer for their livelihood.

S. E. Lee, M. C. Press & J. A. Lee, Dept. of Animal and Plant Sciences, Western Bank, University of Sheffield, Sheffield S10 2TN, UK. T. Ingold & T. Kurttila, Dept. of Sociology, University of Aberdeen, Aberdeen AB24 3QY, Scotland, UK.

General circulation models (GCMs) predict that regions in high latitudes are likely to experience large increases in temperature with a doubling in current atmospheric CO_2 concentrations. This increase in temperature is likely to be particularly noticeable in winter – up to 5°C (Cattle & Crossley 1995). Rainfall is also expected to increase (Maxwell 1992) although this may vary spatially.

This paper is concerned with recent climate change in northern Finland where the vegetation is particularly sensitive to environmental variables, and where there is a strong human dependence on natural resources. Plant growth and distribution in this region are heavily constrained by the duration of the snow-free period, by generally low air and soil temperatures, soil moisture and low soil nutrient availability, as in much of the Arctic (Press et al. 1998). In Lapland, the local indigenous people – the Saami – have strong links with the natural environment, both through their reindeer herding and through their dependence on berries and mushrooms to supplement their diet. They are heavily dependent on reindeer for their livelihood. There is mounting concern about the effect of a changing climate on the distribution of lichens, the main winter food source for the reindeer.

Deep snow causes reindeer difficulties in accessing food. They have to move around more frequently and use valuable energy. This leads to the death of weaker members of the herd and, for pregnant females, a reduction in energy and nutrients to developing foetuses (Sæther 1985, cited in Post et al. 1997; Langvatn et al. 1996). The autumn months are important as this is the season of the deer rut. If autumn is warm and wet this means that there is plenty of food accessible for the adult animals and they are in good physical condition. If the weather is cold and dry, the snow should be powdery and easier for the reindeer to reach their food. However, if a cold, dry autumn is interrupted by a few warm spells, there are likely to be considerable ice layers formed over the lichen on the ground, which would make it harder for the reindeer to access their food, reducing their energy levels. This has been noted for red deer (*Cervus elaphus*) in Norway (Langvatn et al. 1996). Furthermore, Albon et al. (1992, cited in Post et al. 1997) observed that the fecundity of female red deer in Norway was negatively correlated with winter precipitation while they were pregnant.

This paper concerns climate effects on reindeer numbers as identified within a managed reindeer herd in northern Finland. A combined ecological/ social anthropological study was undertaken in Lapland from 1995 to 1997 to determine the changes in climate which have occurred in this particular region over the last 100 years, both from a scientific viewpoint, using official meteorological measurements, and from the Saami viewpoint. The results from the meteorological analysis are presented in Lee et al. (2000).

The northern half of Finland is separated into 57 reindeer husbandry units, called *paliskunta*, with a total land area of 114 355 km^2. Muotkatunturi, one of these units, covers a land area of 2482 km^2. The most southerly paliskunta are situated in the Oulu parish. One-third of all Finnish reindeer are found the 12 northernmost units, situated in the Saami region. Hence these areas are extremely important for the reindeer herding economy in Finland. The Reindeer Herding Association (*Paliskuntain Yhdistys*) is responsible for reindeer management, which includes husbandry, economy and public relations. During the reindeer herding year 1996–97 there were a total of 202 449 live adult reindeer and 88 532 calves recorded for all paliskunta. For the same period there were 8640 live adult reindeer and 4375 calves in the Muotkatunturi paliskunta. Reindeer herding in Finland is highly managed through the use of fencing which restricts the movement of reindeer.

To focus on the influence of climate in this paper, the number of live calves born was selected as the best indicator of the health of the herd. The number of animals slaughtered in the autumn round-up is determined by the number of animals available and their potential market price. The bulk of a reindeer herd is female (for example, between 1992 and 1996 female reindeer were 92 or 93% of the herd in the Muotkatunturi region).

In this study, the number of live reindeer calves recorded by the Reindeer Herding Association for the Muotkatunturi region between 1977 and 1994 were compared with the seasonal temperature and precipitation anomalies for 1976 to 1993. During this period there were a number of changes in management strategies by the reindeer herders in Finland in response to economic conditions, technological developments and government policies. Such strategies led to a rapid increase in the number of reindeer during the late 1970s and into the 1980s, with a peak occurring in 1990. Since then there has been a decline in reindeer numbers. This decline is due to a number of factors, including government intervention, decreased economic returns caused by increased slaughtering and supplementary feeding, and problems of overgrazing, along with adverse weather conditions.

Here we focus on an analysis of both the climate data in the region and reindeer calf numbers to determine how reindeer may be influenced by temperature and precipitation. The reindeer calf numbers are analysed with these climate data and the results presented and discussed. No snow data have been analysed, but it is assumed that in a warm, wet winter there will be more snowfall than would occur in a cold, dry winter.

Reindeer

Reindeer are particularly dependent on various species of lichen in winter, which represent an easily digestible food supply rich in carbohydrates. Finnish reindeer spend their winter in the lowland forests, and depend on the food resources found in these forests for their survival in this season.

The spatial and temporal distribution of plants is considerably affected by climatic conditions. For example, after snowy winters (which are also warm) plant growth begins earlier and is more variable among sites due to differences among landscapes (Forchhammer et al. 1998).

Severe weather conditions in spring, or a late snow melt, can have important effects on reindeer populations and be responsible for the death of young or weak animals after the winter starvation. Several authors (Helle 1984; Helle & Tarvainen 1984a; Collins & Smith 1991) have identified snow and ice conditions in winter as critical in determining the availability of forage. Also, in years when insect pest populations are particularly large, often during warm summers when reproductive rates are high and the female insects lay their eggs, harassment can lead to reduced weight gain before winter (Helle & Tarvainen 1984b).

In northern Finland, the calves from herded reindeer tend to be born in the period 10 to 29 May (Eloranta & Nieminen 1986) but slightly later, into early June, for forest reindeer (Helle 1981).

Reindeer owners and herders

Out of a total of around 7000 reindeer owners in Finland, two-thirds own fewer than 25 reindeer and only 7% own 100 or more reindeer. There are around 100–120 reindeer owners within the Muotkatunturi region, most of whom also herd the reindeer. The majority of herders in this region are Saami although some herding is also carried out by Finns. Reindeer are allowed to graze naturally within the fenced boundaries. In winter, some supplementary feeding occurs which, while less than further south, is on the increase.

Reindeer herding is an important source of income for the Saami, bringing in between half and three-quarters of their gross earnings. However, this income has to be supplemented by agricultural and forestry work, as well as other cash-earning jobs.

Methods

Temperature and precipitation anomalies from 1951–1980 mean temperature and mean precipitation values were extracted from the Global Historical Climate Network (GHCN) (Vose et al. 1992) created by the Global Climate Laboratory of the National Climatic Data Center (NCDC/GCL), USA. Temperature and precipitation anomaly data were extracted for the $5^\circ \times 5^\circ$ grid covering Lapland and plotted for the period 1880 to 1993. A 10-year Gaussian filter was used to smooth these data over the 113 year period.

Live calf numbers recorded during the period from 1 June 1977 to 31 May 1994 were extracted from the February issues, 1979–1996, of the magazine *Poromies*, produced by the *Paliskuntain Yhdistys*, and a regression analysis was performed. This analysis included comparisons with spring, summer, autumn and winter temperatures and precipitation for Karasjok (69°47′N, 25°50′E) in northern Norway (the nearest meteorological station to where the Saami reindeer herders operate). As the meteorological records for Karasjok ceased in 1970, but meteorological data are still collected for Sodankylä (67°37′N, 26°65′E), the Karasjok temperature data (1908–1970) and precipitation data for 1907–1970 were regressed against those data for Sodankylä for the same time periods, for each season and for the year. These regressions enabled temperature and precipitation anomalies for the period 1970–1993 to be calculated for Karasjok. The seasons fall into the four meteorological categories of winter (December, January, February), spring (March, April, May), summer (June, July, August) and autumn (September, October, November). These seasonal data have been derived from the monthly data so, for example, current winter temperatures for 1987 would be derived from adding together the monthly temperature anomalies for December 1986, January 1987 and February 1987 and dividing by 3 to obtain a mean winter temperature anomaly for 1987. These data have been extracted from the National Climatic Data Center (NCDC) records. The close relationship between the Sodankylä and Karasjok temperature and precipitation data for all seasons is statistically significant ($p < 0.01$).

The seasonal anomalies were extracted for both temperature and precipitation from the calculated Karasjok data for the years 1976–1993 and plotted against the number of live reindeer calves for the year previous to which the calves were born. In addition, the anomalies for the current winter and spring were also plotted against the number of calves. The results are shown in Table 1. For example, the number of calves recorded in 1985 would be regressed against the previous autumn months of September, October and November 1984, the previous winter months of December 1983, January 1984 and February 1984, and the current winter months of December 1984, January 1985 and February 1985.

Results

There is no discernible warming trend between 1880 and 1993, but a clear warm period occurs

Table 1. Results of the regression of the number of live calves (y) on the seasonal temperature and precipitation anomalies recorded at Karasjok in Norway, 1976–1994 (x). It should be noted that, except for the current spring and winter, the climate data are for the period 1976–1993 and the reindeer calf data are for the period 1977–1994 (see text).

Season	Regression equation	r	p
Temperature			
Current spring (1977–1993)	y = −11.645x + 1337.4	0.028	NS
Current winter (1977–1993)	y = −42.23x + 1290.4	0.246	NS
Previous autumn	y = 246.44x + 1440.6	0.474	<0.1
Previous summer	y = −143.71x + 1292.8	0.246	NS
Previous spring	y = −139.35x + 1382.8	0.341	NS
Previous winter	y = −91.684x + 1223.2	0.529	<0.05
Precipitation			
Current spring (1977–1993)	y = 6.4567x + 1265.2	0.107	NS
Current winter (1977–1993)	y = −22.222x + 1438.9	0.292	NS
Previous autumn	y = 7.9741x + 1301.7	0.153	NS
Previous summer	y = 1.7444x + 1284.2	0.100	NS
Previous spring	y = 6.5339x + 1250	0.112	NS
Previous winter	y = −32.68x + 1477	0.427	<0.1

d.f. = 17. NS is not significant.

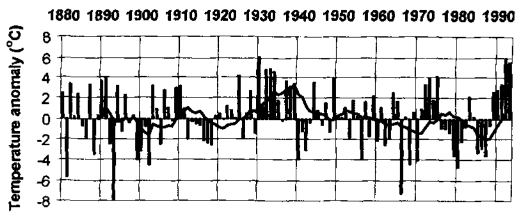

Fig. 1. Northern Finland surface air temperatures by year, 1880 to 1993. Data are expressed as °C anomalies from 1951–1980. The smooth curve was obtained by using a 10-year Gaussian filter.

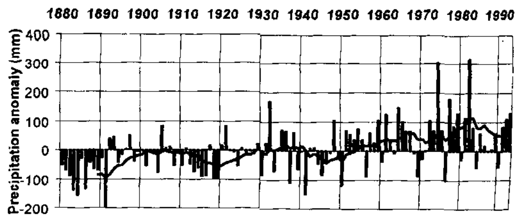

Fig. 2. Northern Finland precipitation by year, 1880 to 1993. Data are expressed as mm anomalies from 1951–1980. The smooth curve was obtained by using a 10-year Gaussian filter.

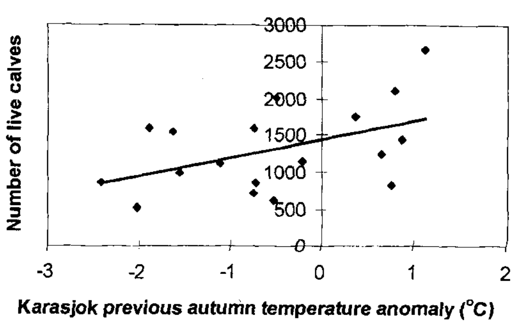

Fig. 3. Scatter plot of the number of live reindeer calves vs. previous autumn temperature for the period 1977–1994. y = 246.44x + 1440.6, r = .474 and p < 0.10.

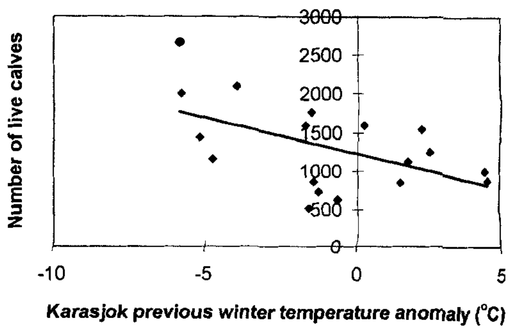

Fig. 4. Scatter plot of the number of live reindeer calves vs. previous winter temperature for the period 1977–1994. y = 91.684x + 1223.2, r = .529 and p < 0.05.

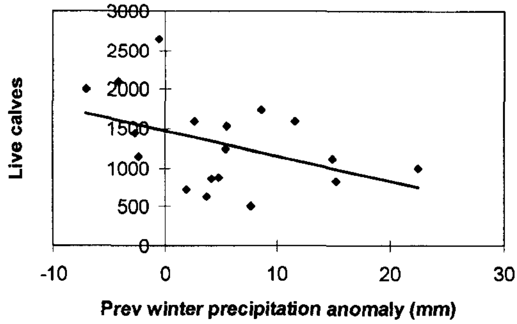

Fig. 5. Scatter plot of the number of live reindeer calves vs. previous winter precipitation for the period 1977–1994. $y = -32.68x + 1477$, $r = .427$ and $p < 0.10$.

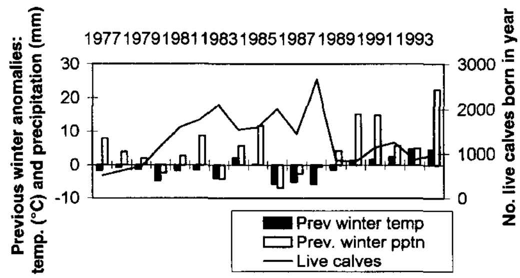

Fig. 6. The number of live reindeer calves born between 1977 and 1994 (Muotkatunturi region, Finland) with temperature and precipitation anomalies for the winter of the previous year. Data are expressed as °C and mm anomalies from 1951–1980.

between 1925 and 1948 with temperatures up to 3.2°C above the 1951–1980 mean value (Fig. 1). A number of colder periods can also be identified, for instance, the first decade of the 20th century, the late 1960s and the mid- to late 1980s. Since the late 1980s there has been a gradual warming with the positive temperature anomalies increasing. The dominant influence on the annual temperature in this region is the winter temperature (Lee et al. 2000). Also, though not shown here, summer and autumn temperatures decreased in the early 1990s, and spring and winter temperatures increased (Lee et al. 2000).

Precipitation has increased during the period 1880 to 1993 (Fig. 2). This linear trend was found to be significant for all seasons, particularly spring ($r = 0.460$, $p < 0.001$) and winter ($r = 0.486$, $p < 0.001$) as well as annually ($r = 0.487$, $p < 0.001$). During the early 1990s, spring and winter precipitation has increased, autumn precipitation has decreased but there has been little change in the summer precipitation (Lee et al. 2000).

The results show a positive correlation between the temperature of the previous autumn and the total number of live calves ($r = 0.474$, $p < 0.10$) (Fig. 3). This means that the warmer the previous autumn, the greater the number of calves. A further significant correlation was also found to exist between the total number of live calves and the temperature of the previous winter. This was a negative relationship, i.e. the warmer the winter prior to the rut, the fewer the calves born the following spring ($r = 0.529$, $p < 0.05$) (Fig. 4). In addition, a negative correlation was found between the number of live calves and the amount of precipitation during the winter prior to the rut ($r = 0.427$, $p < 0.10$) (Fig. 5). The greater the precipitation, the fewer the calves. No other significant relationships were found between reindeer numbers and seasonal precipitation over this time period. Calf data were plotted against the winter temperature and precipitation anomalies (Fig. 6). It can be seen that when the previous winters are warm and wet (i.e. when the anomalies are positive) the numbers of reindeer calves decrease, but when they are cold and dry the numbers increase.

Discussion

The herding of reindeer is of great importance to the Saami as it is part of their traditional way of life, as well as providing an income. The greater the number of reindeer owned the higher the status of the owner within Saami society. This is particularly the case in the Muotkatunturi area. Although many Saami herders have additional employment, reindeer herding is still regarded as being of high cultural importance.

The Muotkatunturi area provides about 4% of the reindeer in Finland and covers 2% of the overall herding area. It is within the main reindeer producing area of Finland and herds considerable more reindeer than the southern herding areas. It can therefore be considered to be fairly representative of northern Finnish reindeer husbandry. However, Finnish reindeer herding is unlike other herding within Fennoscandia in that the reindeer are controlled by fences. In other regions of Fennoscandia reindeer are allowed to roam freely and are less protected from predators.

There has been much work carried out on the reproductive success of cervids in relation to climatic and environmental factors (Picton 1984; Sæther & Heim 1993) and body weight (Clutton-Brock & Albon 1983). From studies on red deer, Post et al. (1997) state that animals with low birth weight tend to produce low birth weight calves which are vulnerable and less likely to survive (Albon et al. 1987). They also point out that variations in climate may influence the population dynamics of red deer through effects on winter survival and growth *in utero*, which later affects survival and fecundity of adult animals (Albon et al. 1987). Forchhammer et al. (1998) found that the abundance of red deer decreased following warm snowy winters. This they attributed to higher winter mortality. However, there is an increase in the fecundity of deer born following snowy winters because of improved forage quality and a longer growing season (Post et al. 1997; Forchhammer et al. 1998).

Vibe (1967) found from an analysis of reindeer populations on Greenland that reindeer coped well when the winter climate was cold and dry, even with the poor quality vegetation; but in winters which were wet and warm, the vegetation was covered by thick layers of snow and ice and reindeer died from the lack of food. From their work in the Oraniemi cooperative, Finnish Lapland (67°50'N), Kumpula & Nieminen (1992) also found that the annual variations in calf production were explained best by snow conditions during the previous winter and spring and their effects on the nutritional status of the females.

It has been assumed for this paper that the number of live calves recorded provides an indication as to the condition of the herd. There are problems with this assumption: there is the chance that some weak calves may die over the summer before the autumn round-up, and a high number of calves does not necessarily mean that the herd is healthy. However, the difference in the number of live calves between years serves as a reliable indicator as to whether the herd numbers are rising or falling. The effects of management practices have not been explicitly included in this analysis, but it is assumed that climate affects management decisions through its influence on the reindeer. Even if the overall reindeer numbers rise and fall in response to external economic factors there will also be an underlying response to climatic effects. The Saami themselves are well aware when reindeer numbers have fallen due to adverse weather and are keen to preserve their herd. This is done by adjusting the number of animals slaughtered.

In northern Lapland there is increasing use of supplementary food in winter by the herders. This means that there is less risk of winter starvation for the animals and some natural forage may be protected. It is expected that with climate change the faster growing vascular plants may outcompete the slower growing lichens, which will affect the eating habits of the reindeer. Vare et al. (1996) examined the changes in the distribution of plant species with grazed and ungrazed sites in north-eastern Fennoscandia and found that although there was a reduction in the biomass of vascular plants with grazing there was no change in their coverage. There was also a reduction in lichens such as *Cladina stellaris* at grazed sites. However, there was an increase in other lichens such as *C. arbuscula* and *C. rangiferina* together with bryophytes, especially *Dicranum* spp., which benefited from grazing.

It is interesting to note that there is no significant relationship between the number of live reindeer calves and the temperature and precipitation of the winter and spring of the year in which they were born (Table 1). It appears that even if there are adverse winter and spring conditions (i.e. it is very wet or very cold) when the calves are young and there is high calf mortality, the overall number of calves has already been determined by the preceding autumn and winter conditions.

This paper has highlighted the effects of autumn and winter temperatures and precipitation on the number of reindeer calves. It would appear that the climate has influenced the reproductive success of the female deer. It is clear that if winter temperatures continue to increase as predicted by climate models this will lead to further problems for the winter survival of reindeer. The Saami people will need to take steps to ensure that they are able to adapt to these changing circumstances to preserve both their herds and the vegetation on which they feed.

Conclusions

- There is no discernible warming trend between 1880 and 1993 for the annual time series of temperature, but a clear warm period occurs between 1925 and 1948.

• Since the late 1980s there has been a gradual warming.

• Precipitation has increased during the period 1880–1993. This is significant for all seasons, particularly spring and winter, as well as annually.

• A positive correlation was found between the temperature of the previous autumn and the total number of live calves ($r = 0.474$, $p < 0.10$). This means that the warmer the previous autumn, the greater the number of calves.

• In addition, a negative correlation was found to exist between the total number of live calves and the temperature of the winter prior to the rut, i.e. the warmer the previous winter, the fewer the calves ($r = 0.529$, $p < 0.05$).

• A negative correlation was also found between the number of live calves and the amount of precipitation ($r = 0.427$, $p < 0.10$) during the winter prior to the rut, i.e. the wetter the previous winter, the fewer the calves.

Acknowledgements. – This paper is the result of an Economic and Social Science Research Council (ESRC)-funded collaborative project among the authors. I would also like to thank the EU-funded Barents Sea Impacts Study project and Prof. Terry Callaghan, Sheffield Centre for Arctic Ecology, for allowing me to attend this conference, and Dartmouth College, for providing me with the necessary funding. In addition, I wish to thank the three anonymous referees for their helpful comments.

References

Albon, S. D., Clutton-Brock, T. H. & Guinness, F. E. 1987: Early development and population dynamics in red deer. II. Density-independent effects and cohort variation. *J. Anim. Ecol. 56*, 69–81.

Cattle, H. & Crossley, J. 1995: Modelling Arctic climate change. *Philos. Trans. R. Soc. Lond., Ser. A, 352*, 201–213.

Clutton-Brock, T. H. & Albon, S. D. 1983: Climatic variation and body weight of red deer. *J. Wildl. Manage. 47*, 1197–1201.

Collins, W. B. & Smith, T. S. 1991: Effects of wind-hardened snow on foraging by reindeer (*Rangifer tarandus*). *Arctic 44*, 217–222.

Eloranta, E. & Nieminen, M. 1986: Calving of the experimental reindeer herd in Kaamanen during 1970–85. *Rangifer, Spec. Issue 1*, 115–121.

Forchhammer, M. C., Stenseth, N. C., Post, E. & Langvatn, R. 1998: Population dynamics of Norwegian red deer: density-dependence and climatic variation. *Proc. R. Soc. Lond., Ser. B-Biol. Sci., 265*, 341–350.

Helle, T. 1981: Studies on wild forest reindeer (*Rangifer tarandus fennicus* Lonn.) and semi-domesticated reindeer (*Rangifer tarandus tarandus* L.) in Finland. *Acta Univ. Oulensis, Ser. A, 107*, 1–34.

Helle, T. 1984: Foraging behaviour of the semi-domestic reindeer (*Rangifer tarandus* L.) in relation to snow in Finnish Lapland. *Rep. Kevo Subarct. Res. Stat. 19*, 35–46.

Helle, T. & Tarvainen, L. 1984a: Determination of the winter digging period of semi-domestic reindeer in relation to snow conditions and food resources. *Rep. Kevo Subarct. Res. Stat. 19*, 49–56.

Helle, T. & Tarvainen, L. 1984b: Effects of insect harassment on weight gain and survival in reindeer calves. *Rangifer 4*, 24–27.

Langvatn, R., Albon, S. D., Burkey, T. & Clutton-Brock, T. H. 1996: Climate, plant phenology and variation in age of first reproduction in a temperate herbivore. *J. Anim. Ecol. 65*, 653–670.

Lee, S. E., Press, M. C. & Lee, J. A.. 2000: Observed climate variations during the last 100 years in Lapland, northern Finland. *Int. J. Clim. 20*, 329–346.

Maxwell, B. 1992: Arctic climate: potential for change under global warming. In F. S. Chapin III et al. (eds.): *Arctic ecosystems in a changing climate. An ecophysiological perspective*. Pp. 11–34. San Diego: Academic Press.

Paliskuntain Yhdistys (Association of Reindeer Herders) 1979–1996: *Tilastoja vuodelta. Poromies (Statistics. Reindeer Herder) 2.* P.O. Box 8168, Koskikatu 33A, SF-96101 Rovaniemi, Finland.

Picton, H. D. 1984: Climate and the prediction of reproduction of three ungulate species. *J. Appl. Ecol. 21*, 869–879.

Post, E., Stenseth, N. C., Langvatn, R. & Fromentin, J.-M. 1997: Global climate change and phenotypic variation among red deer cohorts. *Proc. R. Soc. Lond., Ser. B-Biol. Sci., 264*, 1317–1324.

Press, M. C., Potter, J. A., Burke, M. J. W., Callaghan, T. V. & Lee, J. A. 1998: Responses of a sub-Arctic dwarf shrub heath community to simulated environmental change. *J. Ecol. 86*, 315–327.

Sæther, B.-E. 1985: Annual variations in carcass weight of Norwegian moose in relation to climate along a latitudinal gradient. *J. Wildl. Manage. 49*, 977–983.

Sæther, B.-E. & Heim, M. 1993: Ecological correlates of individual variation in age at maturity in female moose (*Alces alces*): the effects of environmental variability. *J. Anim. Ecol. 62*, 482–489.

Vibe, C. 1967: Arctic animals in relation to climatic fluctuations. *Medd. Grønland 170(5)*, 23–180.

Vose, R. S., Schmoyer, R. L. Steurer, P. M., Peterson, T. C., Heim, R., Karl, T. R. & Eischeid, J. K. 1992: *The Global Historical Climatology Network: long-term monthly temperature, precipitation, sea level pressure, and station pressure data. Version 1.* ORNL/CDIAC-53, NDP-041. Oak Ridge, TN: Carbon Dioxide Analysis Center.